BIOECOLOGY AND ECONOMIC INJURY LEVELS (EIL) OF *Dysdercus volkeri* F (HETEROPTERA: PYRRHOCORIDAE) ON SUNFLOWER *(Helianthus annuus* L.) IN SAMARU ZARIA, NIGERIA.

BY

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Ph.D/AGR/01106/2006-2007

DEPARTMENT OF CROP PROTECTION

FACULTY OF AGRICULTURE,

AHMADU BELLO UNIVERSITY ZARIA

JANUARY, 2013

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN CROP PROTECTION

DEPARTMENT OF CROP PROTECTION

FACULTY OF AGRICULTURE,

AHMADU BELLO UNIVERSITY ZARIA

JANUARY, 2013

DECLARATION

I hereby declare that the work contained in this Dissertation for the award of the Doctor of Philosophy (Crop Protection) represents my original work and has not been previously submitted for any degree. All assistance to accomplish the work has been duly appreciated.

_____ Date_____

MANI, Ubaidu

(Student)

CERTIFICATION

This Dissertation titled "BIOECOLOGY AND ECONOMIC INJURY LEVELS OF *Dysdercus volkeri* F (HETEROPTERA: PYRRHOCORIDAE) ON SUNFLOWER *(Helianthus annuus* L.)" meets the regulations governing the award of the Degree of Doctor of Philosophy in Crop Protection of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Field and laboratory studies were conducted on the bioecology and economic injury levels (EIL) of *Dysdercus volkeri* Fab. (Pyrrhocoridae: Heteroptera) on sunflower in Samaru Nigeria. The objectives of the studies were to determine the biology of *D. volkeri*, susceptible stage of sunflower for damage by *D. volkeri,* the economic injury levels of *D. volkeri*, the influence of weather factors on *D. volkeri* and to screen different accessions of sunflower for resistance to *D. volkeri* damage. The result of the studies indicated that growth stages R_7 (when the back of the head has started to turn a pale yellow colour), R_8 (when the back of the head is yellow but the bracts remain green) and R_9 (when the bracts become yellow and brown and the stage is regarded as physiological maturity) took about 10, 14, 14 days respectively. The result of the biological studies showed a marked difference between the life cycle of *D. volkeri* in the field and that in the laboratory. Eggs laid by adult in the laboratory took three days to hatch compared to 3-14 days in the field. *D. volkeri* appeared on sunflower at R_7 growth stage in both 2008 and 2009. Nymphs started appearing at R_8 growth stage in both years. A total of 28--42 days was required from egg laying to adult emergence in the field compared to 24-28 days in the laboratory. There was significant difference (P= 0.05) regarding the number of insects and the damaged seeds on the nine accessions of sunflower tested. On mortality and longevity, there was also a significant difference between treatments. Predators of *D. volkeri* were observed including the phytophagous Pyrrhocorid, *Odontopus sexpunctatus* L. that had not been reported attacking *D. volkeri* before. The result also showed that the number of predators was not commensurate with the number of *D. volkeri* to warrant effective control. The *D. volkeri* sex ratio indicated that it was 1:1 male-female and the

best criterion for sex determination was the size based method. The result showed R8 as most susceptible and 2-3 insects/head of sunflower crop constituted the economic injury level. The gain threshold was 1254 kg/ha and 1255 kg/ha in 2008 and 2009 respectively. Accessions PI 298632, Funtua, Ames 3236 and PI 176974 showed resistance to *D. volkeri* damage. On lipid value, the result indicated significant difference among the treatments. Accessions Ames 3236, PI 176974, PI 193775 and Funtua recorded the highest lipid value. Similarly, the accession that recorded the highest fatty acid value was Ames 1838 with 0.97mg/100ml. On yield, the result showed significant difference $P < 0.05$ among accessions. Funtua and PI 298632 appeared to have the highest yield of 1240 and 1239 kg/ha respectively.

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CHAPTER ONE

1.0 INTRODUCTION

Sunflower, (*Helianthus annuus* L.) (Magnoliopida: Asteraceae) is a common name for annual and perennial herbs of a genus of the family of composite flowers. The daily orientation of the flower to the sun is a direct result of differential growth of the stem due to a plant growth regulator or auxin, which accumulates on the shaded side of the plant when conditions of unequal light prevail. Because of this accumulation, the darker side grows faster than the sunlit side, thus the stem bends towards the sun (Robertson, 1975).

1. 1 Economic importance and uses of sunflower

1. 1. 1 Chemical composition

Sunflower oil contains predominantly linoleic acid in triglyceride form. The British Pharmacopoeia lists the following profile, Palmitic acid: 4 - 9 %, Stearic acid: 1- 7 %, Oleic acid: 14 - 40 % and Linoleic acid: 48 – 74 %. There are several types of sunflower oils produced, such as high linoleic, oleic and midoleic. High linoleic sunflower oil typically has at least 69 % linoleic acid while high oleic sunflower oil has at least 82 % oleic acid. Variation in fatty acid profile is strongly influenced by both genetics and climate. Sunflower oil contains lecithin, tocopherols, carotenoids and waxes. Its properties are typical of vegetable triglyceride oil and are produced from oil type sunflower seeds, The oil is light in taste and appearance and has high vitamin E content. It is a combination of monounsaturated and polyunsaturated fats with low saturated fat levels. Sunflower oil is liquid at room temperature. The refined oil is clear and slightly amber, coloured with a

slightly fatty odour. As frying oil, it has the viscosity of a typical vegetable triglyceride. In cosmetics, it has smoothing properties and is considered non comedogenic. Only the high-oleic variety possesses shelf life sufficient for commercial cosmetic formulation (Praveena *et al.*, 2000)

1. 1. 2 Diet and cardiovascular benefits

Sunflower oil is high in essential vitamin E and low in saturated fat. The two most common types of sunflower oils are linoleic and high oleic. Linoleic sunflower oil is common cooking oil that has high levels of the essential fatty acids called polyunsaturated fat. It is also known for its clean taste and low levels of transfat. High oleic sunflower oils are classified as having monounsaturated levels of 80 % and above. Newer versions of sunflower oil have been developed as a hybrid containing linoleic acid. They have monounsaturated levels lower than other oleic sunflower oils. The hybrid oil also has lower saturated fat levels than linoleic sunflower oil. Sunflower oil of any kind has been shown to have cardiovascular benefits (Thompson *et al.,* 1981). Diets combined with a low fat content and high levels of oleic acid have been suggested to lower cholesterol which in turn results in a smaller risk of heart disease. Sunflower oil fits this criterion. The studies showed that a balanced diet in which small quantities of saturated fats are replaced with sunflower oil has detectable cholesterol-reducing benefits. Research suggests that lower cholesterol levels can be caused by balances of polyunsaturated and monounsaturated fatty acids. Sunflower oil may help with this balance (Praveena *et al*., 2000).

1. 1. 3 Restaurant and food industry uses

Restaurants and food dealers are also utilizing the health benefits of the oil. They are trying to look for ways to offer a healthier selection of food. Sunflower oil may be a healthy way to cook their menu items. The oil can be used in conditions with extremely high cooking temperatures. It may help food stay fresher and healthier for longer periods of time (Praveena *et al.,* 2000). Grocery store shoppers and food producers are using sunflower oil option to lower the levels of transfat in mass production of foods. A number of common snacks foods currently contain sunflower oil, including Sun Chips, Ruffles, and Lay's Potato Chips (Praveena *et al.,* 2000)

1. 1. 4 Sunflower oil as skin protectant

Sunflower oil may have skin health benefits. Sunflower oil like other oils can retain moisture in the skin; however, it may also provide a protective barrier that resists infection. Studies using sunflower oil have been conducted involving premature infants that are often susceptible to infection due to their underdeveloped skin. Research suggests that premature infants with low birth weight can benefit from sunflower oil skin treatments. Infections decreased by 41 % in infants that received a daily skin treatment of sunflower oil. The sunflower oil provided a protective barrier against infection that was not otherwise present on the infant (Praveena *et al.,* 2000).

1. 1. 5 Other uses of sunflower.

Sunflower "whole seed" (fruit) are sold as snack after roasting with or without salt added. Sunflower can be processed into a peanut butter alternative- sunbutter, especially in

China, Russia, the United States of America, the Middle East and Europe. It is also sold as food for birds and can be used directly in cooking and as salads (Ogunremi, 1988). Sunflower oil, extracted from the seeds, is used for cooking, as carrier oil and to produce biodiesel, for which it is less expensive than the Olive product. A range of sunflower varieties exist with differing fatty acid compositions; some high oleic types contain a higher level of healthy monounsaturated fats in their oil than even olive oil (Ogunremi, 1988). During the 18th century, the use of sunflower oil became very popular in Europe, particularly with members of the Russian Orthodox Church because sunflower oil was one of the few oils that were not prohibited during Lent. The cake remaining after the seeds have been processed for oil is used as livestock feed. Some recently developed cultivars have drooping heads. These cultivars are less attractive to gardeners growing the crop as ornamental plants, but appeal to farmers, because they reduce bird damage and losses from some plant diseases. Sunflowers also produce latex and are the subject of experiments to improve their suitability as an alternative crop for producing hypoallergenic rubber (Ogunremi, 1988). Similarly, sunflowers have been used to remove lead from contaminated soils in Post- Katrina, New Orleans and home owners suspicious of the soil in their own back yards use sunflowers prior to planting edible crops (Tunza, 2010).

1.2 The role of Sunflower to Nigerian economy

Groundnut has been an important oil crop in Nigeria for a very long time. The advent of petroleum resources coupled with pests and diseases and high content of saturated fatty acids made its cultivation less attractive. Sunflower is now an alternative crop which adapt

to different climates, seasons, and cropping systems with few distortions. Nigeria, can adopt its cultivation more especially as rainfed and irrigation crop. This will give farmers the opportunity to participate actively in its cultivation, which can be a potential source of income. Additionally, Nigeria could be a good supplier of seed varieties and service provider in respect of sunflower cultivation techniques. This will come about through the gradual improvement of extension services, skills, techniques, infrastructure, and availability of capital.

1. 3 World production of sunflower

The world production of sunflower seeds is primarily governed by the results in the former Soviet Union, the U.S.A. and Argentina in 1981-1982. Together these three countries account for about 60 % of the total world production of sunflower seeds. Sunflowers are extensively grown in Romania and Bulgaria, and on smaller scales in other parts of Europe. Within the tropics, sunflowers are grown on small scales in parts of India and many of the African countries. The crop has great potentials for large scale development and production in Nigeria. The United States of America seems to have strengthened their position as the world's largest exporter of sunflower seeds (International Sunflower Association, 1982) and are about to become the largest exporter of sunflower oil. In 1981 about 400,000 tonnes of seed were processed domestically in the USA producing about 300,000 tonnes of oil of which some 200,000 tonnes were exported. Regarding the consumption in total, over 5 million tonnes of sunflower oil and 6 million tonnes of meal were consumed in 1981. The largest consumer of oil and meal is the former U.S.S.R. where about 30 % of the world production is consumed. Current

production of sunflower seed, oil and meal (Table 1) showed that Russian federation and EU- 27 were the leading producers, followed by Ukraine (FAO, 2010).

Table 1: Sunflower seed, oil and meal production

Country/region	Marketing year	Sunflower seed (million tons)			Sunflower seed oil (thousand tons)			Sunflower meal (thousand tons)		
		2006/2007	2007/2008	2008/2009	2006/2007	2007/2008	2008/2009	2006/2007	2007/2008	2008/2009
Russian Federation	(Sep.-Aug.)	6.35	5.50	6.95	2,465	2,130	2,520	866	666	800
Ukraine	(Sept.-Aug.)	5.55	4.75	6.30	2,050	1,726	2,285	1,483	1,273	1,620
EU-27	(Oct.-Sep.)	6.35	4.94	6.72	2,200	1,773	2,270	146	48	148
Argentina	(Mar.-Feb.)	3.12	4.40	2.50	1,202	1,800	1,785	766	1,225	1,200
Turkey	(Sep.-Aug.)	0.82	0.67	0.85	525	523	544	0	0	0
Other		6,910	7,225	7,225	2,172	1,958	2,270	192	165	159
World Total		**29,812**	**27,196**	**33,421**	**10,614**	**9,910**	**11,674**	**3,453**	**3,377**	**3,927**

Source: FAO data 2010

1. 4 Justification

Most of the damage caused by *Dysdercus* spp is on cotton. The economic importance of injury caused by *Dysdercus* spp on sunflower is not known more especially on the irrigated crop. The high number of *Dysdercus* spp encountered on sunflower made it necessary to conduct an investigation on the relationship between the crop and the insects in order to ascertain the nature of the relationship and to study the economic injury levels (EIL), so as to determine its economic significance and therefore be in a position to determine whether corrective measures need be taken or is economically justifiable. It has been the custom of uneducated and resource poor farmers that whenever insect populations reach certain levels, whether the insect is causing damage or not, farmers would just hasten to apply insecticides. This may sometimes lead to misuse of insecticides and may consequently lead to adverse economic and ecological consequences. If farmers must maximize profit accruing from production with minimum adverse consequence on the environment, we must employ a pest control strategy that may not harm the farmers' crop yield and the environment. Studies on bioecology and economic injury levels of *D. volkeri* on sunflower would contribute significantly to encourage the cultivation of the crop and reduce the amount of insecticides used in its production. Hence the objectives of the study were to:

i- Study the biology of *Dysdercus volkeri* F. on sunflower.

ii- Determine the influence of weather factors on *D. volkeri* damage on the crop

iii- Determine the susceptible of sunflower growth stages to damage by *D. volkeri*

iv- Determine the economic injury levels of *D. volkeri* on sunflower.

v- Screen different accessions of sunflower for resistance to *D. volkeri*

CHAPTER TWO

2.0 LITERATURE REVIEW

The genus *Helianthus* contains about 67 species and is thought to originate in Wetern North America. It is thougt to have been domesticated around 1000 B.C. by Native Americans. In Mexico and North America, sunflower seeds were roasted and beaten into a paste before being boiled in water, the oil that rose to the surface was then skimmed off (FAO, 2010). Heliotropism and Pleiotrophy are important features of sunflower.

2. 1 Heliotropism

This refers to phototropism in which sunlight is the orienting stimulus. Sunflower in the bud stage exhibit heliotropism, at sunrise, the faces of most sunflowers are turned towards the east. Over the course of the day, they move to track the sun from east to west, while at night they return to an eastward orientation. This function is performed by motor cells in the pulvinnus, a flexible segment of the stem, just below the bud. As the bud stage ends, the stem stiffens and the blooming stage is reached (Shostek, 1974). Sunflowers in the blooming stage are not heliotropic any more.

2.2 Pleiotrophy in Sunflower

This refers to the occurrence of anthocyanin pigmentation in many parts of the sunflower plant e.g. petiole, midrib, leaf margin, leaf tip, ray floret and stigma. Pleiotropic genes manifest more characters than one, along with the primary effect. Selection for a particular character or trait automatically leads to the selection for other traits too, which is of

immense importance to breeders and entomologists. Most of the available literature deals with the inheritance of floral/morphological variations (Hieremath and Giriraj, 1984). Though the report indicates that differences in pigmentation are controlled by one or two major genes (Fick, 1976), the knowledge of their relationships is important and whether they influence resistance to insect pests or diseases is a subject of investigation to breeders and entomologists.

2.3 Damage to sunflower by insects pests

Lohar (1987) showed that only sucking pests such as whiteflies and Jassids caused 44 % yield loss in Sindhi, India. The bracteal leaf, the nearest "source" to the pool of grain, increased the photosynthetic area and efficiency of sunflower and its removal by insects reduced the grain yield by 1.9 – 7.6 % in an edible variety and by 1.8 – 5.1 % in a high oil one (Duang, 1991), therefore, measures should be taken to promote and safeguard the growth of the bracteal leaf (Carlson *et al.*, 1972) reported 30 – 60 %, and occasionally 100 % seed loss especially in small weeaker heads as a result of *Homoesoma electellum* (Haist) (Lepidoptera: Noctuidae) infestation (Laurence and John, 1995) reported 59.6 seeds damaged by larval feeding caged with only one adult per plant of banded sunflower moth (*H. electellum*) and 284.3 damaged seeds in the cages with 10 adults per plant. Ahqabullahi and Amjad (1997) on the biology of *Nysius inconspicuous* (Distant) (Heteroptera: Lygaeidae) and its economic impact on sunflower showed that 50 or more bugs per head caused 44 % yield losses in Sindhi, India. Red sunflower weevil, *Smicronyx fulvus* (Leconte) adults use developing seeds as feeding and oviposition sites and both activities leave holes in the seed pericarp that persist as scars. Larvae of the red sunflower

seed weevil feed internally in the seeds and after they mature, they chew an exit hole through the seed and drop to the ground to overwinter. If the population is high, economic damage is caused (Christian and Braness, 1979). *Cylindrocopturus adspersus* Leconte (Coleopteran: Curculionidae) has been reported on sunflower in Georgia (Beckham and Tippins, 1972). Females deposit eggs beneath the epidermis in the lower one third of the sunflower stalk, and maturing larvae penetrate into the pith as they feed and develop. This larval activity in the stalk may cause heavily infested plants to fail to mature and to have dwarfed receptacles (Phillips *et al.,* 1972) or to lodge near the base as receptacle weight increases. In Nigeria, (Mani *et al*., 2010) reported *Pachnoda cordata* Dry, *Agonoscelis versicolor* F, and *Dysdercus volkeri* F. among the key insects that cause damage to irrigated sunflower.

2. 4 Economic injury levels

Modern progressive approaches for managing pests depend upon integrated pest management (IPM) programmes. A key feature of these programmes is the use of formal criterion for making management decisions about pests and the economic injury level (EIL) concept is the foundation of these criteria. Most often, the tactics used in IPM programmes are emphasized over procedures developed to employ those tactics. But the strength of IPM, particularly in maintaining environmental quality, comes from an objective consideration of economic and biological factors in managing pests. The EIL concept is central to such considerations (Hutchins *et al.*, 1988; Leon and Larry, 1993). The EIL is defined by the lowest population density that causes economic damage. The basic concept of the EIL is the restriction of insecticide use to occasions when economic

loss is actually expected, so that control measures need only be taken in case the pest population is likely to exceed the EIL (Poston *et al.*, 1983; Onstad, 1987). Determination of the relationship between pest population density and yield loss is necessary to develop an EIL. The EIL is the guideline for determining a final decision rule. It is a theoretical value that, if realized by the pest population, will result in economic damage. As such, this value is a measure against which the destructive status and potential of a pest population is determined. The EILs have been determined for tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvoise), feeding on developing sunflower seed. Its attack causes kernel brown spot, a serious problem in confection sunflower. The EIL was one adult per 10-15 plants each head averaging 500 to 600 seeds, for a damaged level of 0.5 %. Thus, tarnished plant bug management should be initiated between the R_4 and $R_{5.1}$ stages (inflorescence begins to open and beginning of flower respectively) if adult densities approach the economic injury level (Laurence, 2003). The result of the studies indicated that with aerial application costs of $17.30 per ha, a sunflower market price of $0.20/kg, and a plant population of 44,600/ha, the EIL was 5.9 larvae per head. A decision of whether economic damage is likely to occur is based on known population of adult moths (Laurence and John, 1995). Similarly, report by Adamu (2005) showed relatively lower values of EILs for the ovipositing adult of *Eurystylus oldi* Poppius than on feeding adults among different insecticides used and seasons.

2. 5 Cotton stainers

The Pyrrhocoridae or cotton stainers are a cosmopolitan family of pentatomid bugs including about 65 genera and over 400 species (Schaefer and Ahmad, 2000). They are

most diverse in the tropics and sub-tropics with only a few species in the temperate regions of the world. The Pyrrhocorids are medium to large insects, ranging in size from 8 to 30 mm. Species are mostly elongate, and often aposematically coloured, with striking patterns of yellow, red, black and white. The head is triangular and porrect and the bucculae are narrow. Ocelli are absent. The antennae and labium are 4-segmented, with the labium often extending well beyond the base of the abdomen. The pronotum is trapezoidal and the lateral margins are explanate. The scutellum is triangular. The external efferent system of the metathoracic glands is reduced. The hemielytra membrane has numerous reticulating veins. The abdominal trichobothria are present on segments ii-vi, and ii-vii. The aedeagus has three pairs of conjunctival appendages. The seventh abdominal sternum of the females is complete. The females have a reduced plate-like ovipositor. The larvae have dorsal abdominal gland openings between tergites iii-iv, and v-vi (Van Doesburg, 1968; Slater, 1982; Schuh and Slater, 1995). The following characters were used to typify the Pyrrhocoroidea by China and Miller (1959)

1. Abdominal trichobothria present.
2. Scutellum small, shorter than the clavus, a distict claval commisure present.
3. Antennophores visible from above.
4. Antennae four segmented.
5. Oceli absent.
6. Membrane of the hemielytra usually with two basal cells, from which 7-8 branching, longitudinal veins extend to the apical margin.
7. Medium to large, brightly coloured, usually phytophagous bugs.

The two sub-species, *Dysdercus sidae australiensis* Stehlik and *D. sidae biguttatus* Walker, are reported as among the noxious insects (Ahmad and Schaefer, 1987). Pyrrhocorids are primarily granivorous or fructivorous (Slater, 1982). The majority of species are found on cultivated plants. A few species in the Eastern part of the world are ground dwelling and are thought to feed on fallen mature seeds. Schaefer and Ahmad (2000) speculated that the epigamic habit is the pleomorphic condition for the Pyrrhocoridea. Carnivory has been recorded in the Pyrrhocoridae and Schaefer and Ahmad (2000) argued that cannibalism evolved secondarily from phytophagous pyrrhocorid ancestors. Occasional predatory behaviour has been recorded for the following species: *D. sidae sidae* feeding on pupae of the noctuid, *D. versicolor* feeding on dead larvae of the anartoids, *Lymantriid orgyia* (Walker). Stahle (1981) found that *D. versicolor* feeds on animal protein under laboratory conditions. The isoprenoid linalool, together with several straight carbon-chain aliphatic materials, has been found in the scent glands of the cotton stainers *D. volkeri* (Daroogheh and Oagbemiro, 1982). This is what makes them unsuitable for predators. Steinbauer (1996) also found extra-phytophagous feeding for this species in the field. In Nigeria, two species have been identified, they are *D. volkeri* F and *D. fasciatus* Sign, (Golding, 1928; Amatobi, 2007). The two forms were a banded; one appearing earlier and remaining longer than the spotted one. Golding (1928) believed that the two forms do not interbreed. The name *D. volkeri* was synonymised with *D. superstitiosus* by Freeman (1947), but some work has been done under the former name. The species occurs throughout Sub-saharan Africa, including Madagascar (Freeman, 1947; Beccari and Gerini, 1970).

2.5.1 Economic importance of *Dysdercus* species

The most important economic impact pyrrhocoroids have, is the devastating effect on cotton by *Dysdercus* spp (Schaefer and Ahmad, 2000). This damage is the same regardless of where or by what *Dysdercus* spp it is caused. This account of damage is based on that by Whitefield (1933), which does not make clear if it is based on one or all four of the species, that is *D. superstitiosus* (F), *D. fasciatus* Signoret, *D. nigrofasciatus* Stal, and *D. cardinalis* Gerstaecker.

Dysdercus spp damage cotton in two ways, both serious; Direct and indirect (Whitefield, 1933), (a) Direct damage varies with the age of the boll. In young bolls, the developing seed may be destroyed, and the boll may dry up. Although the frass of the instars is colourless, that of adults is yellowish and stains the cotton lint. As a result, fibres are rendered useless, and seeds are emptied of their oil. (b) Indirect damage is more common. Both fungi and bacteria enter the bolls through the stylet punctures, giving rise to a variety of diseases, almost all of which completely destroy the bolls. The symptoms of such attack vary from a slimy wet rot to a dry rot, which completely eats out the interior of the boll (Whitefield, 1933). Of these indirect effects, the most serious is internal boll disease, which is caused by *Nematospora gossypii* and related fungi; these are probably transmitted from contaminated boll to uncontaminated boll mechanically, on the mouthparts of the bug (Frazer, 1944). The ecology of the bug-fungus association and the early history of its study, are recounted by Frazer (1944), which also provides in detail the way in which the bug becomes infected and the way in which it transmit the fungus on to the plant. In the New World, boll disease is caused by fungi and bacteria, including *Xanthomonas malvacearum* var. campestris and *Colletotricum gossypii* (Moreira *et al*.,

1994). There are also passing references to 'Cotton stainers' or *Dysdercus* spp on several crops; that these insects were not identified suggests that they are of no great importance. There were reports of cotton stainers on cotton in the United States of America (Coad, 1929) and *Dysdercus* spp. on cowpea, *Vigna unguiculata* (LK) Walp; in Benin Republic (Dreyer and Baumgartner, 1995)

2. 5. 2 Natural enemies of *Dysdercus* spp.

Important natural enemies of *Dysdercus* spp**.** are found among the Phylum Arthropoda. Tachinid flies insert their eggs into the body of second instars (Wille, 1952). The full-grown maggot then leaves the victim and pupates in the soil. *Acaulona peruviana* Townsend and *Paraphorantha peruviana* Townsend were found on *Dysdercus howardi* Ballou and *D. howardi* var. *minor* Ballou are occasionally parasitized by a species of *Trichopoda* (Ulrich, 1916). *Megilla maculate* (Coleoptera) has been observed eating young larva of *D. andrea* (L). A small mite and a small arachnid externally parasitize stainers and *D. ruficollis* (L.) have been found at Campinas State, Brazil (Mendes, 1938). *Treatia dysderci* Evans, a parasitic mite was described by Evans (1963) which noted that eggs of *D. delauneyi* may be attacked by a thrips species. The analysis thus lead to the conclusion that with one possible exception none of these predators and parasitoids was sufficiently abundant or host specific to become valuable in controlling cotton stainers, although an *Othopheidethid* mite killed its host *Dysdercus* when in heavy infestation (Shahi and Krishna, 1981). The reduviid, *Rhyncocoris albopunctatus* Stal fed on several pests in Ugandan cotton fields, including *Dysdercus* spp. (Nyiira, 1970). Members of reduviid genus are closely associated with Pyrrhocoridae. Several species of the African *Phonoctonus* ssp are the only predators whose preferred food appears to be Pyrrhocorids,

although (Stride, 1956) considered other preys. So specialized are these predators that they form a mimetic assemblage with their prey, various *Dysdercus* spp. and other pyrrhocorids (Stride, 1956). This phenomenon is sometimes termed "aggressive mimicry" (Bourdouxhe and Jolivet, 1981) a wildly anthropocentric interpretation that assumes firstly that Pyrrhocoroids see reduviids and secondly that they see reduviids as humans do. Neither assumption is in the least likely (Schaefer and Ahmad, 1987); indeed Fuseni and Kumar (1975b) found no relationship between mimicry and predation in *Dysdercus* species and associated reduviids. More probably, reduviids looking like pyrrhocorids share whatever protection the latter gain from their aposematicism (Schaefer, 1999). The mimicked pyrrhocorids (mostly old world *Dysdercus* spp) live in large aggregations with smaller numbers of their mimicking predators. Aggregations of organisms similarly aposematic may warn off predators from a greater distance than would a single such organism (e.g. as may be true of the bug *Parastrachia japonensis* (Scott) (Gamberale and Tulberg, 1998).

There are far fewer *Phonoctonus* species than Pyrrhocorids in the same assemblage (35:1) (Fuseni and Kumar, 1975b), but even under these conditions with a rough calculation of the prey consumed and total life span of the predator and the prey, and also considering the fecundity of both predator and prey, it is estimated that *Phonoctonus* species would diminish a *Dysdercus* population by somewhat more than half (35/20) (Schaefer and Ahmad, 1987). After that time, the full complement of *Phonoctonus* will reproduce as will the remainder of the *Dysdercus* species. It is likely that in a short time good control of *Dysdercus* species could be accomplished. It has been suggested that the efficacy of *Phonoctonus* species as a control agent of *Dysdercus* species be tested (Stride, 1956). The

successful biological control of the cotton stainers on a safe and permanent basis by *Phonoctonus* spp seems possible (Schaefer and Ahmad, 1987).

2. 5. 3 Control of *Dysdercus* spp using chemicals.

The chemicals so far tested on *D. cingulatus* F. are sterilants, "Apholate." Sterilized females exposed for 18 hours to 0.7 mg apholate per cm_2 centimeter; Similarly normal females mated to males similarly exposed laid far fewer eggs than normal (Mustafa and Naidu, 1964). The related compound triphenytin acetate is less effective, and not recommended (Ansari and Khan, 1973). The chitin inhibitors diflubenzuron at concentrations above 100 parts per million applied topically lowered egg hatch to 0-30 % of normal (Chockalingam and Noorjahan, 1984). When applied to surfaces touched by the bugs, diflubenzuron more greatly affected females than males, and did not affect viability or transfer of sperm (Gupta *et al*., 1994). However, *D. cingulatus* may become resistant to diflubenzuron (Gupta *et al*., 1993). The related compound, Penfluron caused 42 to 100 % sterility in females treated topically with dosages from 0.001 - 0.1 % (Ahmad and Khan, 1980; Satyanarayana *et al*., 1985). A dust composed of 3 % gamma isomer of Benzene hydrochloride, 5% dichloro trichloro ethane (DDT) and 40 % sulfur reduced populations of *D. maurus* in Paraguay but only temporarily (Nickel, 1958). TEPA also sterilized in doses of 0.05 % was applied topically to females (Ansari and Khan, 1973). Treated adults mated as readily as the untreated (Sukumar and Naidu, 1980) and affected older adults more than younger ones (Sukumar, 1980). In a life table of *D. koenigii,* Ahmad, (1983) showed that the egg and early instars are probably the most chemical –sensitive stages,

against which the least amount of pesticides might be used. Among compounds tested were Dimilin (LD_{50} = 0.000003 miligram/nymph) and methoprene (LD_{50} =0.000010 miligram/nymph (Ahmad, 1985). Methoprene and two other Juvenile hormone analogs (hydroprene, kinoprene) inhibited mating behaviour of cotton stainers when applied to them as nymphs (Hebbalkar and Sharma, 1980). Several new juvenile hormone analogs showed considerable promise in controlling this cotton stainer (and presumably others) (Tikku *et al*., 1999). Two substituted thiourea compounds sterilized females in a chamber treated with the compounds (Sandhu *et al*., 1984). TEPA applied to third instars also sterilized adults but did not affect reproductive activity (Sehgal *et al.,* 1980). The growth regulator hydroprene also sterilized both sexes (Revathy *et al*., 1979) as did several substituted pyrimidine-2-thiols (Kaur *et al.,* 1993). Whitefield (1933) emphasized and recommended spraying on *D. fasciatus*, but did not say with what. The juvenile hormone analogue tepa (topical 0.00000010 and 0.00000015 milligram/ third or fifth instar) caused some reduction in fecundity (Almeida, 1978).

The eggs of *D. fasciatus* showed increasing resistance with age to the insecticides, allethrin and the triethanolamine salt of 3: 5 dinitro-cresol, but decreasing resistance with age to HETP (Sakeld and Potter, 1953). Some resistance by the fifth instars to carbaryl and (to a lesser extent) lindane and methidathion occurred in Kenyan *D. fasciatus*; carbaryl resistance but not lindane resistance was increased after six generations of laboratory selection (Nyamasyo and Karel, 1982). Of several chemicals tested on *D. koenigii,* mercuric chloride proved to be an effective repellent of *D. koenigii* and remained effective for upto 70 days; melonic acid and 4- phenyle phenol were also effective for about two months (Ahmad and Khan, 1980). Shahi and Krishna (1981) and Banerjee and

Datta (1980) reported a mite *Hemipteroseius indicus* Krantz and Khot reducing population of this red cotton bug. Similarly, *Antilochus coquerbertii* F was reported to be feeding on *D. koenigii* (Kamble, 1974; Schaefer, 1999).

2. 5. 4 Use of plant products in controlling *Dysdercus* spp

Extracts from *Lantana camara, Anthocephalus cadamba, Tectona grandis, Calaphyllum* spp*., Phyllanthus emblica* (Prabhu and John, 1975) and from *Nepeta hindostra* (Roth) (Labiatae) (Srivastava and Neraliya, 1995), all adversely affected insect growth and/or metamorphosis. Several other natural plant products have been tested for sterilizing or growth-inhibiting effects against *D. koenigii*. Stem, leaf, root and reproductive structure extracts of 21 plants were applied to cotton stainer eggs, and the LD_{50} (presumably, inhibition of development) calculated. Some LD_{50} values were as low as 0.0000004-0.0000005 milligrams (*Cassia siamea, Desmodium polycarpum, Mimusops elengi, Vetiveria zizaniodes* (Suryakulla *et al.,* 1995), and these plants deserve a closer look. Similarly, extracts of *Azadiracta indica* A. juss (azadirachtin) (Koul, 1984). *A. indica, Calophyllum inophylum L*. and *Swietenia macrophylla* King Agrawal (1993); *Callistemon lanceolatus* (Australian bottle brush) (Katiyar and Srivastava, 1982; Katiyar *et al*., 1984), and Eucalyptus oil (Srivastava and Krishna, 1990; 1992; Srivastava and Neraliya, 1995), all affected reproduction and/ or insect development adversely. *Artemisia annua* oil applied topically had an LD_{50} of 0.48 microgram/1/fifth instar; development was delayed as well (Rao *et al*., 1999). Plumbagin was toxic to eggs at concentrations of 0.0044 to 0.00066 % Rao and Gujar (1995), and volatiles from *Alium sativum* bulbs significantly reduced egg hatch (Gurusubramanian and Krishna, 1996). Aristolachic acid (from

Aristolochia bracteata Retz), given to late instars and early adults in their drinking water, significantly reduced egg hatch at doses of 0.001 to 0.002% (Saxena *et al*., 1995). Of 12 Lamiaceous plants tested, nine detered oviposition by *D. koenigii* to some extent (Sharma *et al.,* 1981).

2. 5. 5 Use of microbials in controlling *Dysdercus* spp.

Infected by injection of water suspension of *Aspergillus flavus* conidia, late-instar and adult *D. cingulatus* greatly increased oxygen concentration, lost weight (partly from loss of water) and died (Prabhakar *et al*., 1992). In the laboratory, *Bacillus thuringiensis* was quite virulent against *D. cingulatus* (Kaushik and Chopra, 1969), as was the fungus, *Paecilomyces farinosus* (Kuruvilla and Jacob, 1980).

2. 5. 6 Use of cultural methods to control *Dysdercus* spp.

Early workers, Cowland and Ruttledge, (1927), emphasized cultural control measures in Sudan such as using blow lamps to burn out residual populations sheltering in baobab trees (successful in low population years), and destroying post harvest cotton debris as well as nearby baobab trees (Whitefield, 1933). Chemengich and Khaembra (1998) suggested planting unsuitable malvalian plants as trap crops. Ullyett (1930) recommended removing wild malvaceous plants, the wild hosts of this cotton stainer. An alternative might be to introduce such plants, as traps.

2. 5. 7 Host range

Host range or host specificity of a parasite is the collection of hosts that an organism can utilize as a partner and on which the insect can breed and can mature sexually.

Pyrrhocorids are commonly associated with plants belonging to the Malvaceae and Neotropical *Dysdercus* spp have been recorded feeding on ripe fruits and seeds of plant species belonging to the Bombacaceae (Adis and Froeschner, 1982), and Compositaceae (Mani, 2004). Species of Dysdercus are commonly referred to as cotton stainers, as they introduce staining fungi to cotton lint during feeding. They are known to have serious economic impacts on cotton, as well as okra, *Abelmoschus (Hibiscus esculentus* Moench). Like other *Dysdercus* spp, it feeds widely on seeds of various Malvaceous plants. The key features of the most important species have been summarized by Schaefer and Ahmad (2000). In Africa, a number of pyrrhocorid species occur in large colonies that exhibit complex biology. In such cases, there are reports of reduviids being both mimetic and predaceous on pyrrhocorids. Within these species aggregations – possibly examples of aggressive mimicry had been observed (Fuseini and Kumar, 1975a). Zrzavy (1990) considers the evolution of warning coloration within this large complex, and Zrzavy and Nedved (1999) the evolution of mimicry complexes in New World *Dysdercus*. *Dysdercus* spp have been a severe pest of oranges on occasions. In puncturing an orange, a cotton stainer often inserts its beak full length with no visible wound; nevertheless, a single puncture may cause the orange to drop from the tree in a few hours and decay (Mead and Fasulo, 2005). There are reports of orange trees well reddened with cotton stainers in which whole crops were lost (Hubbard, 1885) in Mead and Fasulo (2005). Some other hosts of *D. suturellus* include tangerines, okra pods, ripe fruits of papaya pods, and blossoms of oleander, seed pods of Jamaica sorrel (*Hibiscus sabdariffa*), tree hibiscus (*H. syriacus*), teaweed (*Sida sp*.), Caesar' s weed or Spanish cocklebur (*Urena lobata*), Spanish needle (*Bidens pilosa*), Seaside mahoe or portiatree (*Thespesia populnea*), rose

buds and blossoms, eggplant, nightshade, and guava (Mead and Fasulo, 2005). The hosts of the other species of *Dysdercus* spp are essentially the same as far as *D. suturellus.* The Division of Plant Industry has one record of royal Poinciana being severely damaged by *D. andreae*. The feeding activities of cotton stainers on cotton produce a stain on the lint, which reduces its value (Mead and Fasulo, 2005). Some authors reported *D. volkeri* associated with *Urena lobata*, *Ceiba pentandra* (cheese plant) and *Bombax buonopozense* (Kapok plant). *Dindymus versicolor* (Heteroptera: Lygaeidae) is regarded as a minor pest of soft fruit orchard, market gardens and home gardens in Southern eastern Australia and Tasmania (Stahle, 1981). The report added that significant losses occurred on sunflower and apple crop as well as the introduction into peaches of fungal infections via the bugs feeding punctures. *Dysdercus cingulatus* has been reported by Frazer (1944) as a vector of internal boll disease that caused considerable damage to ripening seed heads of wheat (*Triticum aestivum* Lamk) in Rajasthan (India) during February to March. One variety of wheat, N.P. 718, was resistant, but a local variety suffered considerable damage. *D. koenigi* does not appear to be a major pest of cotton everywhere in the Indo-Pakistan subcontinent, but it is an important one in Pakistan (Ahmad and Muhammad, 1983). Ahmad (1985) reported that *D. koenigi* may also be a pest on other plants of economic importance such as, egg plant, holly hock, *Abelmoschus esculentus*: Malvacea in Bihar, India (Pathak and Sinha, 1993). It has also been a minor pest of early varieties of the legumes, red gram, pigeon pea *Cajanus cajan* (L) Mill sp (Singh and Singh, 1978 a, b, and c) and peanut (groundnut) (*Arachis hypogea* L) Jayanthe, *et al*., (1993 a, b, c,) both near New Delhi (India) and Chandel *et al.,* (1984) reported that the red cotton bug, *D. koenigii* Fabr is the most damaging pest of Solanacious vegetables. *D. volkeri* has been reported in

Nigeria as a minor pest of soybean, whose leaves it attacks (Ezueh and Dina, 1980). Similarly in Nigeria, (Mani *et al*., 2010) reported *D. volkeri* as among the major insect species damaging irrigated sunflower. *Urena lobata* (Malvacea) (Aramina fiber) is a fibre crop grown for some years in Sierra Leone as a substitute for Jute (Harris, 1981). *D. volkeri* does considerable damage to the seeds, inducing up to 70 % non availability, the abundance of wild alternative hosts makes control of this cotton stainer difficult (Harris and Bindi, 1983), as in the case also with other species on other crops. Ullyett (1930) mentioned that *D. nigrofasciatus* has been recorded as feeding on citrus fruit and like all Old World *D. species*, this insect too feeds on such malvaceous crops as okra (bhindi) and kapok; it also attacks pigeon pea, *Cajanus cajan* (Lateef and Reed, 1990).

2. 5. 8 Sex ratio

The ecological and social bases of the mating system of the seed-feeding bug, *D. bimaculatus* were studied in the laboratory and in aggregations at the host tree, *Sterculia apetala* Malvales: Malvaceae, in Panama, (Scott and Jenella, 1988). Adult sex ratio at numerous sites was significantly male biased, and females whose mates were removed remated before oviposition (i.e. sperm utilization). These results predict that a mate defense tactic is likely to be superior to a non mate defense tactic. The biological significance of the parameters is supported by observations that captive pairs often remained in copula for several days, until just before oviposition. Causes of male biased adult sex ratio were investigated by monitoring demographic changes within a single aggregation over two months. Both female juvenile and adult mortality rates were greater than in males. Greater rates of immigration among both mature and young males suggests

that excess of males may also be found in the populations of bugs that subsequently colonize other host plants, so that female scarcity is typical of aggregations in all stages of development. The evolution of sex limited flight muscle histolysis may be explained by greater patchiness of females than males as mating resources, plus a lower benefit/cost ratio of histolysis for males (Scott and Jenella, 1988)

2. 5. 9 Responses of *Dysdercus* spp to relative humidity and temperature

Cotton stainers, *D. fasciatus* Sign are hygrosensitive to both dry and moist air, but not to intermediate relative humidities. Madge (1965) showed that the hygroreceptors are located on the 4th segmented antennae. Bilateral amputation of the terminal and sub-terminal segments resulted in a moist reaction. The *Sensilla basiconica* (peg organs) on the terminal segment are probably responsible for the moist reaction, and the *Sensilla trichodea* (sensory hairs) on the two terminal segments are probably responsible for the normal dry reaction. Other sensory areas on the antennae are probably not hygrosensitive. In temperature gradients of 15 ^{0}C - 38 ^{0}C mainly (in moist air) cotton stainers first aggregate at the cold end, and then aggregate in two peaks, one at the cold end, and another at 23 ^{0}C - 34 ^{0}C . The thermoreceptors are not located on the antennae, but elsewhere on the body (Madge, 1965). Migration of adults of a new generation from one breeding site to another is an important feature of the biology of many insect species (Bowden and Gibbs, 1973; Dingle, 1974) and migrants must therefore be considered as active colonizers of every potential habitat, and not just as individuals leaving an unsuitable environment (Dingle, 1972.) This recent concept of migratory behaviour modifies drastically the concept of colonization of new habitats by pest. The accent in

studies on migration has been on physiological aspects in the work of Edwards (1970) and Dingle (1974), and field work has been restricted, until recently, to occasional observations by light-trapping (Bowden and Gibbs, 1973) or to the classical type of cotton field survey (Pierrard, 1972).

Curiously, the idea that stainers are common migrants is based on old observations, which have not attracted much interest from field workers, possibly because these insects can be controlled easily with pesticides. During the migratory period, the adult stainers make nocturnal flights, which end with the discovery of the host plant, followed by the reproductive and sedentary period. Such migratory flights are dependent on climatic conditions (Duviard, 1973) and bugs in the migratory state will fly in the correct conditions of sunshine, air temperature and atmospheric humidity. Annual observed variations in this migratory phenology led to a hypothesis of a link between migrations and movements of the Inter Tropical Convergence Zone (I.T.C.Z). Two types of factors are responsible for the precariousness of the habitats of *Dysdercus* spp. that is food factors and climatic factors. The food factors include the host plants either malvaceous hosts or occasional graminaceous hosts. This provides fruit, bolls and seeds that are necessary for the development of *D. volkeri*. These sources of food are available during part of the year only. Each host species releases its seeds during a short period of time (a few weeks to a few months) in a given area and the different plant hosts do not present similar seeding phenology although, for a given host plant, sharp variations may be observed with changes of latitude. Although the seeding periods of the different host plants are not wholly synchronous, it does not seem that, when added to each other, they would facilitate the

survival of the insects throughout the year at one locality (Duviard, 1977). Host plants are scattered in the whole non-steppe Zone of West Africa ranging from dry Sudan Savanna to evergreen rain forest. The second factor is climatic – the sensitivity of *Dysdercus* spp to temperature and humidity affecting the survival of eggs and young nymphs as well as the activity of nymphs and adult stages is well known. It has been shown that, in the case of *D. volkeri*, favourable climatic conditions were generally encountered together with available food (Duviard, 1973) but this was not a perfect synchrony. According to Duviard, 1973 during the dry season, the southward movement of the I.T.C.Z may, with the establishment of the harmattan (a dry warm wind from the Sahara) restricts development of cotton stainers for some time in the savanna habitats, although food may be available. Dryness and high temperature associated with this wind, first stop the activity of adult and immature stages and eventually kill the eggs and nymphs. In the main forest belt areas with much available food, survival of *D. volkeri* is difficult especially when there is heavy rainfall. High mortality then occurs due to drowning of colonies of nymphs by rainfall and to a lethal fungal disease associated with high humidity (Duviard, 1977). It has been observed that in a given area where *D. volkeri* was completely absent for several months, the pest appeared suddenly in large numbers (Bowden and Gibbs, 1973). This type of sudden appearance occurs with the onset of the dry season as observed in the cotton growing area during the period when cotton forms bolls and seeds at Ibadan, Nigeria (Pierrard, 1972) and Ghana (Bowden and Gibbs, 1973). This immigration follows a total disappearance of the species during the preceding rainy season, and was observed only in the southern part of the geographical area. Immigration of *D. volkeri* occurs with the onset of rains. This has seldom been described for it happens during the

absence of cotton crops from the fields. Thus, there are two areas exploited by *D. volkeri* in West Africa, which is limited in the north by the 800 mm isohyets, a southern one and sub-Sudanian where the insects immigrate suddenly with the dry season and disappear with the rains and a northern one, roughly Sudanian, where insects immigrate with the rains and disappear during the dry season (Leroux, 1972). However, Leroux (1972) showed that dry season and wet season climates are not uniform throughout West Africa. The link between flight activity, weather and survival had been studied by Duviard (1973). The results of the observations confirm this interpretation of flight ecology in *D. volkeri*. Whenever it was observed, the migratory activity is related to warm, wet and sunny conditions occurring in the climatic belts as determined by the constitution of the Inter-Tropical Convergence Zone (I.T.C.Z.), which according to the evaluations of meteorologists (Leroux, 1972) represents a belt of 60–900 km width. In places like Bamako (Mali) Ferkessedouguo (Cote d' voire) and Kano (Nigeria) where the harmattan wind blows, the survival of *D. volkeri* is only possible for a short period of time. If these areas have this type of weather for long periods *D. volkeri* disappear since temperature and humidity are not compatible with the survival of eggs, nymphs and adults, or with locomotory activity. Conversely, in places like Adiopodoume, Lamto and Foro-foro (Cote d'voir), Tafo, Kwadaso (Ghana) and Ibadan (Nigeria) where heavy rainfall occurs and humidity is very high, despite lesser rains; the drowning of colonies of *D. volkeri* and the development of a lethal fungal disease curtail population of the species (Duviard, 1973). A consequence of migration or dispersal is that crowding is reduced. Crowding hastens development, but increases nymphal mortality and egg production. Decreasing crowding

thus increases fecundity and longevity, and thus the damage done to cotton (Egwuatu and Opara, 1985).

2. 5. 10 Biology

Little work was done on the biology of *Dysdercus* spp. on sunflower particularly on *D.volkeri*. The following is taken from the report of Taylor (1982) about *D. fasciatus* on cotton in Zimbabwe. They mate within a few days of becoming adults and may remain in copulation from 3 to 8 days. Eggs are deposited in batches of 50 in hollows or in crevices in the soil. Up to 350 eggs are laid over a three weeks period. Nymphs emerge within six days of oviposition. First instar nymphs do not feed and remain in groups, in the soil near where the eggs were laid. The remaining four instars feed and disperse widely and tend to be gregarious. Development may take from 25 to 53 days. Young adults are strong fliers and disperse freely. In Southern Nigeria, the highest fecundity was recorded on silk cotton tree (*Bombax buonopozense*. P. Beauv) (309 eggs) and okra (307 eggs); cotton was next (249 eggs), then roselle (*Hibiscus sabdariffa* L) (164 eggs); no eggs were laid by bugs fed on kenaf (*H. cannabinus* L.), flame of the forest (*Delonix regia* Boj ex Hook), aramina fibre (*Urena lobata* L.) , or green gram (*Vigna* [= *Phaseolus*] *aureus*). Total nymphal durations varied little among the plants except that development was incomplete with green gram and flame of the forest. Percentage emergence (to adult) ranged from 57 to 75 %, except 38 % on kenaf. Males lived up to 50% longer than females, and females lived longest on okra (17 days). Overall, okra seems to have been the best plant tested, and cotton intermediate (Egwuatu, 1980). There is some evidence that *D. volkeri* can survive on non-malvaceous plants. Geering and Coaker (1960) raised cotton stainer successfully on *Sorghum vulgare, Vigna unguiculata* and the grain crops, *Pennisetum typhoides* and

Zea mays; however, cotton promotes higher fecundity and longer life than the other crops. In Ghana, on a different series of food plants (all Malvales), *Ceiba pentandra* was preferred over three species, but comparative tests of fecundity and longevity were not made (Fuseni and Kumar, 1975a). The fact that the bugs require ripe seeds, move from host to host, as the seeds of each plant become available (Edmunds, 1978); this pattern appears to characterize *Dysdercus* spp (VanDoesburg, 1966 and Janzen, 1972).

2. 5. 11 Habitat preference.

Population of *Dysdercus* spp were too low in sweepnet collections made in surveys conducted in Cote d'voire and Guinea to determine their distribution in relation to climatic zones and toposequence site (WARDA, 1994). In Cote d'voire, low numbers were found in upland fields in the forest zone (WARDA, 1994). Emosairue and Usua (1994, 1996) reported *D. vokeri* to be an important pest of upland rice where they were noted as the most abundant insect species with 32 % of all insects collected. Mani (2004) reported *D. volkeri* as one of the most abundant insect species on irrigated sunflower in Samaru Zaria, Nigeria. Duviard (1977) reported that *Dysdercus* spp. in West Africa differ in relation to their abundance in the various climatic zones. *D. melanoderes* is a forest species, seldom found in the savannas of the northern part of Cote d' voire, and *D. haemorrhoidalis* Signoret is mostly present in the savannas of the central part of Cote d' voire, and *D. volkeri* is more numerous in the savanna than in the forest zones. Duviard (1977) also reported on the relationship between the movement of the intertropical convergence zone and the migration of *Dysdercus* spp. In West Africa, migration of *D. volkeri* in the Ferkessodougou, (Cote d' voire), area occurs between the time of the harmattan and the beginning of the wet season.

2. 6 Insect pest resistance in sunflower

One problem with incorporating pest resistance into crop plants is that the pest represents living, evolving populations; that makes plant breeder's job a never-ending task. New pests can arise from seemingly innocuous species, or old pests can mutate into virulent new biotypes capable of decimating cultivars that once were resistant. Wild species of Helianthus are also attacked by many species of pests in their natural environments. These pests might also mutate into biotypes, which could attack the domesticated sunflower. Such a transition in pest status of a species from scattered wild populations to domesticated monocultures would greatly enhance the immediate biological fitness of the pest species, causing great increases in pest population density. Intraspecific differences, both within wild *H. annuus* and other *Helianthus* species, need to be recognised because not all plants of a species exhibit identical levels of resistance to a given pest. It is important to consider more than one accession of a species in determining whether resistance genes are obtainable from that species. Differences in expression of resistance may even be seen within genotypes grown in the field and in the green house (Thomson and Rogers, 1977). Until recently, very little attention was given to developing insect-resistant sunflower. In the USA Teetes and Randolph (1971) reported tentative resistance and/or differing degrees of susceptibility to larvae of the sunflower moth, *Homoeosoma electellum* (Hulst) in *H. petiolaris* and other commercial varieties. Thompson and Rogers (1977) and Rogers and Thompson (1978a) reported on the potential use and evaluation of *Helianthus* species as a source of resistance to insect pests. Because wild sunflowers are native to the USA their associated insect herbivores and their entomophages coevolved in natural communities that often exist in cultivated fields of sunflower. The long

association of wild sunflower and insects in the USA has resulted in hundreds of species of insects that frequent the plants. Fortunately, most species of insects associated with sunflower are either innocuous or benefactors of the plants and relationships range from obligatory to purely causal and non essential (McGregor, 1976). However, pest problems on sunflower have been more acute in the USA than elsewhere due to natural coevolutionary associations of sunflower with its natural herbivores. Species of insects that are recognised as pests of cultivated sunflower in the USA have been summarised by Beckham and Tippins (1972).

Several species of Lepidoptera use sunflower as a host and attack cultivated sunflower (Rogers, 1988). Historically, the sunflower moth has been and continues to be the most damaging insect pest of cultivated sunflower in the USA. Wild species of sunflower have served as sources for moth-resistant germplasm lines (Rogers *et al*., 1984). These germplasms were based on *H. tuberosus* and *H. petiolaris*. The three released germplasms have a phytomelanin layer, which becomes extremely dense after its deposition in the pericarp, making the achenes with these characteristics more resistant to mechanical puncture by larvae at an earlier stage of development (Stafford *et al.*, 1984). The hardened pericarp is thought to protect achenes from damage by younger sunflower moth larvae. All species of *Helianthus* have phytomelanin in pericarps, although the characteristic does not appear to be present in all populations of a species (Seiler *et al.,* 1984).

Wild sunflower species may offer natural defences for control of economically important insect pests. Recently, it has been found that sesquiterpenes lactones extracted from glandular trichomes on the apex of anthers of *H. maximiliani* caused a high acute mortality

of *H. electellum* larvae in laboratory bioassays (Gershenzon *et al.*, 1985; Rossiter *et al.,* 1986; Rogers *et al*., 1987) chemical extracts from *H. annuus* florets contain diterpenoid acids that produce a chronic lengthening of larval stadia but not high mortality (Waise *et al.,* 1977).

The curculionids, as a group, have been the most economically damaging insect pests of cultivated sunflower in the central and Northern Great Plains States of the USA. Weevil larvae attack every part of the plant and often inflict severe tissue destruction and yield loss before their presence is evident. A stem weevil, *Cylindrocopturus adspersus* (Le conte), has been a particularly troublesome pest of cultivated sunflower wherever the crop is grown West of the Mississippi River (Phillips *et al.,* 1972; Rogers *et al.,* 1983). Twenty-four species of *Helianthus* (11 annuals and 13 perennials) have significant levels of resistance to *C. adspersus* female oviposition and/or larval development (Rogers and Seiler, 1985). Hence, the use of host resistance through germplasm derived from wild sunflower species holds considerable promise as an enduring, efficient management strategy for stem weevil control in cultivated sunflower.

The carrot beetle, *Bothynus gibbosus* (De Geer), is a widely distributed pest of several crops in the USA. It is a potential pest of sunflower found on sandy soils in the USA. *Helianthus petiolaris* is among the preferred natural hosts of carrot beetle (Rogers, 1974). No effective control strategies, either cultural or chemical, are presently available. When grown in an infested field at Munday, Texas, severe root damage occurred in *H. annuus, H. argophyllus,* and *H. maxiliani,* while the roots of *H. hirsutus, H. tuberosus* and *H. mollis* showed no evidence of injury by the carrot beetle (Rogers and Howell, 1973).

Laboratory and green house studies showed that about one-half of wild *Helianthus* species are resistant to carrot beetle injury (Rogers *et al*., 1978; Rogers and Thompson, 1980). Carrot beetle feeding on the roots of *H. arizonensis, H. atrorubens, H. occidentalis ssp.,* Plantagineus, and *H. porteri,* suffered a high acute mortality in no-choice feeding tests (Rogers and Thompson, 1980). The sunflower beetle, *Zygogramma exclamationis* (L.) has long been recognized as an important defoliator of sunflower in the Northern Plains of the USA but not a serious pest in the southern Plains (Rogers, 1977). In laboratory studies, about one-half of the wild sunflower species exhibited resistance to feeding and/or reproduction by sunflower beetle (Rogers and Thompson, 1978c, 1980). Antibiosis against both larvae and adult beetles was strongly expressed, particularly by perennial *Helianthus* species in sunflower has merit as a management strategy for sunflower beetle and other Coleopterous pests. Several other insect species attack cultivated sunflower but are of no great economic concern. Aphids, *Masonaphis masoni* (Knowlton), and leafhoppers, *Empoasca abrupta* (Delong), are sometimes abundant on sunflower. Laboratory and greenhouse studies showed that several species of Helianthus that are cross-compatible with cultivated sunflower are resistant to attack by the aphids and the western potato leafhoppers (Rogers and Thompson, 1978b; 1979; Rogers, 1981).

Host resistance in cultivars through incorporation of germplasm from wild *Helianthus* offers a tremendous potential for long – lasting, economical management of several insect pests of cultivated sunflower. Also for the short term, it appears that if more were known about the bionomics of pests on the native *Helianthus* spp much could be learned about ecologically sound strategies which could be developed for management of insects on cultivated sunflower (Rogers, 1988).

2. 7 Oil content and seed quality

Wild sunflower species possess considerable variability for most economic and agronomic characteristics and seed quality factors (Thompson *et al.,* 1981). Seed oil content of most wild species has been reported (Fick *et al.,* 1976; Thompson *et al.,* 1978; Dorrell and Whalen, 1978; Thompson *et al.,* 1981; Seiler, 1985a). All wild *Helianthus* spp that were evaluated had lower oil content than the cultivated sunflower. *Helianthus niveus* ssp canescens has the highest oil content (40.2%) among the wild species, followed by *H. niveus* ssp tephrodes 37.48%, *H. petiolaris* ssp. petiolaris 37.4% *H. petiolaris* ssp. fallax 37.7% and 37% for *H. salicifolus*. Seiler (1985a) reported oil content of 37.9% in *H. anomalus* and 34.3% in H. *deserticola*. Oil content of several native populations of *H. annuus* averaged 22.3 to 30.3% (Fick *et al.,* 1976; Thompson *et al.,* 1981 and Seiler, 1983). Environmental factors, especially temperature during the period of seed development and maturation, affect both the content and composition of oil in maturing cultivated sunflower seeds. The effects of temperature on oil content, however, are variable (Harris *et al.,* 1978; Robertson, 1979; Unger and Thompson, 1982). Average oil content of wild *H. annuus* does not vary significantly when native populations are grown in a uniform environment (Seiler, 1982, 1983, 1986). Average oil content of *H. annuus* varies from 23.8 to 25.5% very close to the average for native populations. Seeds from seven of 22 perennial species grown at a common location had significantly different seed oil content than seed from the original populations (Seiler, 1985b). Very little information is available about effects of environmental factors on oil contents in perennial species. In perennial species, oil content may be under more rigid genetic control or less influenced by environmental factors than in the annuals, at least in the populations evaluated thus far.

Path coefficient analysis indicated that minimum temperature and total solar radiation have the greatest direct effect on seed oil content in the wild annual sunflower, though the influence is minimal (Seiler, 1986).

2.8 Fatty acid profile

Most wild species of *Helianthus* have been evaluated for fatty acid concentrations (Thompson *et al.,* 1978; Thompson *et al.,* 1981; and Seiler, 1986). Concentrations of linoleic acid averaging over 72% have been reported in *H. porteri* (82.3%), *H. simulans* (78.0%), *H. laevigatus* (77.5%), *H. heterophyllus* (75.5%), *H. smithii* (75.2%), *H. rigidus* ssp. subrhomboides (75.1%), *H. microcephalus* (74.1%), *H. cusickii* (72.8%), *H. debilis* ssp. tardiflarus (77.6%), *H. exilis* (77.8%), *H. strumosus* (73.7%), and *H. raduia* (76.6%), (Thompson *et al.,* 1981; Seiler, 1985a;). Several species had one or more populations having linoleic acid concentrations above 72%; the range for the entire genus was from 37% in one population of *H. argophyllus* to 83% in *H. porteri*.

Oleic acid, another important fatty acid, appears to be quite variable in wild sunflower species. Species accessions having oleic acid contents of 40% and above are: *H. arizonensis* (41.2%), *H. hirsutus* (46.8%), *H. annuus* (46.30%), *H. silphioides* (45.7%), *H. praecox* ssp runvonii (41.0%), *H. annus* (46.30%), *H. argophyllus* (47.5%), and *H. radula* (49.3%), (Thompson *et al.,* 1981; Seiler, 1985a). Seeds of species of many accessions examined for fatty acid concentrations were from plants in a common location. Environmental conditions in various locations where individual accessions were collected may have influenced oleic and linoleic acid concentrations. Fatty acid concentrations of 22 perennial species (one accession each) from the original habitats were compared with

these traits in seeds of respective accessions grown at a single location (Bush land, Texas) to determine environmental influences on fatty acid concentrations (Seiler, 1985a). Oleic acid concentrations were significantly different for 10 of the 22 species examined for the original vs common environments, while linoleic acid concentrations were significantly different in five of the 22 species. Palmitic acid was not significantly affected by different environments in any species, and stearic acid was significantly affected by different environments in only *H. mollis* and *H. occidentalis* ssp occidentalis. Undoubtedly, some of these variations were caused by differences in environments at different locations. However, the fact that different individual plants within a species accession at a single location have distinctly different levels of oleic and linoleic acids suggests that the variations may also have a genetic component (Knowles *et al.,* 1970). Multiple regression analysis indicated that day of year, total solar radiation, and maximum temperature significantly influenced linoleic acid in *H. annuus*, whereas oleic acid was influenced only by the latter two factors (Seiler, 1983). Path coefficient analysis indicated that minimum temperature and solar radiation had the primary influences on oleic acid concentration in wild annual sunflower and cultivated sunflower, with maximum temperature being less important (Seiler, 1986). Linoleic acid concentration was primarily influenced (negatively) by minimum temperature and solar radiation in wild annual and cultivated sunflower, as indicated by path coefficient analysis. The analysis also indicated that wild annual sunflower reacts similarly to cultivated sunflower to the environmental factors examined.

2. 9 Sunflower diseases

Cultivated sunflower lacks genes for acceptable level of resistance for the majority of sunflower diseases. Diseases are still a limiting factor to high productivity in the majority of sunflower growing countries. Crossing it with the numerous wild *Helianthus* species as sources of genes are identified from the wild species may increase genetic variability of cultivated sunflower. According to Putt and Sackston (1963), *Puccinia helianthi* was the first disease to be genetically controlled by resistance gene Race 1 and Race 2 incorporated from wild annual, *H. annuus* from Renner, Texas. Wild *Helianthus* species, *H. annuus* and *H. petiolaris* contain a vast reservoir of rust resistance genes that can broaden the rust protection base of domestic cultivars (Hennessy and Sackston, 1972; Zimmer and Rehder, 1976). Resistance to Races 1 and 3 of rust was found in *H. praecox* ssp runvonii, *H. praecox* ssp. hirtus, *H. aroghyllus* and 18 wild *H. annuus* populations (Thompson *et al*., 1978). Rust resistance appears to be common in wild sunflowers (Fick *et al*., 1974). Wild annual *Helianthus* species provides a sanctuary for the rust fungus in the absence of susceptible cultivars (Zimmer and Hoes, 1978). Studies in wild annual sunflowers suggest that many races of rust occur, with their number being limited only by the number of differentials used. Rust can be controlled effectively on sunflower for long periods by using specific genes for resistance, especially since a free breeding rust population exists on wild sunflowers. *P. helianthus* is confined to the genus *Helianthus,* where it occurs on more than 35 annual and perennial species (Hennessy and Sackston, 1972; Zimmer and Rehder, 1976). Wild populations of annual sunflower contain some rust resistant plants (Hennessy and Sackston, 1972; Zimmer and Rehder, 1976) but completely resistant or totally susceptible populations are rarely found.

Resistance to downy mildew in cultivated sunflower is conditioned by PL genes, PL_1, PL_2, PL_3, PL_4 and PL_5 (Vranceanu *et al.,* 1981). Wild *Helianthus* species has served as a source of downy mildew resistance genes. *Helianthus praecox* ssp runyonii, *H. praecox* ssp hirtus; *H. argophyllus*, and 18 wild *H. annuus* entries were resistant to race two of downy mildew (Thompson *et al.,* 1978). Further testing has shown that these species are also resistant to races three and four. The resistance in some of the species may be due to the PL_2 resistant materials were originally found (Zimmer and Kinman, 1972). Downy mildew resistance to Red River Race 2 is most common among five perennial species (*H. tuberosus*, and *H. nuttallii*), while the annual species were very susceptible (Fick *et al.,* 1974).

Verticillium dahliae (*verticillium* wilt) is an important wilt disease in sunflower. Resistance to *Verticillium* wilt is widespread in wild sunflower (Hoes *et al.,* 1973). *Helianthus annuus* collected from Manitoba, Saskatchewan, and North Dakota generally are less resistance to *V. dahliae* than those collected from more southern latitudes (i.e. Colorado and Kansas). *H. petiolaris* generally is more resistant than *H. annuus*. Population of *H. annuus* from the central and Southern Great Plains, coinciding with the hypothetical center of origin of *H. annuus* and *H. petiolaris*, appear to have relatively higher levels of resistance to *V. dahliae* (Hoes *et al.,* 1973). Putt and Sackston (1963) discovered a source of genetic resistance to *V. alboatrum* in line CH144, which is derived from an interspecific hybrid. Pustovoit *et al.* (1976) reported that *H. tomentosus* is resistant to *V. dahlia*.

Alternaria helianthi (Alternaria leaf spot) has been reported from sunflower in both the USA and other parts of the world. Kong *et al.* (1995) and Morris *et al.* (1983) tested 21 annual and 37 perennial taxa of *Helianthus* spp for resistance to *Alternaria helianthi* under green house conditions. Only three perennial species (*H. hirsutus, H. rigidus* ssp subrhomboideus, and *H. tuberosus*) were moderately resistant. All 21 annual species tested were very susceptible. *Erysiphe cichoracearum* (powdery mildew) is a widely distributed pathogen of cultivated sunflower in various regions of the world. Saliman *et al.* (1982) found annual species *H. dahlia* ssp silvestris*, H. praecox* and *H. bolanderi* and 14 perennial species that were tolerant to powdery mildew in both field and green house tests. Some populations of the perennial species *H. grosseserratus* and *H. maximilliani* were resistant, but others were not. These results indicate that several populations of a species may need to be tested to detect genes for resistance in a species. Jan and Chandler (1985) identified a source of resistance to powdery mildew in the wild *H. debilis* ssp. debilis, which they later transferred to cultivated sunflower. Resistance was completely dominant in the F_1 and backcross progenies. This source of disease resistance may enable the production of resistant hybrid cultivars suitable for warm, humid climate. *Rhizopus* head rot (*Rhizopus* spp) has become an important disease of sunflower in the USA (Rogers *et al.,* 1987). Only four of the 32 native *Helianthus* species (*H. divaricatus*, *H. hirsuatus, H. laetifilorus* and *H. resinosus*) evaluated for resistance using the insertion inoculation method were moderately resistant to *R. arrhizus* and *R. oryzae* (Yang *et al.,* 1980).

Orobanche cumana (broomrape) is a seed producing root parasite of cultivated sunflower in several countries (Cubero, 1986). Most sources of genetic resistance to this disease were derived from wild *H. tuberosus.* Pustovoit *et al.* (1976) have developed several

varieties based on *H. tuberosus,* which are resistant to several races of broomrape. Broomrape can be an important disease in some of the drier areas, such as Turkey.

Diaportha/Phomopsis helianthi (Stem Canker) is one of the most widely distributed diseases of cultivated sunflower (Skoric, 1985). This disease is now prevalent in Serbia, Romania, Hungary, Brazil, Argentina and Australia. (Mihaljcevic *et al.,* 1980; Skoric, 1985) reported a high degree of susceptibility to stem canker in all hybrids and in most varieties. Cuk (1982) reported that a certain number of wild sunflower species were free of *Diaportha/Phomopsis helianthi*, and it was assumed that these species were potential sources of resistance to the pathogen. Four lines tolerant to stem canker were identified (two based on *H. tuberosus,* one on *H. annuus,* and one on *H. argophyllus*) (Skoric, 1985). Other wild species that are potential sources of resistance are *H. debilis* and *H. rigidus* (Cuk, 1982). Hybrids based on the *H. tuberosus* and *H. argophyllus* species have been developed and have a high field-tolerance to stem canker (Skoric, 1985). Resistance to stem canker is positively correlated with resistance to *Macrophomina phaseoli, Phoma oleracea* var helianthi and drought (Skoric, 1985). It remains to be determined whether these resistances are controlled by linked genes.

Sclerotinia sclerotiorum is a major pathogen of sunflower that causes roots, stems, and flower heads to rot or wilt (Zimmer and Hoes, 1978). The pathogen causes root rot and wilt in wild *H. annuus* and crown rot of *H. tuberoses.* Genetic resistance to *Sclerotinia* spp is badly needed in North America (Orellana, 1970) and in Europe. Thompson *et al.* (1978) found that most of several hundred accessions of wild *Helianthus* spp from the USA and Canada were highly susceptible (> 90 % infected plants), but some were moderately

resistant (70 – 79 % infected to *Sclerotinia* spp under green house condition). The *Sclerotinia* spp disease complex appears to be very complicated. Looking at the wild sunflowers for resistance to this disease has not been very successful, and the prospect of finding a single dominant gene for resistance does not look too promising at the moment (Thompson *et al.*, 1978) felt that annual species (especially *H. annuus*) may be the best source of resistance.

2. 10 Some key insect pests of sunflower and their management

Cultivated sunflowers in Kansas and other parts of the Globe, host a variety of insects. Most are not damaging and many are beneficial. Harmful species are not always present in sufficient numbers to cause economic loss. However, when certain pest species are abundant, significant damage may result from root, stem, leaf, flower or seed feeding. In addition, significant losses can occur from lodging caused by stem weevils, stem girdlers or by vertebrates such as skunks and raccoons foraging for grubs. Some insects also can spread certain diseases. Wild sunflowers and various shrubs, trees and weed species serve as hosts for many pests of cultivated sunflowers. Because many sunflower pests overwinter in or near host plant residues, crop rotation and control of wild sunflowers may reduce the intensity of subsequent infestations. Some insects have been found to be pestiferous to sunflower in so many parts of the world and some of these insects proved to cause economic damage (Charlet *et al*, 1987).

2. 10. 1 Stem and root weevils

Three species of weevils occur in stems or roots of sunflowers in Kansas (Brewer, 1991). The most important of these is the sunflower stem weevil, *Cylindrocoptorus adspersus* Le

conte. It is 1-2.25 mm long and mottled gray-brown with irregular white spots. The antennae, snout and eyes are black. The second species is the black stem weevil, *Apion occidentale* Fall. It is shiny black and tiny, only 1.00 mm long from the tip of the slender, curved snout to the back of the spherical body. The economic impact of these insects is increased because they are vectors of phoma black stem rot. Spores of this fungus have been isolated from adults of both species (Brewer, 1991).

Emergence of sunflower stem weevil adults occur mid-May to early June, and females begin laying eggs at two weeks of age. Stem weevil adults feed on foliage, and females insert their eggs into the base of stalks. Larger plants are preferred for oviposition, and single stalks may accumulate more than 200 larvae. Larvae feed in the stem cortex, descending to lower portions of the stalk as they mature. Mature larvae of the sunflower stem weevil form over wintering chambers in the lower stalk near ground level. Pupation occurs the following spring or early summer (Brewer, 1991). Infestation by 25 or more sunflower stem weevil larvae per stalk results in yield loss through physical stress and interferes with the transport of water and nutrients. Severely affected plants may exhibit delayed development, dwarfed heads, reduced seed size and reduced seed oil content. There is an increased risk of lodging before harvest that can be exacerbated by phoma stem rot, drought stress and high winds. However, late-season lodging also may result from damage by stem girdlers. As harvest approaches, splitting a series of stalks from various parts of the field will provide an indication of stem weevil infestation pressure. This information is important in determining how long the harvest might be delayed and predicting the potential stem weevil problems in nearby fields next season. Non rotated

fields, or fields planted next to where sunflowers were planted the previous year are more likely to have significant stem weevil populations, especially where infestations were serious the previous year (Charlet and Brewer, 2007). Double crop sunflowers or those planted after the first week of June seldom develop severe stem weevil infestations. Some evidence suggests that plant resistance to stem weevil larval development is reduced under drought conditions, so stem weevil damage may be more of a concern under dry land production. When significant populations are present, applications of insecticide may be warranted at the 8 to 10 leaf stage. Systemic insecticides such as carbofuran are effective against larvae within stalks but are best when followed by irrigation to ensure uptake by the plants. Adults can be controlled with most foliar insecticides (Charlet and Brewer, 2007)

Economic thresholds based on cohorts of adults are not well defined, because adults are cryptic in appearance and behaviour and difficult to observe, and because their numbers often do not correlate with numbers of larvae developing within stalks. Since these insects are relatively difficult to scout for, but easy to control with most registered chemicals, a treatment for stem weevils at the 8 to 10 leaf stage should be considered for fields planted to sunflower prior to the first week of June in regions with a history of weevil infestation problems (Charlet *et al.,* 1987).

Black stem weevils overwinter as adults in the soil or plant residue. Adults are active in the early vegetative stage. Larvae are similar to those of the sunflower stem weevil, but only about half the size and more yellowish. Larvae feed in the stem and complete development by early August. Adults emerge in late summer and continue to feed until

harvest. Damage from this species has been negligible, and no economic thresholds or scouting procedures have been developed (Charlet *et al*., 2002)

Adults of the root weevil usually emerge soon after the sunflower stem weevil, and may be found feeding on sunflower foliage early in the morning or late in the evening. Within two weeks, adults migrate down near the root zone. The adults feed at the base of the plant and lay eggs in the callous tissues that develop around their feeding scars. Larvae feed and develop without moving far into the stem and overwinter among decaying roots. Abundant larvae can cause plants to wilt or lodge, but no economic thresholds have been established (Knodel *et al.,* 2000).

2. 10. 2 Sunflower headmoth

The sunflower moth, *Homoeosoma electellum* (Hulst) is the most damaging pest of sunflowers in Kansas (Wilson and McClurg, 1997). Adults are whitish, 9 mm to 7.5 mm long and rest with the wings clasped tightly to the body, giving the moth a cigar shape (Charlet *et al.,* 1997). Flowers in the early stages of bloom are favoured for oviposition, and females lay their eggs at the base of the florets. Newly hatched larvae are pale yellow, but darken to shades of brown or purple with longitudinal white stripes. Early instars feed on pollen and florets. Later instars bore into the head and consume receptacle tissues and seeds. Tangled mats of webbing on the face of flowers are signs of larval feeding. The injury caused by larval feeding provides infection sites for *Rhizopus* spp head rot that can lead to complete yield loss. Although a portion of larvae pupate in the heads, the majority of maturing larvae descend to the ground on silken threads to pupate in crevices or under leaf litters. Under warm conditions, a generation can be completed in 30 days.

Field scouting for the moth starts as the first flowers begins to open (Stage R_4 to $R_{5.1}$). Scouting must be done frequently because migratory moths can appear in large numbers virtually overnight when populations are high, moths may be detected by walking through the fields at any time of day and watching for moths to fly up as plants are approached (Charlet *et al.,* 1997). When populations are lower, it may be best to scout at fields after dark with a flashlight and look for moths resting on the opening blooms. The treatment threshold is around one or two moths per five plants. After treatment, scouting should continue every two to three days until plants reach the $R_{5.9}$ stage. Sunflower moth activity can be monitored with commercially available pheromone traps that attract and capture male moths. These traps should be placed on T – posts above canopy level at least 10 rows into field on north and south sides by placing at least four traps per field (Wilson and McClurg, 1997). Trapping should begin as the first flowers reach the R_4 stages (buds beginning to open) and trap catches should be monitored daily until flowering is nearly complete ($R_{5.9}$ stage). Insecticide applications should be considered when pheromone traps have four moths per trap per day from the $R_{5.1}$ to $R_{5.9}$ stages. Economic implications are not well established for traps catches of less than four moths per day. If trap catches average less than four per day, field scouting to determine the action threshold is justified. Trap catches averaging less than one per day are non-economic infestations. Early planted fields typically suffer the most damage from sunflower moths. Fields planted in early July that bloom after August 10 are less likely to develop economic infestations, but delayed planting can increase the risk of losses to seed weevils and migratory birds (Knodel *et al.,* 2000). A preventive insecticide treatment is best applied as blooms begin to open. If

moths are above the threshold, treatments should be applied as 20 to 40 percent of the plants begin to flower ($R_{5.1}$ stage). When populations are low, treatments can be delayed until 90 – 100 percent of the plants have reached stage $R_{5.1}$. Most failures to obtain control, results from delaying treatment. Some recent findings indicate that in some cases, later moth flights can produce significant egg laying several days after flowers begin to bloom, which emphasizes the need for continued scouting (Knodel *et al.,* 2000). Early insecticide applications target adults and small larvae, and the objective is to kill females before eggs are laid in the flowers, or kill larvae before they feed deep in the head. Additional applications, applied at five to seven day intervals, may be required for heavy moth infestation pressure (Wilson and McClurg, 1997). Once flower disks are fully expanded, a treatment will be more effective if it is applied directly into the face of the flowers. Various pyrethroids irritate larvae and will make them to leave the heads, but only when deposited on the flower face. Factors such as gallonage, wind direction, flight direction and height will probably all affect the success of these later applications (Wilson and McClurg, 1997).

2. 10. 3 Seed weevils

Two species of weevils attack sunflower seeds in Kansas and may reduce yields. The gray seed weevil, *Smicronyx sordidus* Le conte is about 0.6 cm long, and the red seed weevil *Smicronyx fulvus* Le conte, is 0.3 cm long. The gray seed weevil adults emerge five to 10 days earlier than the red seed weevil in a given season. Both weevils produce one generation per year and feed on plant tissues under the bracts of developing flowers, causing little damage. Gray seed weevils begin to deposit eggs on sunflowers in the bud stage. Larvae penetrate the seed at its base and destroy the ovary. Red seed weevil females

must feed on pollen to mature their eggs (which takes four or five days) and do not oviposit in flowers before pollen release. Flowers at $R_{5.5}$ stage are preferred and oviposition is concentrated in the developing seeds along the outer edges of flower (Rana and Charlet, 1997). Larvae of both species feed within seeds. At maturity, an exit hole is cut and the larva drops to the ground and burrows into the soil and overwinters. It pupates and emerges as an adult in the spring (Rana and Charlet, 1997).

Insecticide treatments for the red seed weevil must be timed to target adults before oviposition occurs. As fields approach 85 percent bloom (80 percent of the plants pass R_4), select five mature heads and count the weevils and repeat this five times at different locations in the field and away from the margins. The treatment threshold can vary from 10 to 20 weevils per flower for oil seed varieties depending on the expected yield, projected value and the cost of treatment. The threshold drops to one weevil per head for confection varieties because of the lower tolerance for insect damage. Because adults emerge over an extended period, follow early treatment with continued scouting to determine the need for a second treatment. Treatments applied for sunflower moth also may provide some seed weevil control (Rana and Charlet, 1997).

2. 10. 4 Stem borers – Beetle larvae

This group of stem borers is long horned beetles (beetles with long antennae) that attack sunflowers and utilize a variety of composite weed hosts, including wild sunflower, cocklebur, and ragweed. The most important is *Dectes texanus* Le conte*,* a species that has recently expanded its host range to include soybean. Adults are bluish gray and 0.46 cm to 1.2 cm long with antennae as long, or longer than the body. A related species, *Ataxia*

hubardi Le conte, is usually less abundant in cultivated sunflower in Kansas, but is often present with *D. texanus* larvae and can predominate in early planted fields. Adults of this species are larger (1.25 cm to 1.80 cm long), more brownish in colour and emerge 10 to 14 days earlier than *D. texanus*. Both species produce only one generation per year with adults emerging over an extended period, usually beginning in June, and remaining active throughout the summer. Adults mate and feed on plants, leaving longitudinal feeding scars on stems and petioles. Females become reproductively active and a week eggs mature. Eggs of both species are normally laid in leaf petioles. In the case of *A. hubbardi* eggs are inserted just below the surface of the epidermis, whereas *D. texanus* females place their eggs deep in the central pith (Charlet *et al.,* 2002). Larvae bore down the central core of the stalk, feeding on the pith. The effect of larval feeding on yield is negligible in healthy plants, but reduces plant resistance to attack by other insects such as stem weevils. Larvae of both species are pale, legless, cylindrical and deeply segmented. Larvae of *D. texanus* are more cream- coloured and tapered towards the rear so that final segments are narrower. Larvae of *A. hubbardi* are more deeply segmented, translucent in colour, and have a large, blunt terminal segment covered with bristles (not tapered). Stalks split in August may contain more than one larva of one or both species, but usually only one survives. As stalks dry down, mature larvae of *D. texanus* descend to the base of the stem and begin to girdle the interior surface near the soil line, and then plug the tunnel with chewed fibres that resemble sawdust before retreating to the base of the plant to overwinter. Plants weakened by complete or partial girdling, snap off easily when pressure is applied laterally to the stem. Infestations approaching 100 percent may go completely unnoticed when fields are harvested early, but any delay in harvest can result in serious

losses due to lodging. In contrast, larvae of *A. hubbardi* do not girdle stalks or seal themselves off in an overwintering chamber. Rather, they remain active within the stalk throughout winter, growing and feeding on the dead tissues. During cold periods, they may be found deep in a hollowed out root, but on warm days can be found moving around in upper portions of the stalk (Charlet *et al.,* 2002). Planting after 1st June seems to greatly reduce infestation by *A. hubbardi*, much like it also reduces attack by stem weevils, but *D. texanus* can heavily infest even the latest planted sunflowers. Because *D. texanus* larvae overwinter in the base of the stems, reduced tillage probably increases the survival of this insect and the popularity of reduced tillage may explain why problems from stem borers appear to be increasing. Although adults are susceptible to many foliar materials, their extended activity period means that a single application would not provide control. Research indicates that larval boring has no direct impact on seed yield, so yield losses result only from plant lodging (Charlet *et al*., 2002). They added that growers should check fields in late summer, splitting stalks to determine if *D. texanus* stem borers are present, and harvest as soon as possible if infestation is extensive.

2. 10. 5 Banded sunflower moth, *Cochylis hospes* (Walshingham)

Adult: Straw – coloured forewings marked with dark brown. Larva: less than 2.5 cm long and off – white, pink or green. The head capsule is dark brown (Charlet, 2001). Larvae generally appear one week after sunflower moth larvae. Larvae feed on seed and florets in the center of the head. Recommendations from other States of U.S. suggest control treatment if one banded sunflower moth is observed per two plants. Although large numbers of adults were frequently caught in pheromone traps, few larvae were found in

the heads, making pheromone traps unsuitable for decision-making for this pest (Charlet, 2001).

2. 10. 6 Sunflower bud moth, *Sulaima helianthana* (Riley)

Adult is small gray moth with transverse, black crescents on the wings. Eggs are laid on upper portions of the plant. Points of larval entry accumulate granular black frass, especially at leaf axils. Damage is never widespread enough to warrant treatment, although affected plants may suffer distorted growth and branching if the apical meristem is killed at vegetative stages, and improper head development may result when unopened buds are attacked (Charlet and Brewer, 2007).

2. 10. 7 Sunflower midge (*Contarinia schulzi* Gagne)

Adult is small (1.25 cm), dark, gnat – like insect. Larva is cream or yellowish coloured. 1.25 cm long, tapered at front and rear. Adults lay eggs on heads 2.5 cm to 5 cm in diameter. Larvae feed in ray petal area and on base of seeds (especially near center of head), causing shrinkage and distortion of heads and seeds. Treatment is rarely justified in Kansas (Glogoza *et al.,* 1997).

2. 10. 8 Spittle bugs (*Poophilus costalis* L. syn *adustus).*

It is a homopteran and widely distributed throughout Nigeria. Alternative hosts include sorghum, millet, rice, sunflower, sugarcane and native grasses. Aduts are active insects. They are 10 – 12 mm in length and carry their wings folded in a roof – shape over the abdomen and are brown (Anonymous, 1996). The nymphs are lighter in colour and develop in a mass of foam (spittle) on the plant stem or foliage. They are not active. They occur on sunflower before heading (Misari, 1990). Adult spittle bugs lay their eggs and

insert them into the plant stems. On hatching, the nymphs pass through several instars in the spittle. Sunflower crop infested by the insect recover from damage later, and insecticidal treatment provide good control of the insect (Mani, 2004).

2. 10. 9 Black coreid bug (*Anoplocnemis curvipes* F.)

It is found throughout Nigeria. The insect has a wide host range including leguminous trees. Pest migrates from the wild host plant into the crop. Adult bugs are about 27 mm long, black and strong fliers. The males have large hind femora with a single large spine on each. Adult female laid 10 – 40 dark grey eggs in batches in long chains on a leguminous tree or wild host, but rarely on cowpea. Each female may lay 6 – 10 batches of eggs. The eggs hatch in 7 – 11 days and there are five nymphal instars lasting a total of 30 – 60 days. The early nymphal instars resemble ants (Anonymous, 1996). Severe damage is caused by adults and nymphs sucking sap from the developing pods. This prevents normal seed formation and causes premature drying. In sunflower, it sucks sap from near the head and delays blooming (Mani, 2004). Several egg parasites exist, which normally keep the pest under control. Chemical control is effective.

2. 10. 10 *Dysdercus volkeri* F. (Heteroptera: Pyrrhocoridae)

It is a common pest of cotton and sunflower (Misari, 1990) throughout Nigeria. Main host is cotton but will attack related crops such as kenaf, okra and also sorghum and millet. On irrigated sunflower, it attacks the seeds (Mani, 2004). *D. volkeri,* migrates into the common crop from surrounding alternative hosts. Adults are very active and disperse readily when disturbed. Adults are about 2 cm in length and are red or orange in colour with black marks at the base of the wings and the underside of the thorax and abdomen.

First instar nymphs are the same in form but smaller than the adults. They are yellow in colour at first, turning darker orange before they moult. Eggs are laid in batches of up to 100 in damp soil or plant debris under the host plant. The eggs are ovoid, 1.5 mm in length and yellow in colour when first laid but later darken. Hatching occurs between 4 – 13 days and there are five nymphal instars, which last a total of about 25 days. The first instars do not feed and can be seen clustered around the eggs shells. The second and third instars feed on cotton seeds near the ground. Later instars can be found on seeds over the whole plant. Females can lay 800 – 900 eggs in their 60 days life span (Anonymous, 1996). Damage caused to seeds of sunflower made the seeds to shrivel. It fed on sunflower seeds when it started drying (Mani, 2004). Natural enemies do not exert effective control of this pest because of their large number. Chemical control proved effective.

2. 10. 11 ***Sphaerocoris testudogrisear*** Goer. (Hemiptera: Pentatomidae)

This is an important insect pest of sunflower in Samaru, Zaria. The insect has not been reported on any crop in Nigeria. *S. annulus* was found associated with the crop under surface of the leaf of sunflower but later on stems and capitulum (Misari, 1990; Mani, 2004). *S. testudogrisear* is brown with circular black lines while *S. annulus* is larger, green with black circular lines. Both species are not active fliers. *S. testudogrisear* is found feeding by sucking the seeds of sunflower from milk stage up to when the crop is harvested. The population on a capitulum was always high for dry season trials (Mani, 2004).

2. 10. 12 *Pachnoda cordata* Dry (Coleoptera: Scarabaeidae)

This insect is of increasing importance in Northern Nigeria and is cosmopolitan.The insect causes damage to many cultivated crops. On cowpea, the adults feed on flowers. On cashew, the larvae feed on the buds, blossoms, leaves and more commonly, the fruits of cashew. On guava, adults feed on mature and ripe fruits. On citrus, the insect feeds on blossoms and fruits and can cause dieback of growing shoots; small numbers can do a lot of damage. On millet, the insects feed on flowers and the milky grains. They also feed on ripe grains. They feed on ripe grains as well, which have been exposed by grasshoppers. On Sorghum, the insect attacks plants at grain development stage, feeding on the endosperm of the hardening kernels and allowing secondary fungal attack. Losses can be in the region of 5-10 % (Anonymous, 1996). On sunflower crop, the adults feed on the developing achenes and can completely destroy the whole capitulum, leaving a broom like skeleton (Misari, 1990; Mani, 2004). Adults are 13-17 mm in length with a black body and yellowish-brown or reddish brown markings on the wings. They are strong fliers and the antennae have 7 segments. The apical segments are flattened into plates at the apices. Eggs are laid in the soil and hatch in 4-8 days. Emerging larvae feed on fruits, decaying vegetable matter and plant roots; development to pupation taking around 36-38 days. Alternative hosts include pawpaw, mango, almond fruit and citrus. Most of the control is carried out before July. Lambdacyhalothrin, cypermethrin, permethrin and dimethoate combined with cypermethrin can give effective control (Anonymous, 1996). Other insect pests reported by Mani (2004) on sunflower include *Agonoscelis versicolor* F.*, Exochomus flavipes* Thumb*, Cryptobathys setarius* Thoms*, Microtermes* spp.*, Pyrgomorpha vignaudi* F. and *Zonocerus variegatus* L.

Table 2: 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. v_1	These are determined by counting the number of true leaves at least 4 cm in length beginning as v_1 v_2 v_3 v_4 etc
v_2 v_3 v_4 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 R_1	The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above the immature bracts for a many-pointed star like appearance.
R_2	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.
R_3	The immature bud elongates more than 2.0 cm above the nearest leaf.
R_4	The inflorescence begins to open. When viewed from Directly above immature ray flowers are visible.
R_5 (decimal) i.e R5.1	This stage is the beginning of flowering. The stage can be divided into substages dependent upon the percent of the head area (disk flowers) that has completed or is in flowering.eg R5.3 (30%) R5.4 (40%) etc
R_6	Flowering is complete and the ray flowers are wilting.
R_7	The back of the head has started to turn a pale yellow colour.
R_8	The back of the head is yellow but the bracts remain green.
R_9	The bracts become yellow and brown. This stage is regarded as physiological maturity.

Source: Schneiter and Miller (1981)

CHAPTE THREE

3.0 MATERIALS AND METHODS

3.1 Determination of the biology of *Dysdercus volkeri* F on sunflower

Preliminary studies were conducted at National Agricultural Extension and Research Liaison Service (NAERLS) in 2007 to determine the different growth stages and the time of infestation on the crop. The growth stages were followed and recorded from germination to harvest. On the biology of *D. volkeri* on sunflower, the study was conducted at the irrigation site of the IAR farm located at Samaru Latitude 11^0 10' N, and Longitude 7^0 37' E, Zaria in 2008 and 2009. Nine accessions of sunflower namely PI 267665, Trad 10, Ames 3236, Ames 1838, Ames 3390; PI 193775, PI 176974, PI 298632 and Funtua were planted in a randomized complete block design (RCBD) which was replicated three times. Observations on precopulation behaviour, mating time, population build up, mortality, longevity; sex determination and sex ratio were made on time of appearance of the insect on the crop.

3.1.1 Population studies

Nine aforementioned accessions were planted at the irrigation site of the Institute for Agricultural Research Samaru, Zaria. Each accession was planted in plots 5 m x 4 m and 0.75 between ridges in a randomized complete block design (RCBD), which was replicated three times. As the insects appeared only at seed stage (R_7), population build up was followed from the time the insect appeared to the time the crop was harvested for each of the nine accessions above. Three heads were randomly selected from each plot for the study. Weekly observations and visual counts were made and recorded.

3.1.2 Development of *D. volkeri* on sunflower

Five mating pairs of *D. volkeri* were collected from sunflower experimental plots and placed in five Petri dishes. Tissue paper was placed inside the Petri dishes with the insects on top of the tissue paper. A piece of cotton wool soaked in water was placed inside the Petri dishes so that the insect will not desiccate and die. Small quantities of sunflower seeds soaked in water were placed as food. Observation was made on the nymphal development. The nymphs were reared up to maturity. As the insect starts ovipositing, average number of eggs was obtained by dividing the numbers of eggs deposited by the number of oviposition.

3.1.3 Sex determination and sex ratio

The sampling was done by bagging the capitulum with the insects so that all the insects were collected inside the bag. The insects were killed by using 70 % formalin and stored in a deep freezer one day before counting the specimens. Sex determination was done by observing the insect life. The insect that mounts the other was suspected to be the male. Sex determination continued by taking the stored sample to the laboratory for microscopic examination of other features of the insect. Three methods of sex determination were used. They were: Sternal notch method, abdomen squeezing method and gender based size method (Vinod *et al*., 2008)

3.1.4 Longevity

Longevity was assessed in field condition from the time the insect started appearing to the time the crop was harvested. The number of days the insects stayed alive was counted. Longevity was estimated as the sum of the means of nymph, pupal and adult durations (Vinod *et. al*., 2008). Similar studies were conducted in the laboratory in which ten mating pairs were held in kilner jar and fed sunflower seeds. A piece of cotton wool soaked in water was put inside the kilner jar to prevent desiccation. Records were taken for the survival of the insect from nymph to adult till death.

3.1.5 Biotic mortality agents

The objective of this experiment was to determine the predators that exert control on *D. volkeri*. Levels of adult predation by densities of potential predators were estimated throughout the growing season. Potential predators and prey were monitored in the study plots by counting members of species known to feed or parasitize on *D. volkeri* eggs, adults and nymphs or have polyphagous habits. The common predator during the experiment was *Rhinocoris segmentarius*. In the field experiment, 10 adults and 10 nymphs of *D. volkeri* were caged with *R. segmentarius* and were replicated three times. The predators were first starved in a cage for 6 hours before they were introduced into the containers with *D. volkeri.* Predator – prey population phenology and peaks in relation to the number of *D. volkeri* was determined through visual counting. Follow up was conducted in the laboratory of the department of crop protection by using five perforated plastic containers with 10 adults and 10 nymphs of *D. volkeri* with *R. segmentarius*. The predators were first starved in a cage for 6 hours before they were introduced into the containers with *D. volkeri* (Parker, 1969). This was replicated three times. Observation

was by counting the number of dead *D. volkeri* daily. This was to test for the daily consumption of the potential predator and its efficacy as a biological control agent.

3. 1. 6 Data Analysis on biology

Differences of the mean were tested by Analysis of Variance (ANOVA). Where significant differences were detected, multiple comparisons were made using Student Neumans Keuls (SNK) procedure on development times, adult mortality, feeding and adult longevity.

3.2 Determination of relative phenologic stage of sunflower susceptible to *D. volkeri*

This experiment was conducted at the irrigation site of the Institute for Agricultural Research, Samaru, Zaria research fields. The aim of the study was to determine the most susceptible stage of sunflower for damage by *D. volkeri*. This was determined by initially bagging randomly selected heads at the R_7, R_8 and R_9 stages, that is, at 92, 106 and 120 days after planting (DAP), respectively. Adult *D. volkeri* was obtained from already existing culture and was confined (zero, five, ten and fifteen mating pairs per head) on four randomly picked heads at each stage with four uninfested heads serving as control plot. This was replicated three times in a randomized complete block design (RCBD). *D. volkeri* bugs were introduced at the onset of every stage and insects were allowed to stay till harvest. At maturity, the sunflower heads were removed for evaluation. The heads were sundried, threshed and the seeds cleaned. The seeds from individual heads were counted and weighed with a metler 500 electric weighing balance. Empty achenes were separated using floatation method. Each head was examined for signs of damage caused

by *D. volkeri* and those found empty were subsequently removed. The ANOVA option of the SAS procedure was used to compare the total number of seeds per head and number of damaged seeds per head for each study (SAS Institute, 1990). Significant differences among pairs were separated using Student Newmans Keuls (SNK) and a regression analysis was used to predict the number of achenes damaged based on adult infestation ($P<0.05$).

3.3 Determination of economic injury levels of *D. volkeri* on growth stages of sunflower.

3.3.1 Colony Establishment

The aim of this experiment was to establish a culture of *D. volkeri* that will serve as an infester plot. A culture of *D. volkeri* was established by planting sunflower crop earlier than the main experiment. This was done in a separate plot 15 days before planting the main experiment. This helped build up the population before the experimental plots reached the stages for infestation by the insects. Sunflower accession Funtua was used for this experiment. The accession was commonly found among farmers.

3.3.2 Damage Density Relationship Test

Mating pairs of *D. volkeri* were used to determine the economic injury levels for *D. volkeri* by confining them to sunflower heads (Laurence, 2003) when the heads reached R_7, R_8 and R_9 growth stages. At each stage, four heads were bagged with muslin cloth. Each respective head was infested with zero, five, ten and fifteen pairs of adults which were replicated three times. The insects were allowed to stay in the cage till harvest that is about 134 days. At harvest, *D. volkeri* adults were removed from the sunflower heads and

counted to ensure that all had been recovered. The sunflower heads from the economic injury level studies were removed for evaluation. The heads were sundried, threshed, the seeds cleaned, and seeds from individual heads were counted. Achenes were weighed using metler 500 electric weighing balance. A total of 100 sampled achenes were examined for colour change due to *D. volkeri* feeding. Damaged achenes were counted and recorded. The ANOVA procedure was carried out to compare the total number of seeds per head and number of damaged seeds per head. Significant differences among means were separated using Studentized Neumans Keuls and regression analysis (SAS Institute, 1990) was used to predict the number of seeds damaged based on adult infestation levels ($P< 0.05$). Simple linear models were used to predict crop yield loss at different pest densities and crop stages in order to establish the economic injury level (Ogunlana and Pedigo, 1974). In relation to yield loss and pest density, significant regressions using the linear models E (Y) a + b x was fitted to the data collected on percentage yield reductions of achenes infested for different stages of the crop growth. The EIL was computed by a formula modified by Pedigo (2004). Gain threshold or minimum economic damage is the cost of insect management/ha per market value (price)/ kg.

$$\text{Gain Threshold} = \frac{\text{Management cost (\#/ ha)}}{\text{Market value (price) (\#/ kg)}}$$

Gain threshold/ minimum Economic damage began to occur when money required for suppressing insect injury is equal to the potential monetary loss from a pest population. Here, gain threshold is expressed as a unit of measure of the marketable product per a specified land area. For example, if management costs for application of an insecticide

were #I0.00 per hactare and harvested sunflower is marketed for #2.00 per kg, the gain threshold would be 5 kg per hectare. In other words, an insecticide application would need to save at least 5 kg per hectare for the activity to be profitable. The gain threshold, therefore, is an important measure because it is a worksheet standard and the margin for determining benefits of management and establishing decision indices. The EIL is therefore defined as the lowest number of insects that will cause economic damage, or the minimum number of insects that would reduce yield equal to the gain threshold. The basic steps required to calculate the EIL are as follows:-

1- Estimate the loss per insect.
2- Determine the gain threshold.
3- Determine the loss that can be avoided by applying the management practices (e.g., 0.8 or 80 percent mortality or 1.00 if loss is avoided).
4- Calculate the EIL as:

$$\text{EIL} = \frac{\text{Gain threshold}}{\text{Loss per insect} \times \text{Amount of loss avoided.}}$$ (Pedigo, 2004)

To understand the development of an EIL using conventional insect numbers, consider the previous example of a 5 kg / ha gain threshold for pest management in sunflower. If one insect/plant causes 1 kg/ ha loss, then the EIL for the pest would be 5 insects / plant. In this example, 5 insects / plant potentially could consume enough plant tissue to reduce yields by 5 kg/ ha. Therefore, such an insect population would be considered economic, and management activities justified. Insect population below this level would be considered sub economic; and no management practice advised.

$$\text{For example, EIL for R7} = \frac{5 \text{ kg/ha}}{0.55 \text{ kg/ha/insect x1.00}} = 9.09 \text{ insects /plant}$$

3.4 Determination of factors responsible for migration of *D. volkeri* to Sunflower

This experiment was to determine the factors responsible for migration of *D. volkeri* on sunflower. Nine aforementioned accessions of sunflower seeds were planted at the irrigation site of the Institute for Agricultural Research Farm Samaru, Zaria. The experiment was laid out in a randomized complete block design with a plot size of 5 m by 4 m and 0.75 m between ridges. Seeds were planted 30 cm between stands and the treatments were replicated three times. The population of *D. volkeri* was monitored and recorded from R_7 to R_9 stages of sunflower growth. The numbers of the weekly populations of *D. volkeri* were correlated with the following weather variables, mean maximum temperature (^{0}C), mean minimum temperature (^{0}C), minimum and maximum relative humidity (%). Data were obtained from the Meteorological unit of IAR, ABU Zaria. All these parameters were taken on a weekly basis. The parameters of in a week and for the period of the insect pest incidence were used for fitting a multiple regression of insect population at different growth stages. The r^2 (coefficient of determination) value for the four weeks were compared. The multiple regressions with the most significant r^2 value were selected to show which variable significantly influenced insect population (Gomez and Gomez, 1984).

3.5 Screening accessions for resistance to *D. volkeri*

3.5.1 Screening accessions for resistance to *D. volkeri* (free choice).

The objective of this experiment was to find out accessions that were resistant to *D. volkeri* damage. The nine accessions of sunflower were used. These included PI 267665, Trad 10, Ames 3236, Ames 1838, Ames 3390, PI 193775, PI 176974, PI 298632 and Funtua. The damage severity scale was used thus:

1:- indicating 1-9 achenes damaged per head as resistant

2:- indicating 10-19 achenes damaged per head moderately resistant

3:- indicating 20-29 achenes damaged per head as intermediate resistant

4:- indicating 30-39 achenes damaged per head as susceptible and

5:- indicating 40-59 achenes damaged per head as highly susceptible (Wilson and Mcclurg, 1997; Bracken, 1991).

One hundred achenes were sampled from each head. The experiment was conducted in the dry season at the irrigation site of the Institute for Agricultural Research, A.B.U., Zaria and was a free choice experiment. Screening for resistance to *D .volkeri* was based on the number of the insect species on the crop and the number of damaged achenes. The experiment was laid out in a randomized complete block design, replicated three times. Sampling for *D. volkeri* was at the physiological maturity (R_8 stage) and resistance rating was

1 – 4 insects per head as resistant,

5 – 10 insects per head as moderately resistant,

11 – 15 insects per head as intermediate resistance,

16 – 20 insects as susceptible and

21 – 25 insects as highly susceptible (Wilson and Mcclurg, 1997; Bracken, 1991).

Lipid and fatty acid value of different accessions of sunflower was determined at the Product Development Programme of the Institute for Agricultural Research, Ahmadu Bello University, Zaria. Percentage lipid content was determined by Soxhlet Extraction Method using the procedure developed by Association of Analytical Chemists (A.O.A.C., 1980; Paquat, 1988). Fatty acid value was determined by Titration Method using the procedure developed by (A.O.A.C., 1980). Data were analysed separately for different accessions of sunflower. Student Neumans Keuls procedure was used for separation of treatment means. Yield differences were determined for different accessions. For yield differences, five heads were taken, threshed, winnowed and weighed using metler 500 electric weighing balance. Yield was converted to kg/ha.

3.5.2 Screening accessions for resistance to *D. volkeri* (no choice)

This was an advanced screening of the accessions that proved resistant. Resistant accessions were selected and retried. Cage screening was done at the irrigation site of the IAR farm using muslin cloth. Cages measuring 45 cm by 50 cm each with an openings and a rope for tying the frame to the pedicel (Laurence and John, 1995) was used (Plate I). The sunflower head was artificially infested with populations of the insect.



Plate I: Sunflower capitulum caged with bag

The experiment consisted of five treatments in a randomized complete block design which was replicated three times with the population of zero, ten, ten, ten, and ten pairs of the insects respectively. Insects count, seed damage, achene weight, lipid value, acid value and yield were computed for each sunflower accession as described above. Means were separated using Student Newmans Keuls (SNK).

CHAPTER FOUR

4.0 RESULTS

4.1 Determination of the Biology of *Dysdercus volkeri* F. on Sunflower at Samaru

The result indicated that the average period for maturity of sunflower crop was 120 days. At this period, most of the accessions attained their maturity. The R_7, R_8 and R_9 growth stages were determined to be 10, 14 and 14 days that is 92, 106, and 120 days after planting (DAP) respectively for all the accessions (Table 3)

4.1.2 Population studies

The biology of *D. volkeri* was studied both in the field and in the laboratory at the Department of Crop Protection of Ahmadu Bello University, Zaria. Adult *D. volkeri* appeared in sunflower field and continued feeding (Plate II) on the maturing achenes at R_8 growth stage and population continued to increase until peak was reached.

The result of the studies indicated that *D. volkeri* appeared first at R_7 in 2008 and 2009. There was significant difference in the number of the insects in all the accessions and years (Tables 5-6). The population of the insects continued to increase in all the accessions with the highest population on accession Ames 1838 followed by PI 267665 and Ames 3390 (Fig 1) Accessions Trad 10 and Ames 3236 had moderate number of insects while accessions PI 176974, PI 298632 and Funtua had the least number of insects. The highest number of insects occurred at R_8 in both 2008 and 2009 and the number tended to decline at R_9 growth stage in both the seasons. Interactions of years on the population of the insect

on the first and fifth weeks showed significant difference across the years 2008 and 2009 (Table 4)

Table 3: Incidence of Insect Pests on accessions of Sunflower at various Growth stages on Inrrigated field at Samaru in 2007

GROWTH STAGES	Average Number of Days After Planting										
	v1	v2	v3	v4	v5	v6	v7	v8	v9	AVE	INSECTS
Vegetative emergence	7	7	6	7	7	7	7	7	7		NIL
v1	8	7	7	7	7	7	7	6	7		NIL
v2	6	7	7	7	7	7	7	7	7		*Poophilus costalis*
v3	7	7	7	7	7	8	7	7	7		*Pyrgomorpa vignaudi*
v4	7	7	8	7	7	7	8	7	7		-do-
Reproductive stage											
R5.1	7	7	7	7	7	7	7	8	6		-do-
R5.2	4	4	3	4	4	4	5	3	4		*Anoplocnemis curvipes*
R5.3	4	4	3	4	5	4	4	4	4		-do-
R5.4	2	2	1	2	2	2	2	2	2		-do-
R5.5	1	2	2	3	3	2	1	1	3		-do-
R5.6	3	2	3	2	1	2	2	2	2		-do-
R5.7	3	2	2	2	3	1	2	3	2		-do-
R5.8	2	2	2	3	2	3	1	2	1		-do-
R5.9	4	4	3	4	4	5	4	4	4		*Cryptobathys setarious*
Flowering complete R6	4	4	3	4	4	3	4	4	4		*Sphaerocoris annulus*
Capitulum back started to turn pale yellow R7	10	10	10	11	10	10	10	10	11	10	*Dysdercus volkeri*
Capitulum back yellow but Bracts green R8	14	13	15	14	14	13	14	14	14	14	*S. testudogrisear*
Bract yellow & brown R9 (Physiological maturity)	14	14	14	13	14	14	14	15	14	14	-do-
Total	121	119	118	122	120	119	121	120	120	120	

Table 4: Interaction of years on incidence of *D. volkeri* on sunflower at Samaru 2008 and 2009.

WK	Mean number of *D. volkeri*	
	2008	2009
1	3.33 a	3.00 b
2	7.22 a	6.11 b
3	23.66 a	14.11 b
4	26.22 a	16.29 b
5	10.51 a	5.88 b

Means with the same letters with in the same row are not significantly different $P \geq 0.5$

The precopulation behaviour was studied in the field in the years 2008 and 2009. The insect was observed to display some form of courtship behaviour. The male which is smaller in size, always initiated courtship and approached the female with its antennae and forelegs. When the female was ready for mating, it allowed the male to mount on to its back with both their heads facing the same direction. Some little scuffles sometimes preceeded mating when the female was not ready. In the process of mounting, the male rubbed its terminalia against those of the female. When the female was not ready for the mating, it quickly kicked and brushed the male and then ran with the male in hot pursuit, still rubbing its antennae against the female. When the female was ready, the male succeeded in mounting on to the back of the female and held it with its legs. In this situation, the male then tried to bring the tip of its abdomen underneath that of the female in an attempt to engage its genital capsule with that of the female. When the two genitalia were in firm contact, the male slipped off the back of the female and faced in the opposite direction in an end to end position.



Plate II: Adult *D. volkeri* feeding on sunflower achenes at R_8 stage 2008

Table 5: Mean number of *Dysdercus volkeri* (adult) on different accessions of Sunflower from R_7 to R_8 growth stages at Samaru in 2008.

Accessions	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
V1 PI 267665	03bcd	10a	30b	45b	20a
V2 Trad 10	01de	06b	05d	09c	02c
V3 Ames 3236	04bc	06b	15c	12c	04c
V4 Ames 1838	07a	10a	45a	46b	15b
V5 Ames 3390	05b	11a	46a	46b	18a
V6 PI 193775	05b	12a	50a	55a	20a
V7 PI 176974	00c	04bc	08d	10c	05c
V8 PI 298632	03cde	03c	08d	09c	05c
V9 FUNTUA	02cd	03c	06d	04d	06c

Means followed by the same letter(s) within column are not significantly different SNK P ≥ 0.05

Table 6: Mean number of *Dysdercus volkeri* (adult) on different accessions of Sunflower from R_7 to R_8 growth stage at Samaru in 2009.

Accessions	Wk 1	Wk 2	Wk 3	Wk 4	Wk5
V1 PI 267665	02cd	08a	20b	35ab	08c
V2 Trad 10	00d	05b	10c	15c	05d
V3 Ames 3236	03bc	03dc	06d	08d	02e
V4 Ames 1838	05ab	09a	30a	38a	09bc
V5 Ames 3390	05ab	08a	20b	32b	10b
V6 PI 193775	05ab	09a	32a	05d	14a
V7 PI 176974	07a	02a	04d	05d	02e
V8 PI 298632	00d	04d	03d	04d	01e
V9 FUNTUA	02cd	02bc	02d	04d	02e

Means followed by the same letter(s) within column are not significantly different SNK P ≥ 0.05

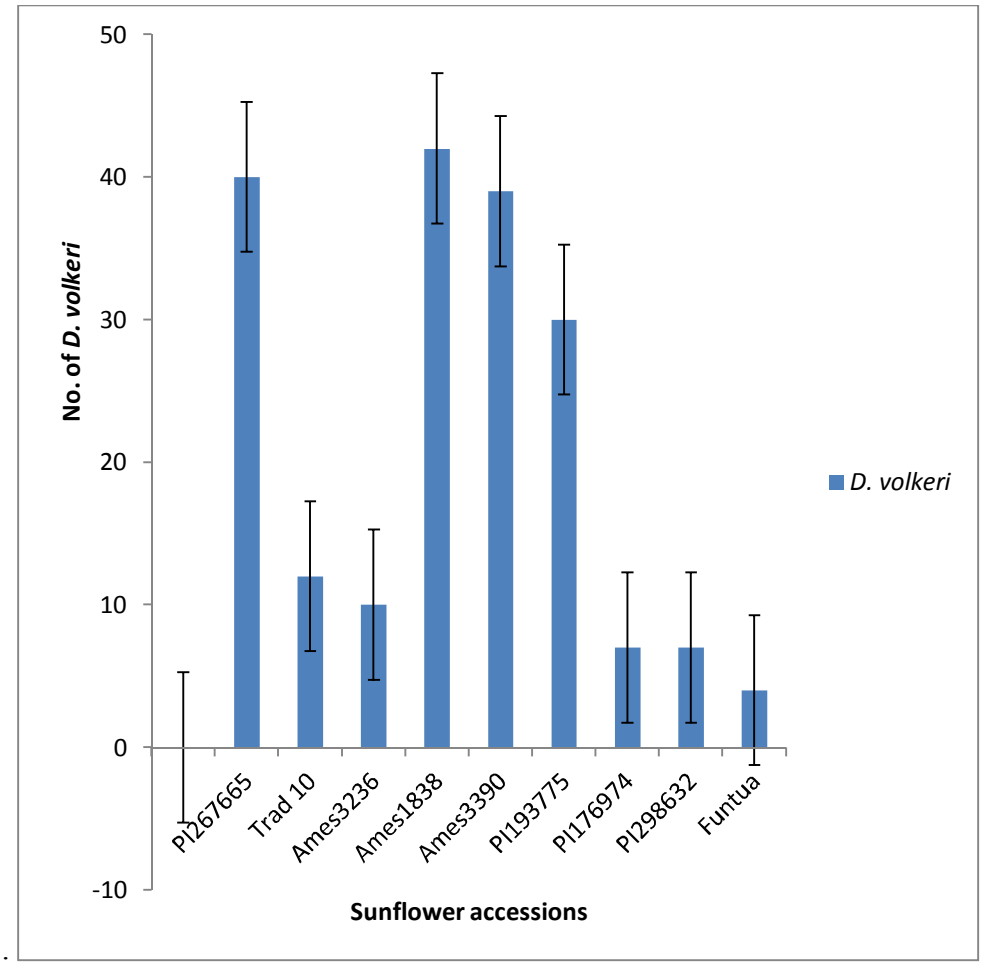


Fig 1: Mean number of *D. volkeri* (adult) on different accessions of sunflower across the two years of experiments (2008 and 2009) at Samaru Nigeria.

The female usually moved about pulling the male, while they are in copula, an observation similar to that of Fuseni and Kumar (1975a). While in copula, the male did not bother much to feed. The female laid eggs in the capitulum of sunflower and in the soil. The eggs could hardly be seen because they were usually inserted in between the achenes on the capitulum of sunflower. When the eggs hatched, the nymphs were seen aggregating on the capitulum of sunflower an indication that eggs were laid inside the capitulum. The female laid eggs and after 2-6 days later mated again. In some cases, for example when disturbed during copulation, the male may do the moving and pulling. The process of interlocking of male and female genitalia took only a few seconds if the female is responsive to the advances of the male. Oviposition was studied in the laboratory. This was observed with the insects that were at their 5^{th} nymphal instar which was the last nymphal instar. On reaching the adult stage, the insect was observed ready for oviposition. The bugs mated 2-3 days after they emerged. The eggs were deposited on the side of the kilner jar from inside and from inside the wire gauze cover. Three batches of the eggs were observed. Each batch had eight to nine eggs with individual eggs sticking to one another. The total number of eggs laid per female ranged from 64 to 72 eggs. Pearson (1958) stated that about 82 ± 4 eggs can be laid by a female of *D. volkeri*

The egg of *D. volkeri* was observed to be ovoid. Freshly laid eggs are somewhat creamy white in colour but gradually the colour changed to orange or pink as development of the embryo progressed. The eggs incubated for a period of 3 days before hatching under laboratory conditions. In the field, the first instar larvae were rarely seen because after hatching they remained clustered together in the hole in which their eggs were laid. On sunflower crop, the first nymphal instars were seen aggregating on the capitulum and they

did not feed. After moulting, that is the second instar, the nymphs moved about in search of food. On sunflower, they clustered round the seeds to feed. It took three days for the instars to change to the third instars. The third instars, took four days to change to the next stage. The fourth instars took 6 to 7 days while the last instar took 7 to 9 days. The changes were expected to take 23 to 26 days if temperature and relative humidity were tolerable. Observations also revealed intimate physical contact between individuals in an aggregation in *D.volkeri*. This observation is in accord with that of Youdeowei (1966a and b) on *D. intermedius.*

4.1.2 Mating time

The result of the studies indicated that mating started at 102 days after planting (DAP) (Plate III) on accession PI 193775 followed by PI 298632 and Funtua (Table 7) in the year 2008 while in 2009 the insect appeared on Ames 3390 and PI 298632 followed by PI 267665 statistically. The result showed significant differences among the accessions regarding mating time but no significant difference was observed between the years. Combined analysis indicated that mating started on 102 days on accessions PI 193775 and Funtua. However there was significant difference regarding the mating time on accessions PI 267665, Trad 10, PI 298632 but no significant difference was observed on accessions Ames 3236 and Ames 1838, PI 298632 and Funtua. (Table 7)



Plate III: Adult *D. volkeri* mating on sunflower crop at R_8 growth Stage 2008

Table 7: Mating Time Days after planting (DAP) of *Dysdercus volkeri* on different accessions of Sunflower at Samaru in 2008 and 2009

	Time of Mating (DAP)		
Accessions	2008	2009	Combined
V1 PI 267665	104bcd	103c	103c
V2 Trad 10	108ab	107ab	107ab
V3 Ames 3236	108ab	110a	109a
V4 Ames 1838	108ab	110a	109a
V5 Ames 3390	108ab	102c	105bc
V6 PI 193775	102d	104c	102c
V7 PI 176974	107c	105bc	106bc
V8 PI 298632	103d	102c	103c
V9 FUNTUA	103d	102c	102c

Means followed by the same letters within column are not significantly different SNK $P \geq 0.05$

4.1.3 Nymphal development

D. volkeri adults were reared in the insects museum of the Department of Crop Protection ABU, Zaria for oviposition and the results indicated that laid eggs hach in 4 days time. The egg was observed to be ovoid and reddish in color in the 3rd day. Nymphal growth was studied in the field during these experiments to prove the fact that sunflower is one of the preferred hosts of *D. volkeri*. Nymphs were observed on the dried capitulum feeding on the dried seed at R_8 up to R_9 growth stage of the crop till harvest (Plate IV). Similarly, the result of the studies indicated a significant difference ($P \geq 0.5$) for the nymphal growth on the 9 accessions.

The results showed that Ames1838, PI 193775 and PI 298632 had more nymphs during the studies than the other accessions. PI 267665, Ames 3390, Ames 3236 and Funtua recorded the least number of nymphs (Fig. 2)

4.1.4 Mortality

Mortality of *D.volkeri* was assessed in cages and the result of the studies showed that the highest number of death occurred on accession PI 26766 and PI 267665 (Fig. 3). Combined analysis indicated that accession PI 267665 had more death than the other accessions (Fig. 3). No significant differences were observed between the years.

4.1.5 Longevity

On the longevity of *D.volkeri* on sunflower, the result of the studies indicated that there was significant difference (P=0.05) between accessions on the length of time the insect lived on the crop (Fig 4). Mean across the years showed that the insect stayed longer on sunflower accessions Funtua and PI 267665 for 30 and 28 days respectively. PI 298632 hosted the pest for the least number of days. (Fig 4)

4.1.6 Predators of *D. volkeri* observed during the studies.

The *D. volkeri*, being cosmopolitan has so many predators especially those that mimicked them. During the studies, predator-prey relationship was considered and a number of predators were observed. They included the following

* Birds
* *Agama agama*
* Spiders
* *Rhinocoris segmentarius* Germ
* *Phonoctonus lutescence* Guerin, M and P
* *Mantis religiosa* Linnaeus
* *Odontopus sexpunctatus* Laporte 1832

R. segmentarius (Heteroptera: Reduviidae) is a reduviid which mimics cotton strainers. It lived in close association with *D. volkeri*. *R. segmentarius* is stronger than cotton stainers and possesses modified mouthparts which helped the insect to catch and feed on its prey. The insect uses its long proboscis to suck fluids from the body of cotton strainers.



Plate IV: Nymphs of *D. volkeri* feeding on dried seed of sunflower at R_9 growth stage.

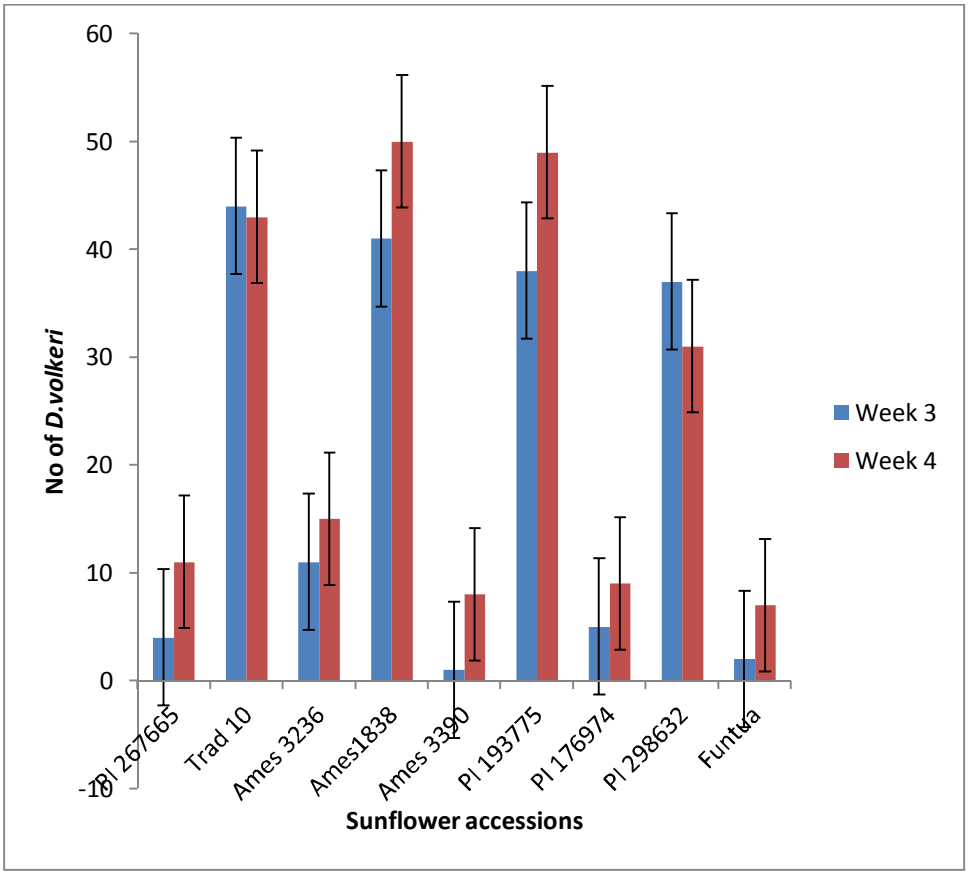


Fig 2: Mean number of *D. volkeri* (nymphs) on different accessions of sunflower at R_8 stage in 2008 and 2009 at Samaru, Nigeria.

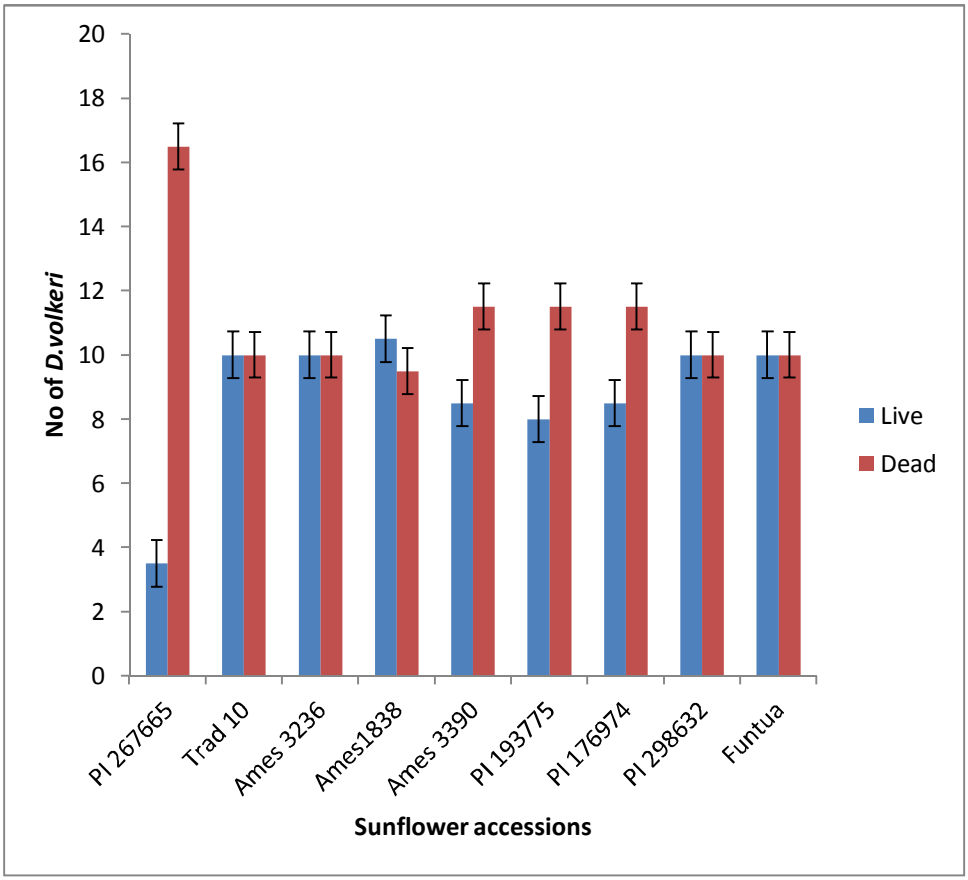


Fig. 3: Mortality of caged *Dysdercus volkeri* on different accessions of sunflower at R_8 stage at Samaru across the two years of experiments (2008 and 2009)

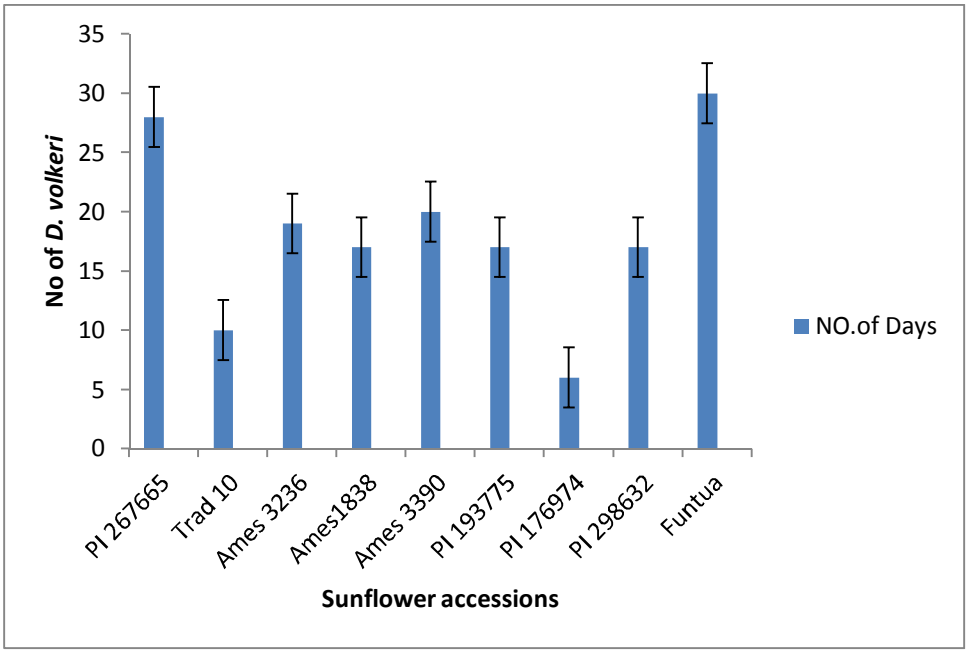


Fig. 4: Longevity of *Dysdercus volkeri* on different accessions of sunflower across the two years of experiments (2008 and 2009) at Samaru, Nigeria

Phonoctonus lutescens (Hemiptera: Reduvidae) (Plate V) resembles the cotton strainer both in colour and morphology. The main difference being that *Phonoctonus* spp is much larger than the cotton strainer.

Odontopus sexpunctatus L (Hemiptera: Pyrrhocoridae)

The family Phyrrocoridae is primarily phytophagous but many members feeding mostly on seeds and fruits attack other insects as well. For instance *Odontopus sexpunctatus* feeds on seeds of various plants but will attack caterpillars (Caswell, 1962).

Odontopus sexpunctatus has been reported by so many authors (Hussey, 1929; Stehlik, 1966), some authors considered it to be phytophagous. Hussey (1929) associated it with Sterculiaceae and Malvaceae. The insect is larger than cotton strainers and the mode of feeding is similar to that of *R. segmentarius* that is feeding by sucking with a long and strong proboscis. The length of the insect ranged between 15 and 18 mm. Both male and female have black separate spots on the corium. The female has a transverse large spot near the apex of the corium. The insect was encountered while conducting the studies in the years 2008 and 2009. The insect was found feeding by inserting its proboscis on the scutellum of the adult *D. volkeri* (Plate 6) and the nymphs (Plate 7) in open capsule of kapok. On all the sampled kapok trees the incidence was observed. The insect has been reported in Angola, Burkina Faso, Chad, Congo (Brazaville), Democratic Republic of Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Sierra leone, South Africa, Sudan and Tanzania (Hussey, 1929)



Plate V: *Phonoctonus lutescence* feeding on adult *D. Volkeri* in 2008

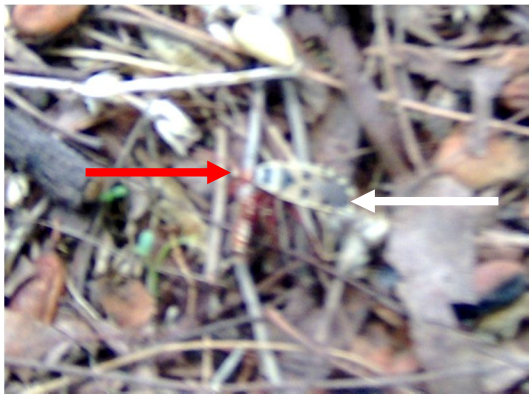


Plate VI: *Odontophus sexpunctatus* feeding on *D. volkeri* in sunflower field at Samaru in 2008

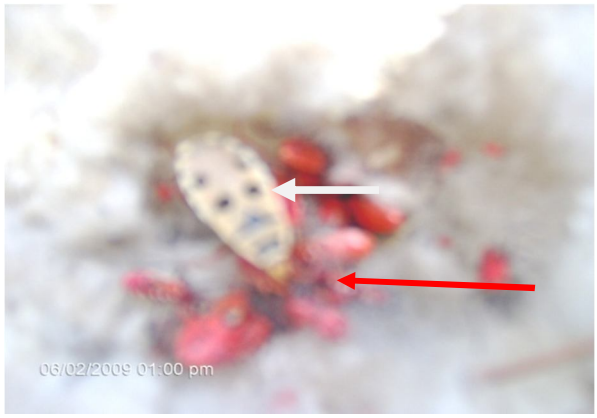


Plate VII: *O. sexpunctatus* feeding on nymphs of *D. volkeri*

4.1.7 *R. segmentarius – D. volkeri* Relationship

The relationship between *D. volkeri* and *R. segmentarius* was studied. The population of *R. segmentarius* was considered very low relative to the number of *D. volkeri* during the study. Therefore, control of *D. volkeri* using *R. segmentarius* will require an avenue by which the number of *R. segmentarius* can be augmented in order to provide effective control of *D. volkeri* in sunflower without employing chemicals. The result of the study indicated significant difference (P=0.05) regarding the number of *R. segmentarius* among the accessions (Table 8)

4.1.8 Observed hosts of *D. volkeri* during the studies

During the study various hosts and the alternative host plants were observed across various micro climates and seasons. The result of the study showed that on the preferred host, *D. volkeri* was observed to oviposit, metamorphose and continue its development and activities till death or till the food was exhausted then it could move to another host. While on the non preferred host, no nymphs were observed (Table 9).

Table 8: *Rhinocoris segmentarius -Dysdercus volkeri* relationship on sunflower.

Accessions	2008 *R.segmentarius*	2008 *D.volkeri*	2009 *R. segmentarius*	2009 *D.volkeri*
V1 PI 267665	05b	27f	03d	25f
V2 Trad 10	04c	75c	04c	70c
V3 Ames3236	04c	90b	04c	82b
V4 Ames1838	06a	97a	06b	85a
V5 Ames3390	05b	20f	04c	26f
V6 PI 193775	04c	30e	02d	70c
V7 PI 176974	06a	60d	04c	47e
V8 PI 298632	04c	72c	08a	61d
V9 FUNTUA	02c	32c	06b	45e

Means followed by the same letter are not significantly different SNK P=0.05

Table 9: Observed host plant species supporting population of *D.volkeri* in 2008 and 2009

PLANT SPECIES	MONTH	PREFERRED	NOT PREFERRED
Gossypium spp.	September,October, November.	Yes	_____
Combretum macranthum	June, July	Yes	_____
Pennisetum typhoides.	August, September.	Yes	_____
Albelmoschus esculenta	September, October	Yes	_____
Psidium guajava	May	Yes	_____
Helianthus annuus	April, May, June	Yes	_____
Sorghum bicolor	November, December	Yes	_____
Hibiscu cannabis	August	Yes	_____
Ceiba pentandra	April, May, June	Yes	_____
Sterculia apelata	April, June	Yes	_____
Zea mays	May, June	__	Yes
Dombeya kirki	April, May	__	Yes
Adansonia digitata	April, May, June, July	Yes	_____

4.1.9 Sex determination and sex ratio.

Taxonomic studies conducted on the culture of *D. volkeri* in the laboratory showed that males were smaller than the females. Viewed under a binocular microscope, the ventral side of the female has five alternating bands of red and white colours. The male has only four white bands plus one blurred red. Both male and female have four antennal segments. The only difference is the last antennal segment being longer in female than the male. The antennae are filiform. The scutellum of the female was larger than that of the male and extends backwards towards the back of the insect. To improve studies on the population dynamics and behaviour of this insect, sex ratio was determined on different captures and the result of the studies indicated a sex ratio of 1:1 (Table 10).

4.1.10 Response of *D. volkeri* to relative humidity and temperature

The adults colonized the sunflower crop during the milk stage. The first adult was captured on April 16 in both years when the relative humidity in the morning was 42 %, afternoon 10 %, temperature 39^0C maximum, 21^0C minimum for the 2008 and relative humidity was morning 42% and afternoon 44 % and temperature 40^0C maximum and 22^0C minimum for 2009 respectively. During this period a fewer number of females were captured in sunflower field. The population continued to build up and fed on the crop. The insect started mating at R8 growth stage of sunflower, sex ratio remained 1: 1 male – female.

Table 10: Temporal evolution of mean number of *D. volkeri* captured their sex ratio on two sampled capitulum across 2008 and 2009.

. Gender	Date of capture April		May				Total	Average
	16	24	3	11	19	26		
Male	5	10	41	30	17	6	109	18.1
Female	2	8	37	28	18	5	98	16.3

4.2 Determination of the relative phenologic sunflower growth stage susceptible to *D. volkeri* colonization

The relative phenologic sunflower growth stage to *D. volkeri* was studied in 2008 and 2009. The results indicated that R_8 stage had more damaged achenes than the R_7 and R_9 stages respectively. At R_7 growth stage sunflower seed contains much water than oil and at R_9 seed hardens (Tables 11-16). Percentage achenes damaged indicated significant difference between treatments (P=0.05). The results of the studies indicated that thirty achenes were damged by ten pairs of *D. volkeri* (Table 17).

4.3 Estimation of Damage caused by *D. volkeri*

Damaged sunflower seeds were removed and counted and the result of the study indicated that damagd achenes showed brown and yellow scars and changes in coloration. Regression analysis (Table 18) showed a linear response of sunflower yield to changes in the number of *D. volkeri* infesting the head within the range of 0 to 15 pairs and was significant at 5% level of significance. Thus, the decrease in achene yield of sunflower for every one pair of *D. volkeri* within the range of 0 to 15 pairs is expected to reduce yield between 1.38 kg/ha and 4.098 kg/ha 95% of the time for the year 2008 and 0.87 kg/ha and 2.81 kg/ha in 2009. The regression of yield on *D. volkeri* number showed a negative linear relationship. The appropriate model for the Yield- *D. volkeri* relationship was used thus Y = a+ b x where Y is the expected yield, a= the intercept, a constant representing average

yield of infested plots, b is the slope of the regression line and x representing the number of *D. volkeri* present per plant.

Table 11: Damage to Sunflower achenes (Funtua) by *Dysdercus volkeri* at R_7 Stage 2008 at Samaru, Zaria.

	Replications					
	R1	R2	R3	Mean achenes	Mean damage	% damage achenes
Treatment						
00 pairs	00(520)	00(500)	00(600)	540a	0.00b	0.00
05 pairs	02(515)	02(515)	01(567)	532a	3.00ab	0.56
10 pairs	03(530)	04(510)	06(520)	520a	4.33a	0.83
15 pairs	07(500)	04(520)	04(522)	514a	5.00a	0.97

Means followed by the same letters are not significantly different SNK P=0.05
Key: Number in parenthesis is number of achenes per capitulum.
Number outside parenthesis is number of damage achenes per capitulum

Table 12: Damage to Sunflower achenes (Funtua) by *Dysdercus volkeri* at R_8 Stage 2008 at Samaru, Zaria.

	Replications					
	R1	R2	R3	Mean achenes	Mean damage	% damage achenes
Treatment						
00 pairs	00(420)	00(500)	00(532)	484a	0.00b	0.00
05 pairs	20(509)	22(571)	23(525)	535a	21b	3.92
10 pairs	32(601)	31(582)	29(540)	574a	31a	5.40
15 pairs	25(500)	30(562)	20(545)	535a	25b	4.67

Means followed by the same letters are not significantly different SNK P=0.05
Key: Number in parenthesis is number of achenes per capitulum.
Number outside parenthesis is number of damage achenes per capitulum

Table 13: Damage to Sunflower achenes (Funtua) by *Dysdercus volkeri* at R_9 Stage 2008 at Samaru, Zaria.

	Replications					
	R1	R2	R3	Mean achenes	Mean damage	% damage achenes
Treatment						
00 pairs	00(500)	00(530)	00(503)	511b	0c	0.00
05 pairs	04(520)	02(561)	03(520)	533a	3bc	0.56
10 pairs	05(550)	08(562)	02(530)	537a	5ab	0.93
15 pairs	07(525)	09(572)	10(516)	547a	9a	1.64

Means followed by the same letters are not significantly different SNK P=0.05
Key: Number in parenthesis is number of achenes per capitulum.
Number outside parenthesis is number of damage achenes per capitulum

Table 14: Damage to Sunflower achenes (Funtua) by *Dysdercus volkeri* at R_7 Stage 2009 at Samaru, Zaria.

	Replications					
	R1	R2	R3	Mean achenes	Mean damage	% damage achenes
Treatment						
00 pairs	00(500)	00(600)	00(590)	563a	0c	0.00
05 pairs	02(510)	02(520)	03(540)	523a	2b	0.38
10 pairs	03(522)	04(497)	02(520)	513a	3b	0.58
15 pairs	06(490)	04(570)	10(572)	544a	6a	1.10

Means followed by the same letters are not significantly different SNK P=0.05
Key: Number in parenthesis is number of achenes per capitulum.
Number outside parenthesis is number of damage achenes per capitulum

Table 15: Damage to Sunflower achenes (Funtua) by *Dysdercus volkeri* at R_8 Stage 2009 atSamaru, Zaria.

	Replications					
	R1	R2	R3	Mean achenes	Mean damage	% damage achenes
Treatment						
00 pairs	00(500)	00(521)	00(530)	517a	0c	0.00
05 pairs	18(520)	22(534)	22(534)	529a	20b	3.78
10 pairs	30(550)	45(570)	45(570)	563a	40a	7.18
15 pairs	20(525)	25(500)	25(500)	500a	25a	5.00

Means followed by the same letters are not significantly different SNK P=0.05
Key: Number in parenthesis is number of achenes per capitulum.
Number outside parenthesis is number of damage achenes per capitulum

Table 16: Damage to Sunflower achenes (Funtua) by *Dysdercus volkeri* at R_9 Stage 2009 at Samaru, Zaria.

	Replications					
	R1	R2	R3	Mean achenes	Mean damage	% damage achenes
Treatment						
00 pairs	00(540)	00(560)	00(561)	554a	0c	0.00
05 pairs	02(533)	04(509)	04(601)	548a	3b	0.54
10 pairs	09(549)	08(510	08(569)	543a	8a	1.47
15 pairs	10(550)	12(541)	08(571)	554a	10ca	1.80

Means followed by the same letters are not significantly different SNK P=0.05
Key: Number in parenthesis is number of achenes per capitulum.
Number outside parenthesis is number of damage achenes per capitulum

Table 17: Effect of varying pairs of *D. volkeri* on sunflower ahenes production and their percentage damage at R_8 stage in Samaru in 2008 and 2009 combined.

Treatment	Mean achenes	Mean damage	% damage achenes
00 pairs	530	0	0.00d
05 pairs	534	15	2.80c
10 pairs	531	30	5.64a
15 pairs	540	25	4.63b

Means followed by the same letters are not significantly different SNK P=0.05

In calculating Economic Injury Level (EIL) of *D. volkeri* on sunflower the following steps were followed:-

1 liter of Lamdacyhalothrin cost N1200=00 (Caison chemical co. 2008) for spraying once at milk stage. = N1200 x 1

Therefore, application cost of 2 labourers/application/ha at N200/labourer =200 x 2 = 400 +1200 = N1600=00. The market price of Sunflower in 2008 and 2009 was N500 per tiya (a tiya is a local measure which weighs 2.5 kg). Therefore the market price of 1 kg =N500/ 2.5 = N200 per kg. The amount of yield loss that constitutes economic damage is referred to as gain threshold (Pedigo, 2004).

$$\text{Therefore Gain Threshold (GTH)} = \frac{\text{management cost (N/ha)}}{\text{Market (value) (N/kg)}}$$

In this particular case, the gain threshold kg/ha

$$= \frac{\text{Cost of pest control (N/ha)}}{\text{Market price of crop (N/kg)}}$$

$$\text{GTH} = \frac{\text{N1600}}{\text{ha}} \div \frac{200}{\text{kg}}$$

$$= \frac{1600}{\text{ha}} \times \frac{\text{kg}}{200} = 8.00 \text{ kg/ha}$$ which is the gain threshold

The EIL for a given stage R8 which proved to be the susceptible stage, is the number of infesting *D. volkeri* that will reduce yield by 8 kg/ha.

Since Y = a+ b x, it follows that bx = y- a = (a-y). But a-y represent the reduction (the intercept minus the expected yield). Therefore bx =8.00. For the stage R_8, 2008 infestation bx =3.36x =8.00. Therefore, x = 8/3.36 = 2.67 = 3, hence the EIL for R8, 2008 stage of Sunflower growth is 3 *D. volkeri*/ head. Therefore 3 insects/ head potentially could consume enough plant tissue to reduce yields by 3 kg /ha. For R_8 stage 2009 infestation bx = 5.4x = 8.00. Therefore, x = 8/5.4 = 1.6 = 2 hence the EIL for R8 stage 2009 stage of Sunflower growth is 2 *D. volkeri* /head. Therefore, 2 insects/head potentially could consume enough plant tissue to reduce yield by 2 kg/ha (Fig.5 and 6)

Table 18: Effect of varying pairs of *D. volkeri* on sunflower yield at R_8 stage in 2008 and 2009.

Treatment	Achenes yield kg/ha	
	2008	2009
0/head	1260	1258
05/head	1250	1249
10/head	1238	1242
15/head	1218	1228

SE: 0.042 (2008)

SE: 0.053 (2009)

4. 4 Correlation of *D. volkeri* to weather factors

The number of *D. volkeri* caught at different weeks was correlated and the result of the studies indicated that there was positive correlation between the number of *D. volkeri* caught and relative humidity r = 0.803* (Trad 10) and 0.865* (PI 176974) and negative correlation with the number of *D. volkeri* caught and the temperature r = -0.866 * (PI 176974) and -0.846 (PI 298632) respectively in 2008 (Table 19). The result showed negative correlation between the number of *D. volkeri* and relative humidity r = - 0.837 (PI 193775) and temperature r= - 0.809 (PI 176974) in 2009 (Table 20). Therefore, the arrival of *D. volkeri* on sunflower depended on food factors more than the climate though both of them are important.

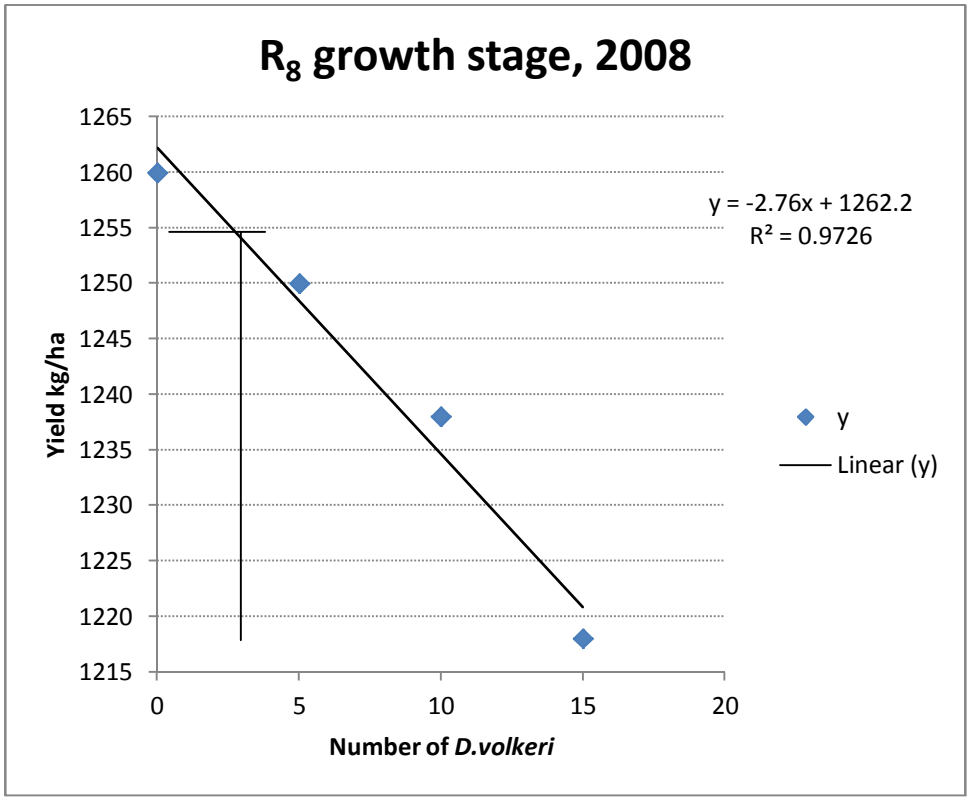


Fig. 5: Graphical representation of EIL of *D. volkeri* on Sunflower at R_8 growth stage in 2008.

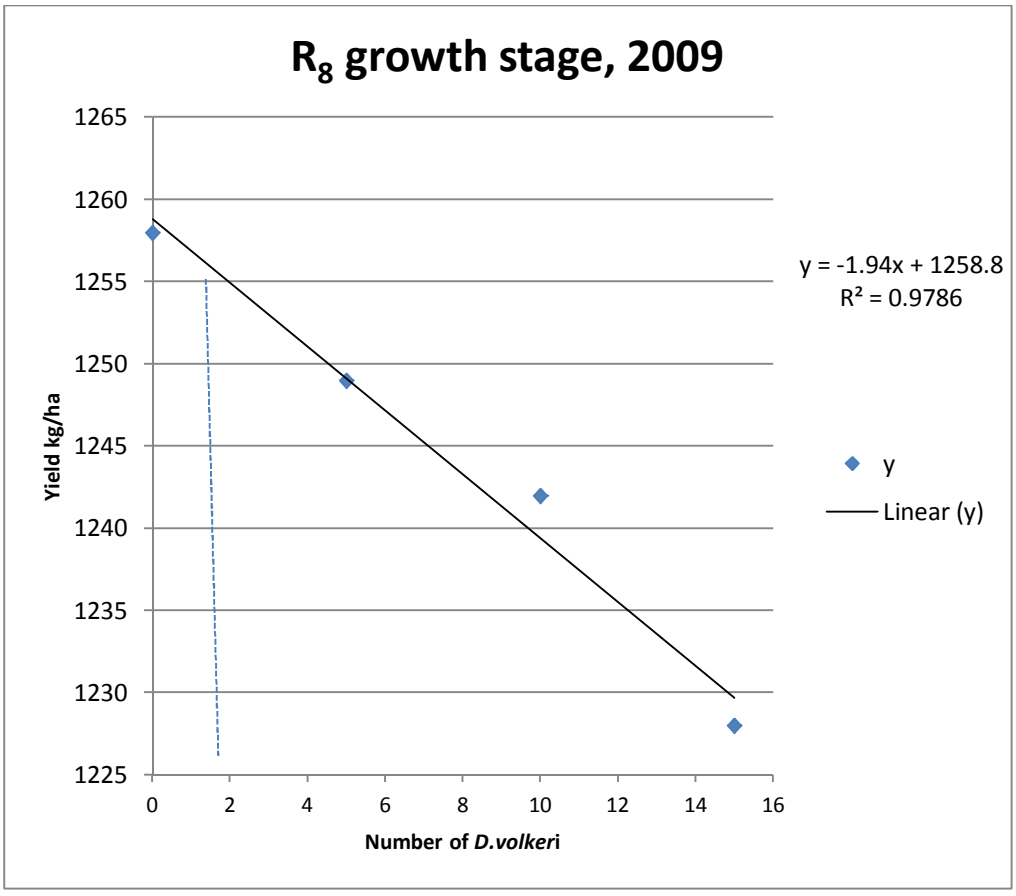


Fig. 6: Graphical representation of EIL of *D.volkeri* on Sunflower at R_8 growth stage in 2009

Table 19: Correlation of the number of *D. volkeri* on different accessions of sunflower to weather factors 2008

	WEATHER VARIABLE			
Sunflower accessions	Relative Humidity Morning	Relative Humidity Afternoon	Temp. Maximum	Temp. Minimum
PI 267665	0.174	-0.176	-0.402	0.393
Trad 10	**0.803 ***	-0.067	-0.269	0.348
Ames 3236	0.550	0.214	-0.631	0.418
Ames1838	0.644	0.282	-0.758	0'224
Ames 3390	0.723	0.307	-0.783	0.154
PI 193775	0.718	0.290	-0.786	0.126
PI 176974	**0. 865 ***	0.493	**-0.866 ***	-0.068
PI 298632	0. 698	0.376	**-0.846 ***	0.036
Funtua	0.1302	-0.192	-0.358	0.153

.

* Significant at P=0.05

Table 20: Correlation of the number of *D. volkeri* on different accessions of Sunflower to weather factors 2009

	WEATHER VARIABLES			
Sunflower accessions	Relative Humidity Morning	Relative Humidity Afternoon	Temp. Maximum	Temp. Minimum
PI 267665	0.012	0.730	0.791	-0.040
Trad 10	0.101	0.745	0.759	-0.040
Ames 3236	0.071	0.559	0.535	0.249
Ames1838	0.506	0.775	0.600	-0.182
Ames 3390	-0.190	0.554	0,672	0.166
PI 193775	**-0.837 ***	-0.076	0.303	0.184
PI 176974	-0.098	-0.455	-0.632	**-0.809***
PI 298632	0.171	-0.586	-0.681	0.034
Funtua	0.130	-0.196	-0.358	0.153

.

* Significant at P=0.05

4.5 Screening Studies

Studies on screening of sunflower accessions for *D. volkeri* were conducted in 2008 and 2009. Result indicated a significant difference (P=0.05) on the number of the bugs on the crop. The number of *D. volkeri* can serve as indices to the preference of the crop to the bug. Combined analysis showed that accessions PI 267665, Ames 3236, and Ames 1838 had more insects during the studies with the rating of 5 indicating that it was highly susceptible to the bug (Tables 20, 21 and Fig. 7).

Damage due to feeding by *D. volkeri* was determined and the results of the studies indicated that there was a significant difference in the number of damaged achenes on accessions PI 267665, Trad 10, Ames 3236, Ame1838 and PI 298632 but there was no significant difference between accessions PI 267665, PI 193775 and PI 176974, PI 298632 and Funtua (Tables 21 and 22). Combined analysis showed that Ames 3236, PI 176974, PI 298632 and Funtua proved resistant due to low number of achenes damaged (Tables 21 and 22) for both the free choice and no choice experiments.

Lipids are one of the major constituents of foods, and are important in human diet for a number of reasons. They are major sources of energy and provide essential lipid nutrients. The result of the studies indicated a significant difference regarding the percentage lipid content for the accessions (Fig. 8). Accessions PI 176974 and Funtua appeared to have high percentage lipid content. Significant differences were observed between treatments with the bug and the untreated control.

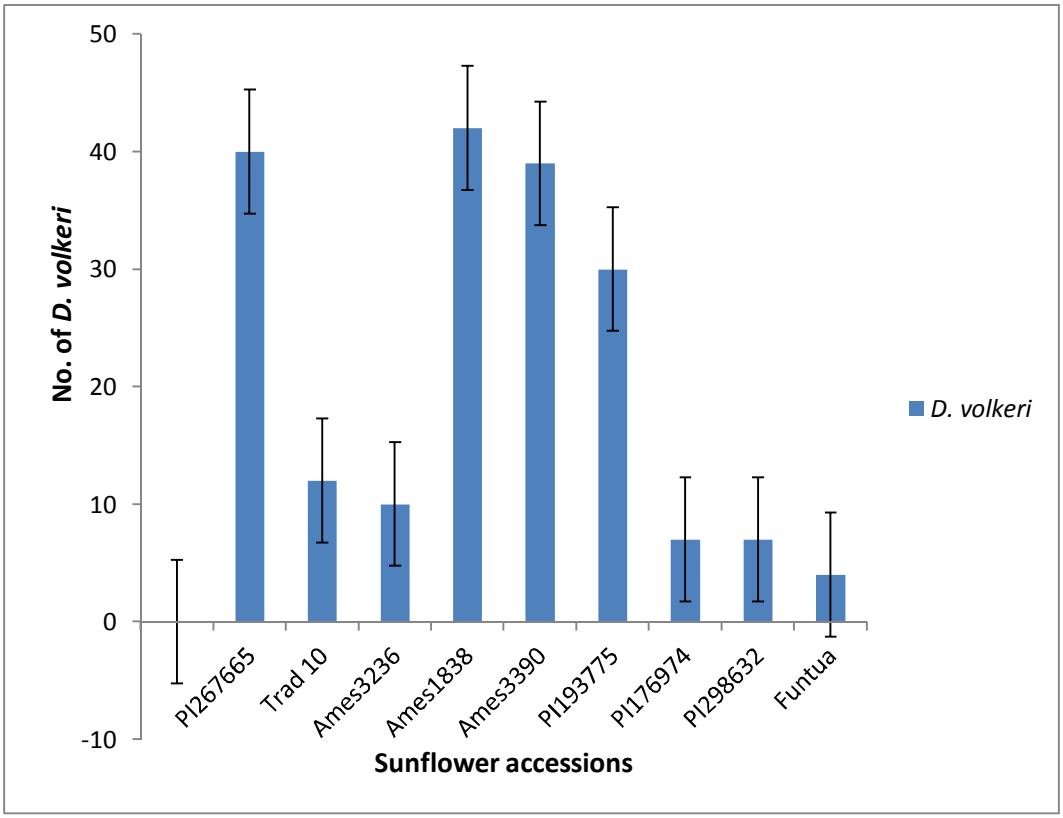


Fig.7: Mean number of *D. volkeri* on different accessions of sunflower at Samaru in 2008 and 2009 .

Fatty Acid value of different accessions of sunflower was determined. This is a measure of the amount of free acids present in a given amount of fat. The acid value is determined by the mg of potassium hydroxyl (KHO) necessary to neutralize the fatty acids present in 1g of lipid. The acid value is often a good measure of the break down of the triacylglycerols into free fatty acids, which has an adverse effect on the quality of many lipids. The results of the studies indicated that there was significant differences (P=0.05) between the treatments with the insects and the ones without insects. (Fig 9)

Yield differences were determined as it was affected by caged *D. volkeri*. The result of the studies indicated a significant difference between the treatments (P=0.05). Funtua and PI 298632 accessions had more yield than PI 267665, Ames 1838, Ames 3390 and Trad 10 (Fig. 10) for both years.

Table 21: Screening varieties for resistance to *Dysdercus volkeri* on Sunflower at Samaru 2008 and 2009 (Free Choice)

	Mean damaged achenes			
Accessions	2008	2009	Combined	Rating
V1 PI 267665	28a	27a	28a	4
V2 Trad 10	05d	06c	05d	2
V3 Ames 3236	09c	07c	09c	2
V4 Ames 1838	20b	17b	20b	3
V5 Ames 3390	18b	28a	18b	3
V6 PI 193775	29a	32a	29a	4
V7 PI 176974	07dc	06c	07dc	1
V8 PI 298632	06dc	05c	06dc	1
V9 FUNTUA	07dc	05c	07dc	1

Means followed by the same letter are not significantly different SNK P=0.05

Table 22: Screening varieties for resistance to *Dysdercus volkeri* on Sunflower at Samaru 2008 and 2009 (No Choice)

	Mean damaged achenes			
Accessions	2008	2009	Combined	Rating
V1 PI 267665	20b	31b	29b	3
V2 Trad 10	30b	08e	30b	3
V3 Ames 3236	08d	09e	08d	1
V4 Ames 1838	30b	28c	30b	3
V5 Ames 3390	17c	20d	17c	2
V6 PI 193775	30b	28c	30b	3
V7 PI 176974	08d	10e	08d	1
V8 PI 298632	06d	09e	06d	1
V9 FUNTUA	09d	09e	09d	1

Means followed by the same letter are not significantly different SNK P=0.05

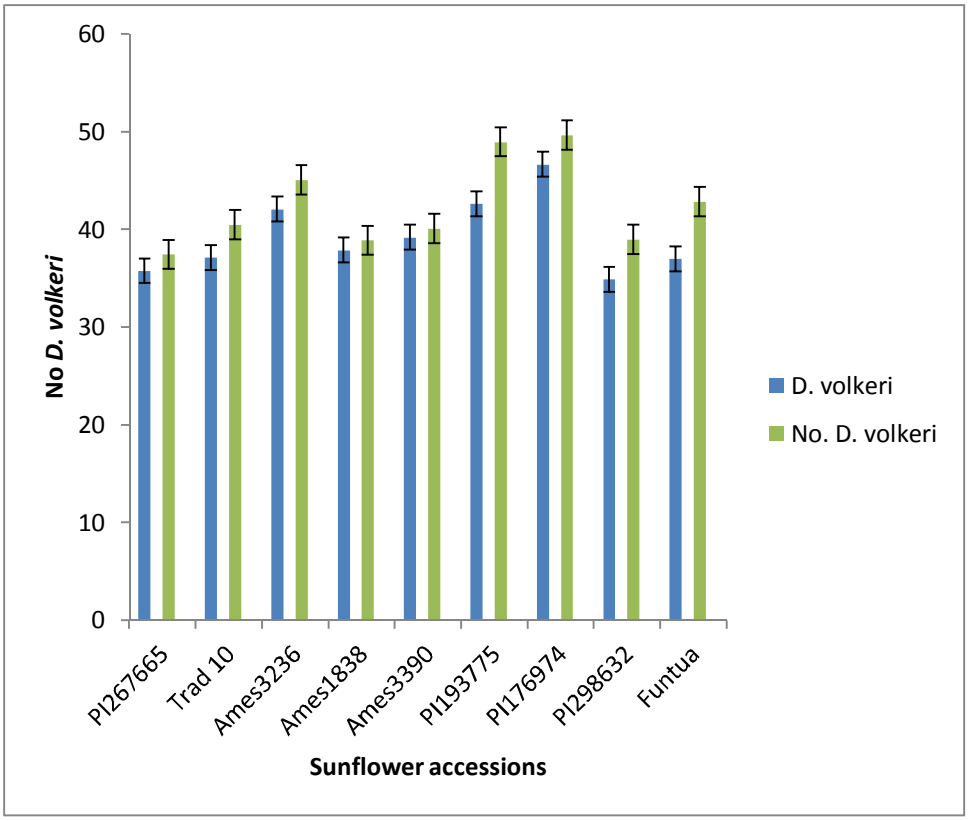


Fig.8: Effect of *D. volkeri* feeding on percentage Lipid value of Sunflower at Samaru (combined) 2008 and 2009

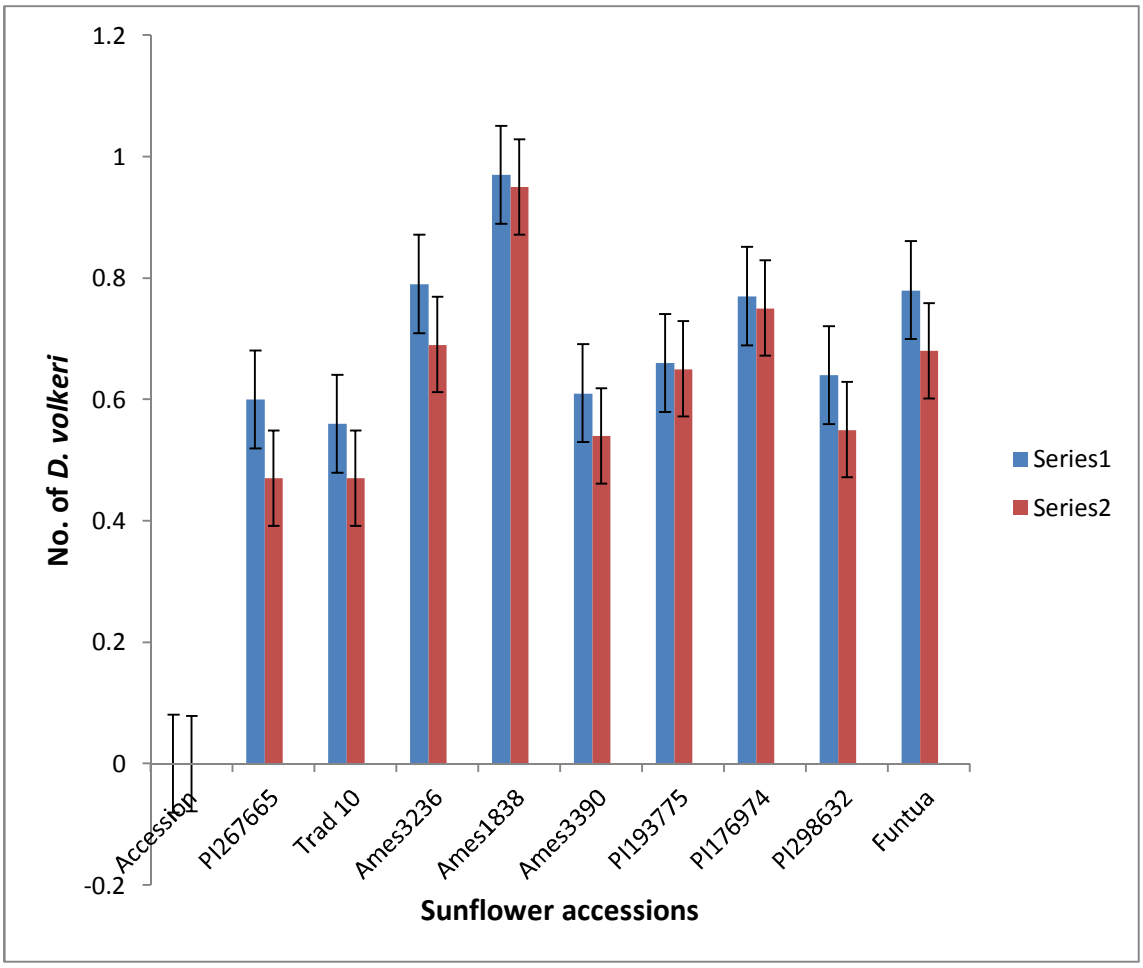


Fig 9: Effect of *D. volkeri* feeding on Acid value of Sunflower at Samaru (Combined) 2008 and 2009. Legend = Series 1: +*D. volkeri,* 2*: –D. volkeri*

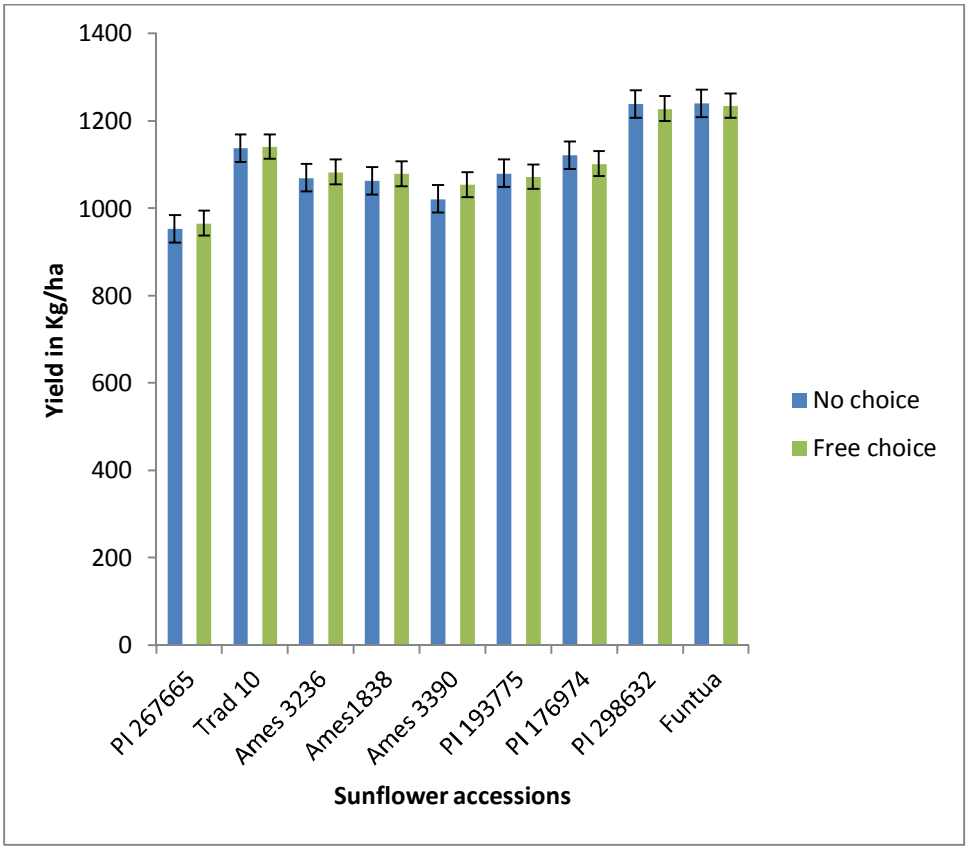


Fig 10: Effect of *D. volkeri* feeding on Yield of Sunflower at Samaru (Combined) 2008 and 2009 (Free and No Choice)

5.0 CHAPTER FIVE

DISCUSSION

The biology of *D. volkeri* on sunflower provided an index on the life style of the insect. *D. volkeri* moved from the alternative hosts to feed on the maturing achenes. The population of the insect continued to increase until when the crop reached maturity or is havested. An understanding of the factors that influence the population dynamics of *D. volkeri* on sunflower and the way in which cropping systems differ from natural ecosystems, can provide indices of the type of strategy that should be employed in the management of the bugs (Charlet and Brewer, 2007). Management of *D. volkeri* on sunflower can be achieved if the techniques used can reduce both the initial numbers infesting the crop and the rate of population growth, i.e they utilize the factors that have been identified. The size of the initial numbers may be reduced by cultural and agronomic practices such as removal of alternative hosts, or through host plant resistance, affecting host attraction. The population growth of *D. volkeri* may also be reduced through agronomic practices such as plant spacing, intercropping and reducing plant palatability (introducing resistant genes).

On the longevity, laboratory studies are crucial to the effort to understand population dynamics, but the studies must be related back to the field if there is any hope of understanding population growth. However, a major problem with this approach is that laboratory studies are typically run under nearly ideal condition of temperature and humidity, rather than the variable conditions encountered in the field. Laboratory studies are particularly useful in generating age-specific reproductive rates, which are nearly impossible to develop in most field situations (Vinod *et al*., 2008). Unfortunately,

longevity estimates based on laboratory studies are typically extremely optimistic, and can affect the perception of population biology. Because temperature is crucial to biochemical reactions, it can be used to predict rates of insect development. The idea of using temperature and time to describe development of cold blooded animals like insects is more than 250 years old. Several methods have been advanced to utilize the relationship for prediction. The most prevalent method of measuring and estimating physiological time is the degree day. The degree day (DD) is the average daily temperature minus the developmental threshold. It represents the accumulation of heat units above some temperature for a 24 hour period. Below this minimum, no development takes place, but above it, heat units are accumulated towards development (Pedigo, 2004). For DD accumulation, if the developmental minimum, or threshold, of an insect is 15 ^{0}C and the average temperature for the day is 27 ^{0}C, then 12 degree days would have accumulated on that day. The most widely used formula to calculate DD for a given insect is the use of simple average method. Although somewhat crude, it probably offers enough precision for most practical programs of pest management. Longevity studies will help explain population dynamics at various times during the season. It is to provide a biological basis for quarantine regulations. A comparison of the differences in longevity on the different accessions of sunflower showed that there were significant differences between them. The result of the studies showed that on some accessions, the insect tended to live an average of 30 days while on others the insect lived for six days. A key finding was that because the life span of *D. volker*i on some accessions of sunflower was relatively short, a delay in mating of even a few days may reduce population growth simply by reducing the length of the oviposition period. For example, if mating was delayed for two days by application of

mating disruption techniques and the maximum longevity was eight days, the time available for oviposition was reduced by 25 percent. This factor would operate regardless of other factors associated with delaying mating that might reduce mating propensity and/or fecundity. Although the best possible outcome of mating disruption is the complete suppression of mating, if mating is just delayed a few days on accession, rather large reductions in population growth rate could still be achieved, a result similar to that of Jones and Wiman (2008) which stated that delay in mating caused reduction in population growth of *Cydia pomonella* L. (Lepidoptera: Tortricidae) and *Choristoneura rosaceana* Guer (Lepidoptera: Tortricidae). While simple summary statistics are of less value to understanding population growth, they may still serve as a basis for comparison of these results with older literature that only provides summary statistics.

D. volkeri has many predators. Should the population density continue to increase then natural enemy populations would ideally start to regulate the population size. Pest management practices would seek to augment the size of natural enemy populations in the cropping system. However, should natural enemies fail to regulate the population of *D. volkeri* on sunflower and its numbers reached a level where it was economically viable to use an insecticide, this could be applied to reduce the number. Abundant predators in sunflower field were *Rhinocoris segmentarious* Germ. and *Lygaeus rivularis* (Mani, 2004; Mani *et al*., 2010). *Phonoctonus lutescens* G& P has been observed to feed on nymphs of *D. volkeri* but as observed the population was not enough to control the large numbers of *D. volkeri* (Mani, 2004). During the studies many predators were observed to be associated with the insect which include arachnids, birds, lizards, *Sphodromantis linneola*

Burn and cattle egrets. Others were *Rhinocoris segmentarius, Phonoctonus lutescens, Odontopus sexpunctatus* and *Lygaeus rivularis*. Considering the strong nature of *O. sexpunctatus* and its sedentary nature, it could be a good biological control agent of *D. volkeri* more especially on sunflower. Dead insects observed for samples collected did not reveal presence of any parasitoid as such death was only attributed to other factors. However, other recorded parasitoids include *Xanthoma lanopsisa* Tach, *Leptomonas seymouri* (Flagellata), *Ancaulona peruviana* Tach Phasinae, *Paraphorantha peruviana* Tach Phasinae, *Leptus sp*. (Acari: Erythraeidae) (Kamble, 1974; Fuseni and Kumar, 1975b).

Various methods of sex determination of D. *volkeri* were tested, but report indicated that the use of abdomen squeezing method of the genitalia can be used but the disadvantage was that it caused a lot of death after squeezing (Vinod *et al.*, 2008). Therefore, gender based method was used. Relevant taxonomic features for separating between the sexes were utilized like the antennae, scutellum and length of the proboscis. Sex ratio was determined by counting both the male and female insect to ascertain the number of males and females in the population. Sex ratio was studied and the result found that most of the populations of the insect observed were in pairs. That is, it was observed 99 percent were in pairs or in copula. This is in conformity with the findings of Pedigo (2004) which reported that sex ratio in most insect populations was 1:1 (male to female). Sexing was based on size of the insect, which was easier when it was conducted during mating.

Studies were conducted to find out the accessions that could sustain damage by *D. volkeri*. The results of the studies showed a significant difference between the treatment in both the number of insects, damaged seeds, high lipid content, acid value and yield. Funtua accession was despite the number of insects recorded on it, to be among the varieties that showed a sign of tolerance to the bug. The accession was the one that was used to study the susceptibility stage and the economic injury levels.

Sunflower is a crop that is very sensitive to pollination. Application of insecticides was reported to have negative impact on seed setting. This is because it sometimes conflicts with seed settings. Misari and Hashimu (1991) stated that the highest sunflower yields of 1960 kg/ha were recorded for untreated plots compared with the lowest yield of 1500 kg/ha for treatments that received insecticides spray during blooming only. The destruction of pollinators during blooming by insecticide sprays might be responsible for the low yield recorded in treatment involving spraying during blooming. In some large farms, holes were dug in order to provide water for the pollinators. This helped increase the number of pollinators. Destruction of pollinators caused reduction in achene yield. Management of the crop is important in order to reduce destruction of pollinators. Susceptibility studies conducted showed that the best time to apply chemical could be the time when the achenes were formed i.e. R_8. The studies showed that the best time to control *D. volkeri* on irrigated sunflower was at the R_8 stage. That was the time when the insect thrived best on the crop and the population increased very fast. Similar studies were conducted in other parts of the world. Laurence (2003) stated that confection sunflower is vulnerable to attack by tarnished plant bug (*Lygus lineolaris* F*)* (Heteroptera: Miridae), from the late bud stage (R_4) through flowering, although damage is reduced in later stages

(R_6 to R_7). Regression analysis showed that infestation by each adult *L. lineolaris* could result in kernel brown spot damage of 33 to 38 seeds per head depending on the number of seeds contained in the head.

Economic injury levels of *D. volkeri* on sunflower was determined and the result of the studies indicated that 2 to 3 bugs/ head could consume enough plant tissue to reduce yield by 2 to 3 kg/ha. The EIL is dynamic, as it would vary depending on fluctuating prices received for sunflower seed, application costs, and plant density. For example, when higher prices for sunflower seed are expected, the EIL for *D. volkeri* would be lower. The decision on whether *D. volkeri* population will reach the EIL is based on the adult population in the field at R_8 growth stage. Various EILs for various host-plant developmental stages were described for other insect pests. Different EIL for corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) and tobacco budworm, *Heliothis virescens* (F) were determined for different developmental stages of cotton (Ring *et al*., 1993). Different EILs for the omnivorous leafroller, *Platynota stultana* (Walsingham) were suggested for different sampling times during the grape season in California vineyards (Shaw *et al*., 1983). Similarly, EILs for sunflower tarnished plant bug was determined to be one adult per 10 to 15 plants with heads averaging 500 to 600 seeds for a kernel brown spot damage level of 0.5 % (Laurence, 2003). EILs have been determined for only a few soil dwelling insects, mainly because the process of sorting of soil sample was very time-consuming (Villani and Wright, 1990; Potter and Haynes, 1993). The EIL for the Japanese beetle in turfgrass was determined by Tashiro (1973) to be 2-3 insects, whereas Potter (1982) suggested 4-5 grubs for the same sampling unit. In Nigeria, report by Adamu, (2005) showed relatively low number of EIL on *Eurystylus oldi*

on feeding adults among different insecticides used. The EIL may change for the same pest in a different crop, or for the same crop in a different environment or for different market demands (Pedigo *et al*., 1986). The use of the EIL for *Maladera matrida* Argaman (Coleoptera: Scarabeidae) grubs in a peanut fields restricted the use of pesticides to situations in which economic damage was imminent. The EIL constituted the first step in developing an Integrated Pest Management (IPM) programme for *M. matrida* population in the fields (Ally *et al*., 2001)

6.0 CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

SUMMARY

Studies of sunflower entomology are very crucial in Nigeria as the crop is gaining popularity as a good oil crop that could supplement groundnut. This is because sunflower could fit very well into various zones in Nigeria without much demand for fertilizer. *Dysdercus volkeri* being cosmopolitan could be a limiting factor for the production of this important ornamental as well as oil crop. The studies observed the biology of *D. volkeri* on sunflower following the incidence, mating time and nymphal development of the insect on the crop. Results showed that the insect appeared when the seeds were maturing, that is when the oil was being formed from R_7 to R_8. The studies further revealed that the insect started mating about 10 to 14 days after arrival on the crop. This showed that there was a marked difference between generations in laboratory and generations in the field. Generations in the field took longer period than in the laboratory. Laboratory studies did not give true life cycle of an insect species. The studies showed that the insect had a very wide host range. *Combretum macranthum* (Geza in hausa) was found to be another host for *D. volkeri.* The insect was found feeding on the floret of the shrub in June and this helped the insect to overwinter up to the time another host became available. Predators of *D. volkeri* were studied and it was found that the insect was preyed on by a number of insects. Notable predators during the studies included *Rhinocoris segmentarius* and *Phonoctonus lutescens.* The activities of *Lygaeus rivularis* could not be understood because it was present whereever cotton stainers were present. The insect stayed on sunflower even after the population of *D. volkeri* diminished. The study found out that *D.*

volkeri could also be preyed on by an insect reported to be phytophagous in nature. This insect was identified at the insect museum of the Institute for Agricultural Research Samaru as *Odontopus sexpunctatus*. This insect was caught feeding on both the nymphs and adult of *D. volkeri.* The studies found that there was a significant difference between treatments in the number of insects among the nine accessions used. Damage rating revealed three accessions i.e. PI 176974, PI 298632 and Funtua that rated as having the least number of insects. The studies found out that the factors responsible for the arrival of *D. volkeri* on sunflower are food and climate, though food is the major factor. On the susceptible stage, the studies revealed that R8 growth stage of sunflower could be the stage that received much damage caused by *D. volkeri.* Simlarly, studies conducted to determine the EIL of *D.volkeri* on sunflower revealed that 2 to 3 insects/ sunflower head could cause economic damage. Gain threshold was determined to be 1254 kg/ha in 2008 while in 2009 it was determined to be 1256 kg/ha. On screening accessions for both the lipid and acid value, the accession that had the highest lipid value is PI 176974 and PI 193775 with 46.67 and 42.62 mg/ 100 ml respectively. Similarly, on the acid value, Ames 1838 had the highest acid value of 0.98 mg/100 ml. On the yield differences accession Funtua and PI 298632 and had 1240 kg/ha and 1239 kg/ ha respectively.

CONCLUSION

Conclusively, further research is recommended on the relationship of *D. volkeri* and *Lygaeus rivularis* on sunflower and the effect of *Anoplocnemis curvipes* and *Sphyrrocoris annulus* on the yield of sunflower.

RECOMMENDATIONS

1: Sunflower crop is a crop that rely much on insect pollination as such application of insecticides should start at R_7 growth stage, at this period fertilization was finished and seed formation completed.

2: As the crop contains high oleic and linoleic acids which are known to have human health preserving factors and the oil has more of unsaturated fatty acids, it could be better for people with much cholesterol deposit to take than groundnut oil which contain much saturated fatty acids.

3: Government should create market for Sunflower by making incentives available in terms of prices and inputs for farmers' inorder to boost the production.

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APPENDICES

Appendix i: Anova on Incidence of *Dysdercus volkeri* (adult) on different accessions of Sunflower at Samaru at WK 1 (3 Sampled heads).

The ANOVA Procedure

Dependent Variable: PD08W1 PD08W1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	115.5555556	11.5555556	14.86	<.0001
Error	16	12.4444444	0.7777778		
Corrected Total	26	128.0000000			

Appendix ii: Anova on Incidence of *Dysdercus volkeri* (adult) on different accessions of Sunflower at Samaru at WK 2 (3 Sampled heads).

The ANOVA Procedure

Dependent Variable: PD08W2 PD08W2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	312.6666667	31.2666667	31.27	<.0001
Error	16	16.0000000	1.0000000		
Corrected Total	26	328.6666667			

Appendix iii: Anova on Incidence of *Dysdercus volkeri* (adult) on different accessions of Sunflower at Samaru at WK 3 (3 Sampled heads).

The ANOVA Procedure

Dependent Variable: PD08W3 PD08W3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	8774.000000	877.400000	134.98	<.0001
Error	16	104.000000	6.500000		
Corrected Total	26	8878.000000			

Appendix iv: Anova on Incidence of *Dysdercus volkeri* (adult) on different accessions of Sunflower at Samaru at WK 4 (3 Sampled heads).

The ANOVA Procedure

Dependent Variable: PD08W4 PD08W4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	10584.22222	1058.42222	247.42	<.0001
Error	16	68.44444	4.27778		
Corrected Total	26	10652.66667			

Appendix v: Anova on Incidence of *Dysdercus volkeri* (adult) on different accessions of Sunflower at Samaru at WK 5 (3 Sampled heads).

The ANOVA Procedure

Dependent Variable: PD08W5 PD08W5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1416.148148	141.614815	48.63	<.0001
Error	16	46.592593	2.912037		
Corrected Total	26	1462.740741			

Appendix vi: Anova on Mortality of caged *D. volkeri* on different accessions of Sunflower at R_8 stage at Samaru 2008 (20 caged *Dvolkeri* per head)

The ANOVA Procedure

Dependent Variable: MLIVE08 MLIVE08

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	201.2592593	20.1259259	14.25	<.0001
Error	16	22.5925926	1.4120370		
Corrected Total	26	223.8518			

Appendix vii: Anova on Effect of *D.volkeri* feeding on Lipid value of Sunflower at Samaru 2008 (10 caged insects) mg/100ml

The ANOVA Procedure

Dependent Variable: WINSL8 WINSL8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	283.7827926	28.3782793	143.81	<.0001
Error	16	3.1573926	0.1973370		
Corrected Total	26	286.9401852			

Appendix viii: Anova on Mean number of *D. volkeri* on different accessions of sunflower at samara 2008 Free choice

The ANOVA Procedure

Dependent Variable: FRC08 FRC08

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2246.888889	224.688889	132.60	<.0001
Error	16	27.111111	1.694444		
Corrected Total	26	2274.000000			

Appendix ix: Anova on screening varieties for resistance to *D. volkeri* on Sunflower at Samaru No Choice 2008 100 sampled achenes

The ANOVA Procedure

Dependent Variable: NOCH08 NOCH08

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	4292.222222	429.222222	203.32	<.0001
Error	16	33.777778	2.111111		
Corrected Total	26	4326.000000			

Appendix x: Anova on Effect of *D.volkeri* feeding on Yield of Sunflower at Samaru 2008 10 caged insects

The ANOVA Procedure

Dependent Variable: YLD08 YLD08

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	209241.5556	20924.1556	792.50	<.0001
Error	16	422.4444	26.4028		
Corrected Total	26	209664.0000			

Appendix xi: Anova on Incidence of *D. volkeri* (nymphs) on different accessions of Sunflower at Samaru 2008. (3capitulum sampled)

The ANOVA Procedure

Dependent Variable: NG08WK2 NG08WK2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	7341.703704	734.170370	343.99	<.0001
Error	16	34.148148	2.134259		
Corrected Total	26	7375.851852			

Appendix xii: Anova on Longevity of *D. volkeri* on different accessions of Sunflower at Samaru (combined) 2008 and 2000

The ANOVA Procedure

Dependent Variable: LONG08 LONG08

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1657.481481	165.748148	63.59	<.0001
Error	16	41.703704	2.606481		
Corrected Total	26	1699.185185			

Appendix xiii: Anova on Mortality of caged *D. volkeri* on different accessions of Sunflower at R_8 stage at Samaru 2009 (20 caged *D. volkeri* per head)

The ANOVA Procedure

Dependent Variable: MLIVE09 MLIVE09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	168.5925926	16.8592593	16.70	<.0001
Error	16	16.1481481	1.0092593		
Corrected Total	26	184.7407407			

Appendix xiv: Anova on Mortality of caged *D. volkeri* on different accessions of Sunflower at R_8 stage at Samaru 2009 (20 caged *D. volkeri* per head)

.

The ANOVA Procedure

Dependent Variable: MDEAD09 MDEAD09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	171.4814815	17.1481481	17.47	<.0001
Error	16	15.7037037	0.9814815		
Corrected Total	26	187.1851852			

Appendix xv: Anova on Effect of *D.volkeri* feeding on Lipid value of Sunflower at Samaru 2009. 10 caged insects mg/100ml

The ANOVA Procedure

Dependent Variable: LIPWINS09 LIPWINS09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	709.5675037	70.9567504	1321264	<.0001
Error	16	0.0008593	0.0000537		
Corrected Total	26	709.5683630			

Appendix xvi: Anova on Effect of *D.volkeri* feeding on Lipid value of Sunflower at Samaru 2009. No insects mg/100ml

The ANOVA Procedure

Dependent Variable: LIPNINS09 LIPNINS09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	650.4780222	65.0478022	2437.13	<.0001
Error	16	0.4270444	0.0266903		
Corrected Total	26	650.9050667			

Appendix xvii: Anova on Effect of *D.volkeri* feeding on Acid value of Sunflower at Samaru 2009. 10 caged insects mg/100ml

The ANOVA Procedure

Dependent Variable: ACWIN09 ACWIN09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.35192593	0.03519259	172.76	<.0001
Error	16	0.00325926	0.00020370		
Corrected Total	26	0.35518519			

Appendix xviii: Anova on Effect of *D.volkeri* feeding on Acid value of Sunflower at Samaru 2009. 10 insects mg/100ml

The ANOVA Procedure

Dependent Variable: ANINS09 ANINS09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.54214815	0.05421481	455.66	<.0001
Error	16	0.00190370	0.00011898		
Corrected Total	26	0.54405185			

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Appendix xix: Anova on Mean number of *D.volkeri* on different accessions of sunflower at samara 2009 Free choice

The ANOVA Procedure

Dependent Variable: FRCH09 FRCH09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	3296.666667	329.666667	69.40	<.0001
Error	16	76.000000	4.750000		
Corrected Total	26	3372.666667			

Appendix xx Anova on Mean number of *D.volkeri* on different accessions of sunflower at samara 2009 No choice

The ANOVA Procedure

Dependent Variable: NCH09 NCH09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	5086.888889	508.688889	590.74	<.0001
Error	16	13.777778	0.861111		
Corrected Total	26	5100.666667			

Appendix xxi: Anova on Effect of *D.volkeri* feeding on Yield of Sunflower at Samaru 2009 . 10 caged insects

The ANOVA Procedure

Dependent Variable: YLD09 YLD09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	217615.4815	21761.5481	2765.00	<.0001
Error	16	125.9259	7.8704		
Corrected Total	26	217741.4074			

Appendix xxii: Anova on Incidence of *D. volkeri* (nymphs) on different accessions of Sunflower at Samaru . WK1 2009. (3capitulum sampled)

The ANOVA Procedure

Dependent Variable: NG09WK1 NG09WK1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	9076.888889	907.688889	666.87	<.0001
Error	16	21.777778	1.361111		
Corrected Total	26	9098.666667			

Appendix xxiii: Anova on Incidence of *D. volkeri* (nymphs) on different accessions of Sunflower at Samaru . WK 2 2009.(3capitulum sampled)

The ANOVA Procedure

Dependent Variable: NG09WK2 NG09WK2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	9752.666667	975.266667	84.81	<.0001
Error	16	184.000000	11.500000		
Corrected Total	26	9936.666667			

Appendix xxiv: Anova on Longevity of *D. volkeri* on different accessions of Sunflower at Samaru 2008 and 2009.

The ANOVA Procedure

Dependent Variable: LON08 LON09

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1498.814815	149.881481	73.58	<.0001
Error	16	32.592593	2.037037		
Corrected Total	26	1531.407407			

Appendix xxv: Anova on Mating Time of *D. volkeri* on different accessions of Sunflower at Samaru (combined)2008 and 2009

The ANOVA Procedure

Dependent Variable: MT08 MT08

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	370.5000000	33.6818182	7.65	<.0001
Error	42	185.0000000	4.4047619		
Corrected Total	53	555.5000000			

Appendix xxvi: Anova on Incidence of *D. volkeri* (nymphs) on different accessions of Sunflower 2008 and 2009 wk1at Samaru . (3capitulum sampled)

The ANOVA Procedure

Dependent Variable: NG08WK1 NG08WK1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	17364.00000	1578.54545	85.07	<.0001
Error	42	779.33333	18.55556		
Corrected Total	53	18143.33333			

Appendix xxvii: Incidence of *D.volkeri* on sunflower wk 1 2008 &2009

The ANOVA Procedure

Student-Newman-Keuls Test for PD08W1

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	3.3333	27	1
A			
A	3.2222	27	2

The SAS System 17:44 Sunday, October 17, 2011

Appendix xxviii: Incidence of *D.volkeri* on sunflower wk 2 2008 &2009

The ANOVA Procedure

Student-Newman-Keuls Test for PD08W2

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	7.2222	27	1
B	6.1111	27	2

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Appendix xxix: Incidence of *D.volkeri* on sunflower wk3 2008 &2009

The ANOVA Procedure

Student-Newman-Keuls Test for PD08W3

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	23.667	27	1
B	14.111	27	2

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Appendix xxx: Incidence of *D.volkeri* on sunflower wk 4 2008 &2009

The ANOVA Procedure

Student-Newman-Keuls Test for PD08W4

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	26.222	27	1
B	16.296	27	2

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Appendix xxxi: Incidence of *D.volkeri* on sunflower wk 5 2008 &2009

The ANOVA Procedure

Student-Newman-Keuls Test for PD08W5

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	10.5185	27	1
B	5.8889	27	2

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Appendix xxxii: Incidence of *D.volkeri* nymphs on sunflower wk 1 2008 &2009

The ANOVA Procedure

Student-Newman-Keuls Test for NG08WK1

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	21.000	27	1
A	19.889	27	2

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Appendix xxxiii: Incidence of *D.volkeri* nymphs on sunflower wk 2 2008 & 2009

The ANOVA Procedure

Student-Newman-Keuls Test for NG08WK2

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	26.111	27	2
A	23.926	27	1

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Appendix xxxiv: Anova on Interaction of years on mating time of *D.volkeri* on sunflower 2008 & 2009.

The ANOVA Procedure

.Student-Newman-Keuls Test for MT08

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	105.7778	27	1
A	105.2222	27	2

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Appendix xxxv: Interaction of years on yield of sunflower as affected by *D.volkeri*

The ANOVA Procedure

Student-Newman-Keuls Test for YLD08

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	YRS
A	1104.148	27	2
A	1102.333	27	1

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Appendix xxxvi: Analysis of variance for the regression of Sunflower yield (achene yield) on number of *D.volkeri* infesting the growth stage R_8 of the plant. 2008

Source	DF	Sum of Squares	Mean Squares	F value
Regression	1	121.578	121.578	71.060 **
Error	2	3.422	1.711	
Corrected Total	3	125.000		

R^2 .973

Appendix xxxvii: Analysis of variance for the regression of Sunflower yield (achene yield) on number of *D.volkeri* infesting the growth stage R_8 2009 of the plant.

Source	DF	Sum of Squares	Mean Squares	F value
Regression	1	122.322	122.322	91.350**
Error	2	3.678	1.339	
Corrected total	3	125.000		

R^2 .979