HOST RANGE, DEVELOPMENT, SURVIVAL AND POPULATION DYNAMICS OF COTTON STAINERS (*Dysdercus spp*) IN KILOSA DISTRICT, TANZANIA

BY

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ABSTRACT

A field survey was conducted in cultivated and uncultivated fields in cotton growing areas in Kilosa District to determine the host range of different species of cotton stainers (*Dysdercus spp*). Five species of cotton stainers were identified, namely *Dysdecus fasciatus* Sign; *D. intermediosus* Dist; *D. nigrofasciatus* Stål; *D. cardinalis* Gerst and *D. superstitiosus* (F). Most of the host plants identified to harbour cotton stainers belonged in the order Malvales. *Dysdercus fasciatus*; *D. intermediosus* and *D. nigrofasciatus* were found to have wider host ranges than *D. cardinalis* and *D. superstitiosus*. Some few plants that were potentially found to host cotton stainers belonged to the families of Asteraceae, Moraceae, Myrtaceae, Caricaceae, Musaceae, Anacadiaceae, Bromeliaceae and Poaceae. In the population dynamics study, fluctuation patterns of the individual species varied greatly. *Dysdercus fasciatus* was dominant on *Gossypium hirsutum* throughout the year except for the two months that *D. intermediosus* was dominant on the same plant species. *Dysdercus fasciatus* was dominant on *G. barbadense, Ceiba pentandra* and *Adansonia digitata*. In this study, it has been revealed that both *D. fasciatus* and *D. intermediosus* are currently the major cotton stainer species in Kilosa district. Among the alternative host plants studied, *G. barbadense, Ceiba pentandra* and *Adansonia digitata* have been regarded as the most dangerous plant species for cotton industry due to their tendency of harbouring large populations of the major cotton stainer species. In the laboratory experiment to determine survival and development of *Dysdercus fasciatus* when fed on various cultivated and wild host plant species, *Gossypium barbadense,* G. *hirsutum,* were better-than-adequate host plants for *D. fasciatus*. *Ceiba pentandra, Adansonia digitata* were adequate, *Hibiscus micranthus* was relatively poor and *Abelmoschus esculentus* was very poor as a host plant. Results of the studies can be used in the formulation of integrated cotton stainer management strategies.

DECLARATION

I, MUKARA MABULA MUGINI, do here by declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has neither been submitted nor being concurrently submitted for degree award in any other Institution.

_________________________ _________________

Mukara Mabula Mugini Date

(MSc Candidate)

The above declaration is confirmed

___________________________ _________________

PROF. Rhodes H. Makundi Date

(Supervisor)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

A.R.I	Agricultural Research Institute
cm	centimeters
CV	Coefficient of Variation
Df	Degrees of Freedom
e.g.	For example
ECGA	Eastern Cotton Growing Area
Fig.	Figure
GDP	Gross Domestic Product
GLM	General Linear Models.
ha.	Hectare
i.e.	That is
IPM.	Integrated Pest management
Kg	Kilogram
Km^2	Square kilometers
m	meters
mm	millimeter
PIER	Pacific Island Ecosystems at Risk
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
TARO	Tanzania Agricultural Research Organization
TCA	Tanzania Cotton Authority

USA	United States of America
WCGA	Western Cotton Growing Area
%	Percent
%age	Percentage
°C	Degrees-Celsius

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Cotton (*Gossypium spp*) is the most economically important natural fibre material in the World. It is mostly composed of cellulose (a carbohydrate plant substance) and formed by twisted, ribbon-like shaped fibres. The word 'cotton' as a plant refers to four species in the genus *Gossypium* (Malvaceae /mallow family) namely, *G. hirsutum* L., *G. barbadense* L., *G. arboreum* L. and *G. herbaceum* L. that were domesticated independently as source of textile fibre (Brubaker *et al*., 1999a). Globally, the *Gossypium* genus comprises about 50 species (Brubaker *et al*., 1999a). The place of origin of the genus is not known, however the primary centres of diversity for the genus are West- Central and Southern Mexico (18 species), North-East Africa and Arabia (14 species) and Australia (17 species). DNA sequence data from the existing *Gossypium* species suggest that the genus arose about 10 – 20 million years ago (Wendel and Albert, 1992; Seelanan *et al*., 1997). Cotton lint was spun and woven into cloth even before 3000 B. C. as revealed by fragments of cloth found at the Mohenjo-Daro archaeological site on the banks of the River Indus (McGregor, 1976). Most commercially cultivated cotton is derived from two species, *G. hirsutum* (American Upland cotton, 90% of world plantings which is available in large number of hybrid varieties or cross-bred cultivars with varying fiber lengths and tolerances to a number of growing conditions) and *G. barbadense* (Sea Island cotton or Pima, or Long-staple cotton). Cotton fibres of the *Gossypium hirsutum* species range from about 2 to 3 centimeters in length, whereas *Gossypium barbadense* cotton produces long-staple fibres up to 5 centimetres length. In India and Pakistan a number of local 'desi' varieties of *G. herbaceum* and *G. arboreum* are grown besides the American hybrids. *G. peruvianum* is cultivated in Egypt (Eyhorn *et al.*, 2005). Its production levels are regulated by yields and price levels. The largest producers of cotton are China, United States of America, India followed by Pakistan, former USSR Republics and Brazil. However, it is grown in over ninety countries and is the leading industrial crop interms of world production (Kohno and Ngan, 2004). Cotton constitutes an important cash crop in more than one third of all countries in sub-Saharan Africa and one upon which millions of rural households depend for their livelihoods. Cotton was introduced in Tanganyika at the turn of the twentieth century by German settlers as a plantation crop. During the 1920s new efforts focused on smallholders' production; first in Eastern and later in Western Tanganyika. Production of cotton on commercial scale started at Ukiriguru, South of Lake Victoria, following the construction of the railway line from Tabora to Mwanza in 1928. Because the first cotton varieties (imported from United States) were not suited to local growing conditions, yields were low. Local research during the 1930's led to the development of a pest resistant variety (Baffes, 2004). Cotton is currently cultivated in Tanzania in two geographical areas, namely the Western Cotton Growing Area (WCGA) which comprises of Shinyanga, Mwanza, Mara, Kagera, Tabora, Kigoma and Singida regions and the Eastern Cotton Growing Area (ECGA) which is made of Morogoro, Coast, Tanga, Kilimanjaro, Arusha and Iringa regions. These two areas vary greatly in terms of weather conditions, soil fertility, diseases and insect pests' occurrences (Tanzania Cotton Board, 2004).

Among the major obstacles hindering cotton cultivation is insect pest infestation. Cotton is a plant that in nature seems to attract insects. It has green succulent leaves, many large, open flowers, nectarines on every leaf and flower, and a vast amount of fruits. All seem attract insects, some beneficial to man and some notoriously obnoxious. Cotton stainers, *Dysdercus spp*. (Heteroptera: Pyrrhocorridae), are one of the major insect pests of cotton plants. They are difficult to control by insecticide application in cotton fields because they are highly mobile and have many alternative host plants (Kohno *et al.,* 2002). Medium to large sized nymphs and adults feed on developing cotton bolls (Sprekel, 2000). They cause serious damage by sucking on developing cotton bolls and ripe cotton seeds (split bolls) and transmitting fungi that develop on the immature lint and seed during the course of flowering which later on stain the lint with typical yellow colour, hence the name ‘ cotton stainers’. There are several (some 50) species of cotton stainer (*Dysdercus spp*) and all cause similar damage symptoms and they tend to be late-season pests which appear during boll ripening (Kohno and Ngan, 2004). *Dysdercus spp* can survive throughout the year in one locality provided there is a sequence of different host plants. The Genus is closely associated with the plants of the order Malvales (Malvaceae, Tiliaceae, Sterculiaceae and Bombacaceae) (Kohno and Ngan, 2004).

The management of insect pests is an integral part of an economic production system. It increases producers' profits and reduces the amount of environmental contamination from pesticides. The management techniques include: Cultural control such as manipulation of planting dates and stalk destruction; crop management practices such as variety selection; biological control, involving conservation of existing natural enemies; Host plant resistance and the wise use of selective insecticides and rates to keep pest populations below economic damaging levels (Knutson *et al.,* 1997). Some insects need more than one host to complete full development (Worth, 1994). The study on host range and survival and temporal population density of the cotton stainers *Dysdercus spp.* aim at improving our understanding on the use of compatible and ecologically sound combinations of pest suppression techniques.

1.2 Statement of the Problem

As cash crop, cotton (*Gossypium hirsutum*) contributed 17.85% of GDP in Tanzania when a record of production of 96 364 tonnes of lint was obtained during the 1992/93 marketing season. However, due to fluctuations in world market prices, cotton's contribution to GDP fell to 5.73% by 2000 (Tanzania Cotton Board, 2005). About 95% of cotton in Tanzania is produced in the Western Cotton Growing Area (WCGA). The rest (5%) is produced in Eastern Cotton Growing Area (ECGA) in which Kilosa District is inclusive (Mrosso *et al*., 2006). The ECGA has the potential to increase cotton production from 26 554 tonnes achieved during the season of 1992/93 through either increased productivity per unit area or expansion of areas under cultivation or both. Only 3187 tonnes was achieved during the season of 2004/05 (Tanzania Cotton Board, 2005).

However, the realization of such potential is mitigated by many factors; among them is the damage by insect pest (Kabissa, 1997). In ECGA, yield loss caused by insect pests is estimated to be as high as 70%. In some years the loss can be as high as 90% (Mrosso *et al*., 2006). Cotton stainers contribute much to this loss in the sense that bolls that have been affected by these pests when up to two weeks old either shed or abort. Bolls infected when three to four weeks old may slightly be distorted in shape, lint is heavily stained to a dirty brown or yellowish colour and when bolls open, the carpel are twisted, the lint does not fluff out and characteristically the fibres adhere to the edges of carpel and the quality of cotton seed is lowered. The damage that stainers cause is especially serious because it affects the end product of the plant, a loss of which the plant cannot compensate (Mrosso *et al*., 2006). Cotton stainers can survive throughout the year in one locality provided there is a sequence of different host plants. Information about host range, temporal population density changes, development and survival of the cotton stainers on alternative host plants in Kilosa District is not sufficiently documented.

1.3 Justification

Cotton is one of the major agricultural commodities in Tanzania and it varies with cashews as Tanzania's second largest export crop. As well as being an important source of foreign exchange, it also makes an important contribution to the income of thousands of rural families in thirteen out of 21 regions of main land Tanzania. The incomes from cotton also contribute to rural households' poverty alleviation. Over 80% of cotton produced in this country is meant for export in which case the question of high quality crop product is of paramount importance and only 10–20% of it is used locally (Tanzania Cotton Board, 2004). Cotton fibre is one of the most important raw materials used in textiles and seed is a source of vegetable oil and a high protein source for animal feed. The cotton stainer as one of the major cotton pests, damages developing bolls by puncturing seeds and causing plant sap to exude from the feeding site. The plant sap stains the lint an indelible yellow colour so there is a smaller amount of grade 'A' cotton and the value of cotton is reduced. Feeding by the cotton stainers also damages the fibres by cutting them and interferes with the bolls' natural development (Bohmafalk *et al.,* 1996). Heavy infestations on the seed affect the crop mass, germination capacity of the seed, marketability of the crop products. They also affect cottonseed as a byproduct of cotton and a valuable source of edible oil, cake, linters and hulls, all of which have several industrial and other applications (Eyhorn *et al.*, 2005). A small initial infestation may not be easily detected but it can cause significant damage. Kohno *et al.* (2002) observed that cotton stainers are difficult to control by insecticide application in cotton fields because they are highly mobile and have many alternative host plants. No detailed studies that have been documented on host range, development, survival and temporal population density changes of the cotton stainers, particularly on their alternative host plants in Kilosa District, yet the studies are important in assessing the pest damage relative to some growth stages of the plants and the potential of the cotton stainers to destroy harvestable parts. Maximum profits in cotton production depend partly on the effective and economic insect pest management programs. These studies are crucial for the prediction of the time of invasions of the cotton stainers into cotton fields and for effective pest control utilizing compatible and ecologically sound combinations of pest suppression techniques.

1.4 Objectives

1.4.1 Overall objective:

To assess the host range of cotton stainers (*Dysdercus spp*.), development, survival and population dynamics on cotton and other host plants in Kilosa District**.**

1.4.2 Specific objectives

i. To determine the host range of the different *Dysdercu*s species
ii. To determine temporal changes in abundance of *Dysdercus spp.* on host plants.
iii. To investigate the development and survival of *Dysdercus spp.* on the different alternative host plants.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Taxonomic Position of *Dysdercus spp*.

PHYLUM: Arthropoda.

SUPER CLASS: Hexapoda.

CLASS: Insecta.

SUB CLASS: Pterigota.

ORDER: Hemiptera (True bugs; Cicadas, Hoppers, Aphids and Allies). Hemiptera is an order of insects, comprising around 80 000 species of cicadas, aphids, plant hoppers, shield bugs, and others, collectively known as the true bugs. The name "Hemiptera" is from the Greek hemi ("half") and pteron ("wing"), referring to the forewings of many hemipterans which are hardened near the base, but membranous at the ends. These wings are termed hemelytra (singular: hemelytron), by analogy with the completely hardened elytra of beetles. They may be held "roof wise" over the body, or held flat on the back, with the ends overlapping. The hind wings are entirely membranous and are usually shorter than the forewings. The antennae in Hemiptera are typically five-segmented, although they can still be quite long, and the tarsi of the legs are three-segmented or shorter (Wikipedia, 2007).

SUB ORDER: Heteroptera (True bugs).

Any member of the insect order Heteroptera, which comprises the so-called true bugs. (Some authorities use the name Hemiptera; others consider both the heteropterans and the homopterans to be sub orders of the Hemiptera. This large group of insects, consisting of more than 40 000 species, can be recognized by an X- shaped design on the back, which is formed by the wings at rest. A combination of features — sucking mouthparts adapted to pierce plant or animal tissues and a hardened gula (underside of the head) — separate the heteropterans from all other insect orders. Although most species of Heteroptera are terrestrial, a few are aquatic. Some species, which feed on plant juices, are serious pests of cultivated crops; other species are predacious and benefit man by destroying various pests. There also are heteropterans that act as carriers of disease (Froeschner, 2007).

The Heteroptera include a diverse assemblage of insects that have become adapted to a broad - range of habitats -- terrestrial, aquatic and semi-aquatic. Terrestrial species are often associated with plants. They feed in vascular tissues or on the nutrients stored within seeds. Other species live as scavengers in the soil or underground in caves or ant nests. Still others are predators on a variety of small arthropods i.e. feed on other invertebrates, including some pest species. If well managed predators can significantly reduce populations of pest species and are therefore beneficial to Man (IOWA, 2007).

A few species even feed on the blood of vertebrates. Bed bugs and other members of the family Cimicidae live exclusively as ectoparasites on birds and mammals (including humans). Aquatic Heteroptera can be found on the surface of both fresh and salt water, near shorelines, or beneath the water surface in nearly all freshwater habitats. With only a few exceptions, these insects are predators of other aquatic organisms. Most species of Hemiptera are plant feeders, sucking sap with many causing considerable damage to crops, ornamental garden plants such as roses, shrubs and trees. The proboscis of hemipterans contains cutting blades and a two channelled tube. Hemipterans feed by cutting into a plant or animal and sending saliva down by one of the tubes to begin digestion. The liquid food is then sucked up by the other tube (IOWA, 2007).

FAMILY: Pyrrhocoridae (Red bugs)

GENUS: *Dysdercus* (Stainers)

COMMON NAME: Cotton stainers (IOWA, 2007).

2.2 Identification

The adult cotton stainer is a ″true bug″ with piercing and sucking mouth parts that they can even suck on seeds in closed bolls (Bohmafalk *et al.,* 1996). There are several species of cotton stainers and all cause similar damage symptoms. Their colours vary from bright red, yellow and orange depending on the species. In most cases dorsal surface is reddish orange to light brown in colour. The adult is about 10 -15 mm long depending on the species. The rostrum is a segmented tube containing the stylet, through which the insect feeds, and is folded beneath the body reaching the second abdominal segment or beyond. Hemelytron usually has a black mark in the broadest part, varying from a round spot to transverse band. Adults can tolerate a wide range of climatic conditions and can disperse and fly up to 15 km, although they usually make short flights and will run rather than flying when disturbed (Eyhorn *et al*., 2005). They spend most of their time coupled in copulation, hence their name '*Kangambili* in *Kiswahili'* (Treen, 1982). The females lay small, ovoid, 1.5 x 0.9 mm creamy white eggs in colour, changing to orange as the embryo develops. Eggs are laid in batches of about seven to100 in the soil or amongst plant debris which require moisture to develop (PAN Germany OISAT, 2007).The first larval instars is yellow, turning to orange- red without markings prior to moulting, and about 2mm long. The nymphs are similar to the adults in shape, but are wingless until the third instars in which the rudimentary wings develop i.e. the fourth and fifth instars have relatively bigger, dark wing pads, and the dividing lines between abdominal segments become very distinct as maturity is approached. Nymphs are found together in the area where the eggs had been laid and later disperse to look for food. They tend to meet again while feeding on seeds and while resting prior to moulting (PAN Germany OISAT, 2007).

2.3 Distribution

The true bug of the genus *Dysdercus* (Heteroptera: Pyrrhocoridae) includes many species distributed throughout the tropical and Subtropical areas all over the world. About 25 species of the genus *Dysdercus* have been encountered feeding on plants of the order Malvales (Malvaceae, Bombacaceae, Sterculiaceae and Tiliaceae) (Ahmad and Schaefer, 1987). Their relative abundance varies greatly in different areas depending partly on the distribution of their wild host plants (Pearson, 1958). In Tanzania, the genus *Dysdercus* is found in all cotton growing areas, particularly in Shinyanga, Mwanza, Nzega, Kahama and North Mara districts of the Western Cotton Growing Areas and in Northern and Western areas of the Eastern Cotton Growing Areas, thus Kilosa district is inclusive. Five out of ten African cotton stainers namely, *Dysdercus cardinalis*, *D. intermediesus*, *D. nigrofasciutus*, *D. superstatiasus*, and *Dysdercus fasciatus* are species commonly mentioned to be found in Tanzania (Mrosso *et al*., 2006).The genus *Dysdercus* is found throughout the tropics in Asia, Central and South America and Africa, each Continental area having its own group of species. The genus is of minor importance in Africa North of Sahara, Pakistan, and the Northern parts of India and the United States (PAN Germany OISAT, 2007).

2.4 Biology and Ecology of Cotton Stainers

The genus *Dysdercus* is an extremely compact natural group and, despite its wide distribution, its members differ remarkably little in their structure and biology. Cotton stainers, *Dysdercus spp*, are bugs that undergo incomplete metamorphosis

(Egg➔Nymph➔Adult). Although adult stainers are mostly solitary, *Dysdercus spp* displays a natural tendency to form aggregations. As a result of increased encounters between males and females of breeding age, aggregations frequently function as a vehicle for sexual selection. As a rule, aggregations are areas of intense male competition, and it has been demonstrated that an increase (or decrease) in competition alters the mating behaviors of the individuals involved (Mead and Fasulo, 2005). They mate end to end. According to Kasule (1991), size is a critical facet of evolution. In particular, large female are often more fecund and produce larger offspring than small ones; and larger males usually have enhanced mating success. Among the African species of cotton stainers, only *D. nigrofasciatus* and *D. melanoderes* are so closely related as to be able to interbreed and produce fertile offspring, crosses between other species occur only rarely and nearly always results in sterile eggs (Pearson, 1958).

Cotton stainer eggs look very much like microscopic hens' eggs. They are creamy white or pale yellow (Mead and Fasulo, 2005). The eggs are laid in shallow holes in the soil or plant litter, and camouflaged with the same materials by the female. The eggs are laid in batches of about seven to 100 and need moisture to develop. Depending on the species, moisture and temperature, some 80% of the eggs hatch in 4 to 13 days into wingless nymphs which lack the cross-markings on their backs (Mrosso *et al*., 2006). The optimum hatch occurs at 30^0C and 80% RH. There is no parental care thus nymphs will care for themselves individually. As human beings, we are used to gradually growing as we approach maturity (Wilson *et al*., 2008).

Arthropods (including cotton stainers) cannot do this, because of the constraints of their exoskeletons. Arthropods, therefore, have a series of life stages called instars or nymphs.

They shed their exoskeletons between these stages. Immediately after each moult, the insect can expand in size before its exoskeleton hardens again. There are five nymph stages or instars (they moult 5 times); the first instars usually is spending underground and is yellow turning to orange red, without markings, except for the red eyes, and about 2-3 mm. long. In subsequent instars, the length increases to about 3.5 – 5 mm; 6 – 8 mm; 9 – 11 mm; and 12 - 14 mm. at successive ecdyses, the adult being about 15mm long (Wilson *et al*., 2008). The duration of each of the first four stages typically averages four to five days, but the fifth stage commonly takes about twice as long. All five stages require from 21- 41 days before reaching the adult stage. The rudimentary wings are just visible in the third instars as black bars on each side of the hind part of the thorax; these are larger in the fourth and fifth stages in which also characteristic cross-markings are visible. The oviposition to adult period is thus 27 to 47 days (Mead and Fasulo, 2005). Stainers mate 2-6 days after their final moult if they have fed on suitable seeds, and pairs often remain in *copula* until oviposition occurs 2 - 8 days later, during which they move and feed (Mrosso *et al*., 2006). Copulation is usually repeated between successive ovipositions until all the eggs are laid. Fertility will be highest when the temperature is 30°C and low at temperature extremes (Wilson *et al*., 2008). No resting stage is known to occur in *Dysdercus*, which is thus dependent for its survival on a continuous supply of food and moisture. The adults remain sexually active at all times, except at low temperatures and in the prolonged absence of their normal food (Mrosso *et al*., 2006).

Records of the number of eggs laid are very variable, but fecundity is greatly affected by nutrition. Most records for *D. nigrofasciatus* give around 900 eggs per female, with a maximum of 1350 in 12 batches, whereas *D. superstitousus* usually lay around 300, *D. melanoderes* averaged 650, with a maximum of 1360 and *D. fasciatus* averaged 815. The process of laying a batch of 120 eggs takes one and a half hours and there is an interval of 4 – 8 days between batches, so that the egg-laying period may last 20 – 66 days, the number of eggs per batch tending to become smaller towards the end of the period (Pearson, 1958). The first immature instars are usually found congregating near the egg shells after emergence. The yellowish first instars nymphs do not feed; although they may drink (Mrosso *et al*., 2006). Without water nymphs cannot survive. They can, however, survive for 7 – 18 days on water alone and sometimes reach the third instars (Pearson, 1958). Wilson *et al*. (2008) reported that availability of water and nectar is important for feeding and development during all stages. Typically, the first-instars nymphs of terrestrial bugs do not suck plant sap when they first emerge. Even if they are phytophagous, they spend some time ingesting bacteria which the female deposited on the eggs when she laid them, and they can frequently be found clustered around their eggs cases. Of course, the first-instars nymphs of terrestrial stainers have to liquefy the food source with saliva before they can ingest it through the stylet (Mrosso *et al*., 2006).

The second instars may disperse in search of food. Their stylets are not yet long enough to penetrate unopened bolls and reach the seed within. Instead they look for ripe, exposed seed or decaying seed. When free water is present they are able to penetrate quite hard, dry seeds. They may be seen to congregate around suitable sources of food. Once the third instars are reached, they are able to commence feeding on developing seed within the bolls. From this stage onward the nymphs will disperse to feed and congregate to moult. Usually therefore, multiplication of cotton stainer tend to begin when the first bolls split open as to support nymphs feeding and survival. Nymphs are very gregarious than adults especially when feeding and prior to each moult (Wilson *et al*., 2008). Prior to moulting, later-stage nymphs often wander from their food plants and congregate in clumps of grass or on the underside of broad leaves, or on stumps, fences and walls. Such situations are usually shady, and aggregations may represent the mutual conservation of water; it seems possible that they may serve as displays of warning colouring, affording protection during moult, when the nymph is particularly vulnerable to predators (Pearson, 1958). This characteristic is especially noticeable with young nymphs feeding on dry seeds, one of which at a time will be attacked by all the nymphs together, possibly in order to facilitate the breakdown of the tissues by the saliva introduced. The contents of such seeds are very rapidly converted to a soft, cheesy consistency, presumably by enzyme action (Pearson, 1958). The availability of water and nectar is important for feeding and development during all growth stages. Adults can survive on water alone for several weeks when food is scarce (Wilson *et al.*, 2008).

Both nymphs and adults tend to cannibalize weak, dying and dead individuals when inadequately fed. Juveniles are easier to find because they are always feeding while the adults feed occasionally and spend most of their time in copula (mating). While in copulation, a female *Dysdercus spp* is usually dragging the male simply because the female's size is larger than that of their counterpart males. Locating a host plant is crucial for phytophagous (herbivorous) insects to fulfill its nutritional requirements and to find suitable oviposition sites. Insects can locate their hosts even though the host plants are often hidden among an array of other plants. Plant volatiles play an important role in this host-location process (Bruce *et al.*, 2005). For the majority of herbivores, host plant selection is closely linked with oviposition site selection, since most phytophagous insects feed and deposit their eggs on the same plant species. In general, the host plant selection behaviour of insects has been divided into several sequential steps comprising habitat finding, host plant finding, host plant recognition and acceptance which are in turn connected to host plant suitability (Collier, 2000). Herbivores like cotton stainers use both chemical and visual cues to locate host plant and to discriminate host from nonhost plant in diverse habitats (Fernandez and Hilker, 2007). It is assumed that phytophagous insects employ during host plant location a specific ‘host plant search image’ which is based on representative chemical and visual characteristics of their host plant (Collier, 2000). Many examples show that typical volatile compounds emitted by host plants guide herbivores while searching and play an important role in host plant recognition (Bruce *et al*., 2005). For instance, it has been reported that host plant odour signals attract herbivores over distances of up to 100 metres (Collier, 2000). The decision to select a host plant for oviposition and/or feeding may further be affected by other types of infochemicals derived from competitors or natural enemies (Dicke, 2000).

Besides chemical host plant properties, visual plant attributes such as growth form, leaves shape or colour can also influence the host location process of herbivorous insects (Prokopy and Owens, 1983). Visual host plant cues were observed to elicit positive responses in herbivores over a distance of up to 10 metres (Collier, 2000). However, within habitats, olfactory and visual plant cues always occur in combination and the relative importance of either cue for herbivores during host location is sometimes difficult to assess. Finally, for host plant recognition and acceptance contact cues such as non-volatile chemicals or mechanical stimuli may be decisive factors. For example, leaf epicuticular waxes and other non-volatile secondary compounds or plant trichomes on the plant surface are known to trigger the acceptance or rejection of host plant for oviposition and/or feeding (Müller and Riederer, 2005). *Dysdercus koenigii* (F.) was also attracted to host plant scents, green leaves of cotton (*Gossypium hirsutum* L.), probably by the presence of essential oils. In the same study, the insects were more attracted to the seeds of cotton and okra, *Abelmoschus esculentus* Moench, than those of other hosts (Ventura and Panizzi, 2005). There are several generations a year. The life cycle can vary from about a month to five and a half months, depending primarily upon temperature differences and diets (Mead and Fasulo, 2005). Like all members of the family Pyrrhocoridae, the genus is closely related/ associated with plants of the order Malvales, the adults and immature stages feeding mainly on the ripe or developing seeds (Pearson, 1958; Kasule, 1991). When cotton crops have been harvested and crop residues destroyed, *Dysdercus spp* move to a succession of host plants depending on their availability in a given area. In some cases they may survive on nectar. Population which has built up on a sequence of wild host plants will attack cotton crops maturing in fields. However, adult stainers disperse from arboreal hosts in the middle of the cotton season (Mathews, 1989). The feeding damage of cotton stainers provide an entry point for the yeast-like fungus which stains the lint, *Nematospora spp*, whose spores are found in the gut and saliva of the *Dysdercus spp*. Fungal material as spores or mycelium is carried as an external contaminant on the mouth-parts, although it is located in the deep stylet pouches, where protection is afforded and spore germination is possible. The fungus is cast off with the exuviae during moulting, but recontamination from exuviae or other sources in the environment occurs (Frazer, 2008).

The transmission is hence purely mechanical with the insect obligatory only in its function as a syringe to inject the fungus which is otherwise unable to reach its substrate. Insect and fungus can develop independently and the insect is apparently unharmed by the presence of the fungus. *Nematospora spp* spores also reach the intestine but don't germinate. The fungus is believed to enter and leave the insect by the same route. The spores are well adapted in shape to reach the stylet pouches of insects (Frazer, 2008). Important predators such as the reduviid bugs of the genus *Phonoctonus* feed both on stainers remaines and other Pyrrhocorid bug, *Odontopus,* that is resident on the trees. Of the obligate predators, two of the most important families are the Reduviidae, or assassin bugs and the Nabidae, or damsel bugs. The reduviids have three main predation strategies: camouflage, subterfuge and bravado. A lot of assassin bugs have gone for the camouflage option. They are covered in sticky hairs and can shroud themselves in bits of detritus, becoming almost completely invisible, particularly if they are on the bark of trees or on forest floors (Mathews, 1989). Subterfuge is deployed by those species which are disguised as other creatures. Some assassin bugs appear identical to plant-eating 'cotton stainer ‘bugs. Cotton stainers are renowned for having garish stripes on the side of the body, which may be an indication of being nasty to eat. Some assassin bugs have copied these markings almost perfectly. Thus the assassin bug warns off its predators and dupes its prey at the same time. But most assassin bugs don't bother to hide. Overt aggressors they hunt with bravado, crawling about over plants and over the ground, overpowering any suitable prey (Mathews, 1989).

They are strong for their size and able to tackle prey far bigger than they are. Many of them have curious sticky pads on the front legs which aid in securing prey. Some of the dispersing cotton stainers enter cotton fields when bolls have already formed, while others will be attracted to alternative Malvaceous host plants e.g. *Hibiscus spp*. (Mathews, 1989). Like herbivores, foraging carnivores also have to locate hosts or prey on different spatial scales, starting with the location of the habitat of hosts or prey, then finding plants harbouring hosts or prey and finally recognize and accept suitable targets (Vinson, 1998). To find their way to their victims, carnivorous insects can use both olfactory and visual plant cues (Henneman *et al*., 2002). The shape and pattern of plants may be important to find habitats and patches with hosts or prey (Freund and Olmstead, 2000). Furthermore, plant colour may provide parasitoids and predators with valuable information during foraging (Henneman *et al*., 2002; Fischer *et al*., 2004 and Goyer *et al*., 2004). However, chemical cues may constitute more specific and reliable signals indicating the presence of hosts or prey within the habitat. Extensive research has elucidated that foraging natural enemies rely on various kinds of infochemical cues, which may originate either directly from host or prey individuals, for example pheromones, or indirectly from the food plants of their victims, for example volatile secondary plant compounds (de Boer and Dicke, 2005; Hilker and Meiners, 2006). Carnivorous insects are known to be attracted by plant volatiles from intact (Reddy, 2002; Bukovinszky *et al*., 2005) and infested food plants of their victims. However, food plants that are damaged by herbivore feeding or oviposition produce specific volatile compounds, which allow the natural enemies to locate and select their targets very precisely (Hilker and Meiners, 2002). Thereby, carnivorous insects often combine the use of direct and indirect cues during foraging and are attracted to infochemicals derived from the whole complex of host/prey and associated food plants (Reddy and Guerrero, 2004). Whether carnivores respond to very specific signals or to signals, which are generally present in multiple host/prey-plant complexes, depends on the dietary specialization of the carnivore species and on the diet breadth of their victims (Steidle and van Loon, 2003). The response to the occurring signals may be either innate or acquired through associative learning when hosts or prey are encountered in their presence (Steidle and van Loon, 2003; de Boer and Dicke, 2006). Provided there is a sequence of host plants within the area, *Dysdercus spp* can survive throughout the year in one locality, but due to its sensitivity to low humidity affecting the survival of eggs and young nymphs, migration occur to reinvade areas. Colonization of new area by certain species e.g. *Dysdercus voelkeri* and *D. melanoderes* in West Africa is thought to be associated with the annual movement of the Inter- Tropical Front (Mathews, 1989). Cotton stainers tend to hide during the heat of the day, thus they are not easily observed at this time (Wilson *et al*., 2008).

2.5 Damage and Crop Loss

Initially, cotton becomes infested by adults that fly into fields around the time of first open boll, though sometimes, perhaps due to seasonal conditions, populations can be found early during boll maturation. Adults will mate soon after arrival. The expanding population of developing nymphs will be the cause of economic damage (Wilson *et al*., 2008). Cotton stainers feed both on immature and mature seeds. The developing bolls are rich in reducing sugars. Male *Dysdercus* which can survive for prolonged periods on simple sugar solutions, show a marked preference on bolls of this age. This is the stage at which attack by *Nematospora* is most damaging; reducing sugars provide a highly suitable source of carbon for fungus. Ripe seed provides food which is essentially satisfactory for nymph development and also for oviposition because specific proteins are supplied by same (Rainey, 2008).

The state of development of the seed is of great importance. Mechanical considerations enter into this; from the second instars, nymphs prefer ripe seeds to immature seeds, this is because their stylets are short, thus they require bolls that have started to split open, their interior of which is moist protected environment for the nymph to feed directly on the seeds. Later they can feed on dry seeds provided moisture, such as dew is available. The nymphs are very gregarious, especially while feeding and before each moult. There are no visible symptoms until the boll ripens, and the presence of the insect is the only outward sign that damage is taking place. If a sample of green boll is cut open, however, recent attack is indicated by dark watery spots on the inside of the boll wall; earlier attacks will have caused rotting of the immature seeds, often accompanied by a yellow staining of the lint (Mrosso *et al*., 2006). Their feeding damage provides an entry point for the yeast-like fungus which stains the lint, *Nematospora gossypii*, whose spores are found in the gut and saliva of the *Dysdercus spp*, which appear to be injected into the green bolls with the salivary fluid hence the name ‘cotton stainers’. *Nematospora coryli* also cause the same damage *(*Heinrichs and Barrion, 2004). Inoculation of *Nematospora spp* into cotton bolls at successive weekly intervals from flowering to maturity show that the symptoms produced are closely dependent upon the stage of development reached by the boll when infected. During the first four weeks of life, bolls are in stage of rapid growth and differentiation, and infection is followed by severe disorganization of all boll structures and complete commercial loss (Pearson, 2008). Bolls up to two weeks old either shed or abort, the embryo being killed; bolls infected when three to four weeks old may be slightly distorted in shape, the lint is heavily stained to a dirty brown or yellowish colour and when the boll opens the carpels are twisted, the lint does not fluff out and characteristically the fibres adhere to the edges of the carpel and are stretched out to form a web; bolls over five weeks old complete their development normally, but the lint is diffusely stained to a depth and extent depending on the time available to the fungus between infection and boll ripening, and increasing from straw yellow to dark brown with time, (Heinrichs and Barrion, 2004).

An average boll will contain nearly 500 000 fibers of cotton and each plant may bear up to 100 bolls. The effect of the fungus occur mostly earlier in the season when stainers migrate into the cotton from alternate host plants, and the moisture content of the bolls is sufficient to allow the fungus spores to develop. Secondary spread of the fungus occurs if the stainer infection is not controlled (Mathews, 1989). However, not all stainer transmit *Nematospora* fungus , when bolls are less than a month old, only the seeds directly punctured are affected, the embryo shrivels up and lint hairs remain un thickened and mat together. In older bolls, seeds in which the embryo is fully formed seem able to withstand punctures without effect on lint, and the boll opens normally showing no sign of damage. Some studies show that the critical period of fruit formations is in the first

30-40 days of blooming (Mrosso *et al*., 2006). The highest quality and quantity of lint is produced at this time, thus, damage inflicted at this period can be most costly (Mrosso *et al*., 2006). *Dysdercus spp* have many hosts, the most common being cotton (Heinrichs and Barrion, 2004). When their host plant fruits are not available, they go to flowers, buds or growing twigs. Heavy infestations on the seed affect the seed cotton weight, oil content, ginning percentage, germination capacity of the seed and marketability of the crop products (Eyhorn *et al.*, 2005; PAN Germany OISAT, 2007).

2.6 Hosts Attacked by Cotton Stainers

Phytophagous insects show specialized feeding habits. In general, each species feeds on a restricted range of taxonomically related plant species and in addition limits its feeding to particular plant parts (Visser, 1986). The *Dysdercus spp* have many hosts, the most common being cotton (*Gossypium spp)* (Heinrichs and Barrion, 2004). They are most closely associated with the plants of the order Malvales. These are mostly in the families of Malvaceae and some plants of the families Bombacaceae, Sterculiaceae and Tiliaceae. Some of these plants include *Hibiscus spp, Abutilon spp, Thespesia spp* such as *Thespesia garekeana,* Baobab tree *(Adansioa digitata)* and *Sterculia spp (*such as *S. africanus, S. appendiculata)* (Mrosso *et al*., 2006), *Abelmoschus spp* such as *A. esculentus,* cultivated and wild cotton plants (Kohno and Ngan, 2004). According to Pearson (1958) other potential host plants include; Asteraceae e.g. *Helianthus annuus* (sunflower); Rhamnaceae e.g. *Zizyphus spina-christi* and Poaceae *e.g. Pennisetum typhoides (bulrush millet), Sorghum vulgare* (cultivated sorghum), *Zea mays* (maize).

2.7 Management Strategies for Cotton Stainers

2.7.1 Chemical control

Control measures have for a long time hinged mainly on pest mortality caused by pesticides applied up to six times at interval of 10 and 14 days during the flowering period in Eastern and Western Tanzania respectively, in order to achieve maximum yield (Mrosso *et al*., 2006). A number of synthetic insecticides have been tested and recommended for use on cotton in Tanzania aiming at reducing the insects and mites population. These insecticides include Endosulfan, Cypermethrin, Alpha cypermethrin, Beta cypermethrin, Lambda cyhalothrin, Cyfluthrin, Beta cyfluthrin, Esfenvalerate among others. Botanical sprays e.g. (Neem', custard apple, garlic bulb, sweet flag, sweet basil, and Derris species) (Eyhorn *et al*., 2005).

2.7.2 Cultural control

Thorough cultivation and clearing field borders: This will destroy most of the insect pests' eggs laid in soil and plant litter. **Early sowing**: Early sown cotton will have already set its main crop and so will escape serious damage by the cotton stainers. **Regular picking**: Regular picked cotton is less likely to be attacked by cotton stainers nymphs and adults. **Avoid stand over of cotton plants (**Uprooting and burning**)**: This provides a period of approximately three months when no cotton is available for the pest to survive on from the end of one season until the start of the next. **Clean cotton stores:** in order to avoid damage of cotton in stores. Cultivating cotton **away from host plants**. **Trapping with attracticides:** seeds of cotton plant and baobab tree can attract the cotton stainers in cotton fields making it easier to destroy them on the spot (Eyhorn *et al.*, 2005; Kabissa, 1997). **Spray the soil, trunks of host plants** to kill the nymphs hatching from eggs laid around the stems/plants. **"Tanglefoot"pest barrier** around tree trunks will keep young bugs from crawling up to fruits and blossoms. Tanglefoot is an organic (castor oil, waxes and resins) paste around the truck of trees and shrubs to block access of crawling insects to leaves, buds and fruits (Acosta, 2008).

2.7.3 Biological control

The predator assassin bug, '*Phonnoctonus principalis*' '*Phonnoctonus fasciatus*' and '*Phonnoctonus nigrofasciatus*' mimic the stainers and by attacking them they are able to reduce their population. The assassin bugs resemble the stainer in general shape and have very similar colour patterns to those of stainer species on which they feed. The predator can be distinguished by its large size and distinct neck between the head and thorax. One adult *Phonnoctonus principalis* is capable of killing four to six cotton stainers per day. Other natural enemies that can be encouraged for use in control of *Dysdercus spp* include the parasitic wasps, spiders- Arachnida. Birds also can be encouraged by coloured rice, bird perches and trees to control the bugs in cotton fields. Chicken grazing is another form of biological control. Ectoparasitic mites (Acarina: *Hemipterotarseius spp*) infect the postnotum of the adults while the parasitic nematodes infest the abdomen of the females (Eyhorn *et al.*, 2005). Other reduviid predators of cotton stainer include the *Harpactor segmentarius* and *Harpactor neaveibergr*. Pentatomid family also does predatation on cotton stainers e.g. the *Macrorhapis dallsupurcata.* Apart from the reduviid predators, certain Tachinids-Diptera- (e.g. *Bogosiella fasciata, Acaulona peruviana, A. brasilliana*) can parasitize stainers on the wild and cultivated host plants, but natural enemies exert very little control on cotton (Mathews, 1989). The pyrrhocorid predator *Antlochus coquebertii* has been reported to attack cotton stainers in India and Malaysia whereby it is believed to inject saliva containing proteolytic enzymes into eggs, nymphs or adults before sucking out the liquefied contents (Heinrich and Barrion, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Location and Duration

Studies were conducted at Ilonga Village in Chanzulu Ward, Malui Village in Mabwerebwere/Tindiga Ward and Rozi Village in Magomeni Ward as indicated in location map herein shown in Fig. 1. These Villages are found in Kilosa District in Morogoro Region, in the Eastern Cotton Growing Area of Tanzania and the studies were accomplished in one year (October, 2007 to September, 2008). Kilosa District with a total area of 14 245 km^2 (1 424 540 ha.), borders Tanga Region in the North, Mvomero District in the East, Kilombero District in the South and Iringa Region in the South – West and has a bi-modal pattern of rainfall. Normally, it rains from November to April or May, with heavy rains being experienced during the months of March and April. A dry spell is normally experienced on June to September or October. Average annual rainfall is 1059 mm (taken over 50 years: 1944 – 2002). It has Tropical temperatures of between 15^0 C and 35^0 C (Mushi, A. J. personal communication, 2007).

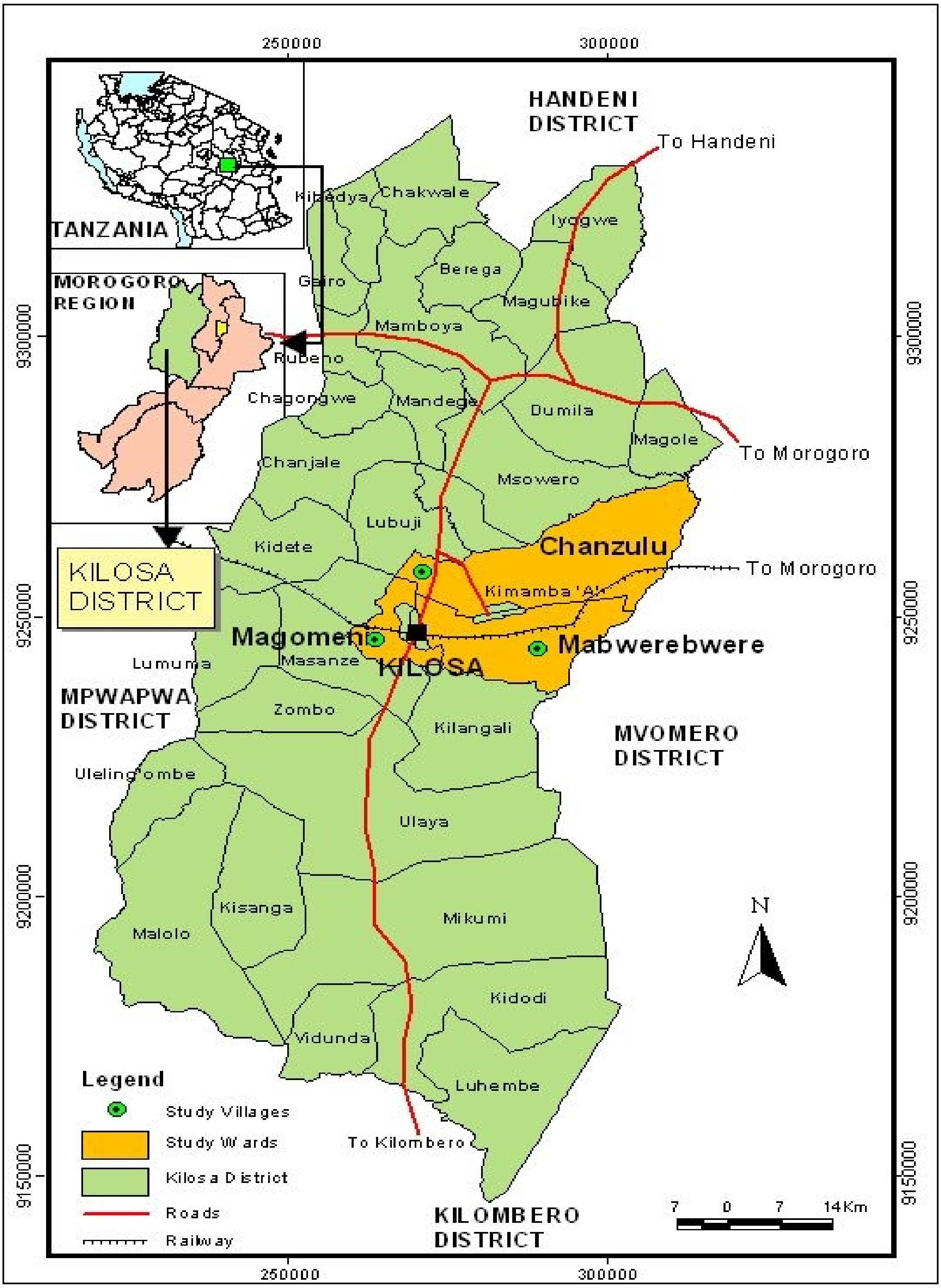

Figure 1: Location map showing Villages/ Wards where studies were conducted.

3.2 Determination of Host Range of the Different *Dysdercus Spp*.

A survey was done in both cultivated and in fallow lands in Ilonga, Malui and Rozi Villages to identify the *Dysdercus* species and their respective host plants. The plant parts which were found being attacked by the bugs were recorded. These host plant samples were taken to a botanist for identification whereas the *Dysdercus* species were identified using the field identification key of principal African species of *Dysdercus* described by Pearson (1958). The criterion for accepting a plant to be a host of cotton stainers was largely based on the presence of the stainers and observation of feeding activities/ damages by the stainers on the parts of that particular host plant in different localities within the study area. Some field photos of the host plants and *Dysdercus* species were taken using a digital camera for later references after thorough identifications of the same. However, photos were considered as additional materials for describing the host plant species and cotton stainer species on paper. Further, investigations on same plants, on the same basis continued for several months during the study year to justify that they were true host plants of the cotton stainers. Since most of the *Dysdercus* species have been associated with plants in the Malvaceae family and to some extent with Bombacaceae family, a close attention was paid to these plant species bearing in mind that not all species of these plant families are currently growing in Kilosa district and that host-plant range is dynamic over evolutionary time. One of the Roselle field surveyed at Ilonga village during host range determination study is shown in Fig. 2.

3.3 Temporal Changes in Abundance of *Dysdercus* Species on Host Plants

Among the identified host plants including cotton (*G. hirsutum*), six species were monitored for population dynamics of the cotton stainers. A cotton (*G. hirsutum*) field of not more than half an acre, okra (*Abelmoschus esculentus*) and *G. barbadense* fields

Figure 2: Cultivated Roselle field being surveyed to determine cotton stainers' host range.

were established while chemical spraying in these fields was strictly prohibited. The other three species, namely the Baobab, Kapok and *Hibiscus micranthus* were sampled in uncultivated areas where they were easily found already growing on their own and thus turned into management for study of population dynamics of the cotton stainers. Ten plants of each of the herbaceous plant species namely cotton (*G. hirsutum*), okra (*Abelmoschus esculentus*), *G. barbadense* and *Hibiscus micranthus* were randomly selected and marked at each field/ site and observed for occurrences of the *Dysdercus* species. The randomly selected plants were repeatedly used in estimating the population of the bugs on monthly basis for twelve months. *Dysdercus spp* population estimation was accomplished by using a whole plant observation method as per Wilson and Room (1982); Wilson and Room (1983); Rothrock and Sterling (1982) and Deutscher and Wilson (1999).

In each case, complete, individual plants were randomly sampled in a given plot and checked for presence of the insect pests, including squares and bolls. This was to ensure that insect pests which were present at lower to upper parts of the plant canopy were recorded, including the nymphs that were usually found congregating near the egg shells on the ground under an individual plant canopy after emergence. For trees, only one tree was selected in each host plant species and five quadrats of 2 m x 2 m were evenly spaced under each of these trees to cover the circumference of the ground part encircled with the tree canopy for population estimates of the cotton stainers, a method of insects population estimate used in ecology (CISEO, 2001; Ito, 1987; William *et al*., 2002). Only those bugs which were found in these quadrats were counted as a representative sample for the whole tree. The method was suitable because most of the cotton stainer were found on the ground feeding on the dropped split open pods. Even those few stainers which were observed feeding on the pods that were still attached on the tree, eventually dropped down to the ground together with their open spilt pods a few days later. (A whole plant count of insects population was difficult as these are big and tall trees). Population estimates of the cotton stainer species in each of the six host plant species were conducted on monthly basis between 0600 – 1000 h as to avoid diurnal variations (cotton stainers tend to hide during the heat of the day, thus they are not easily observed at this time). These data were collected for twelve consecutive months from October, 2007 to September, 2008. Five cotton stainers species that were identified during the course of experimentation were involved in monthly population estimation. Monthly estimates of the Nymph populations, individual mature species populations and total of the mixed population of all the cotton stainers species were recorded and were analysed for temporal changes in their respective abundances.

3.4 Investigation of the Development and Survival of *Dysdercus* Species

In investigating the development and survival of *Dysdercus* species on different host plants, plant parts that are preferred by the bugs from each of the chosen host plants were identified and supplied in *ad libitum* to caged *Dysdercus* species to feed on. During the survey, *Dysdercus spp* were found to prefer seeds to any other parts of these host plants be it green fruits/ bolls, flowers/ squares, green pods or any other plant parts depending on the host plant species. This made it important in this experiment to use seeds of these different host plants to feed the bugs in cages. However, among the five *Dysdercus spp* identified in Kilosa District, only one species of cotton stainer namely the *Dysdercus fasciatus* was conveniently involved in this experiment. According to Dingle and Arora (2004), *D. fasciatus* is the most opportunistic species with the highest reproductive potential and no flight in female in the presence of food but rather histolyse the flight muscles and develop oocytes, the behaviour which renders the species to the status of a major pest. Thus seeds of six host plants namely Cotton (*G. hirsutum*), okra (*Abelmoschus esculentus*) and cotton (*G. barbadense* Linn.), *Hibiscus micranthus*, Baobab (*Adansonia digitata* L.), Kapok (*Ceiba pentandra* L) were prepared. Among the above listed species, *Hibiscus micranthus*, Baobab *(Adansonia digitata* L.), Kapok (*Ceiba pentandra* L.) are wild and widely distributed in Kilosa District. Three breeding and 18 rearing cages (50 x50x 50 cm) were made. All sides of these cages were covered with a zero sized green mesh except the bottom which was filled with moist sand soil for females' oviposition and hatching of the eggs. Eggs' laying female *Dysdercus fasciatus* in a zero sized green mesh covered cage is shown in Fig. 3.

To start with, a sufficient number of breeding / mating pairs of *Dysdercus fasciatus* were caught and caged in an insectary room for breeding purposes so as to produce sufficient day old nymphs. Investigation of the development and survival of *Dysdercus fasciatus* on different host plants started by transferring a cohort of 18 individuals (samples) of 40 day old nymphs each, from the breeding cage(s) to 18 rearing cages. The rearing cages were arranged in a Randomized Complete Block Design (RCBD) with three replications and six treatments (host plants). The experiment was carried out under room temperature. In the rearing cages, each of the host plant seeds was supplied in ad libitum and changed after every three days in line with daily clean water supply. A day old to two weeks old nymphs were supplied with water on wetted soft tissue paper placed in Petri dishes. After two weeks the bugs were capable of crawling to the Petri dishes the bottom of which was filled with gravel and drinking water. Thereafter, the soft tissue paper was replaced by gravel. Mortality of individual stages (e.g. nymphal instars and adults) was monitored and recorded daily to determine their survival. The aim was to

Figure 3: Eggs' laying female *Dysdercus fasciatus* in green mesh covered cage.

determine whether or not *Dysdercus fasciatus* can be able to survive on a particular host plant without feeding on other plants. Developmental parameters such as the durations taken by different stages of growth of the individuals from nymph to maturity stage were also recorded including the number of instars and their durations. Counting the number of instars was achieved through daily observation of the shedding of cuticle in each cage which is usually accompanied with body elongation (changing size) of the individuals. Other developmental parameters recorded were the generation time herein considered as the duration taken from nymph (cohort generation) to nymph (progeny of the cohort generation) and, the life cycles herein considered as a series of some events taking place with the individual species of cotton stainer from day one to death. Five first nymph clutches from each cage were counted and their average was considered to be the average number of nymphs per female per clutch for the particular caging, aiming at comparing the number of nymphs per female in different cages. Data collected in this laboratory experiment were subjected to Statistical Analysis using the SAS software package for analysis by GLM procedure, which basically uses the least squares analysis method (Snedecor and Cochran, 1996) to fit general linear models. Means were separated by the Tukey's Studentized Range.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 *Dysdercus spp* Host Range in Kilosa District

Due to different ecological aspects e.g. ecological succession, host-plant range is dynamic over evolutionary time (Janz *et a*l., 2001; Nosil, 2002). The survey conducted for 12 months in cultivated and uncultivated fields in the cotton growing areas identified five species of cotton stainers feeding on different host plant species ranging from arboreal to both annual and perennial herbaceous types. The cotton stainer species that were identified were: *Dysdecus fasciatus* Sign (Fig. 4); *D. intermediosus* Dist (Fig. 5); *D. nigrofasciatus* Stål (Fig. 6); *D. cardinalis* Gerst (Fig. 7) and *D. superstitiosus* (F) (Fig. 8). According to Pearson (1958), *D. superstitiosus* occurs in two forms, one characterized by a round or transversely elliptical spot on the hemelytron of the adult, the other having a band that extends from the inner to the outer edge of the hemelytron. Only the former was found in Kilosa district and not the later form (Fig. 8).

Figure 4: *Dysdecus fasciatus* on cotton boll

Figure 5: ***D. intermediosus*** **on cotton boll**

Figure 6: ***D. nigrofasciatus*** **on Roselle**

Figure 7: ***D. cardinalis*** **on** ***H. micranthus***

Figure 8: *D. superstitiosus* on Okra

With the exception of the rare *D. superstitiosus*, the other four species were occurring on different host plants almost all the year around, indicating a wide range of hosts plants in Kilosa District, that are able to support the stainers throughout the year at different population levels. At least 31 plant species were found to host cotton stainers in Kilosa District. With the exception of a few plants, most of the host plant species belonged to the order Malvales, particularly of the families Malvaceae, Bombacaceae, Tiliaceae and Sterculiaceae. The results support the findings reported by Pearson (1958), Kohno and Ngan (2004) and Mrosso *et al*. (2006). Some few plants were potentially found to host the cotton stainers to a certain degree, and these belonged to the families of Asteraceae, Moraceae, Myrtaceae, Caricaceae, Musaceae, Anacardiaceae, Bromeliaceae, and Poaceae. However, there were unusual hosts that were found to support the bugs. These included meat from vertebrates, left over of bread, buns or doughnuts and the like. Cannibalism was observed. Although the host range of *Dysdercus spp* was overlapping, this study revealed that *Dysdercus fasciatus, D. nigrofasciatus and D. intermediosus* had a wider host range, whereas *D. cardinalis* had a relatively narrow host range and the rare *D. superstitiosus* had the narrowest host range. However, in the absence of cotton, *D. fasciatus* and *D. intermediosus* tended to specialize much on trees (arboreal host plants) while *D. nigrofasciatus* and *D. cardinalis* specialized much on herbaceous host plants. This finding is supported by Visser (1986) who reported that, phytophagous insects show specialized feeding habits, and generally, each species feeds on a restricted range of taxonomically related plant species and in addition limits its feeding to particular plant parts. Thus, even between the *D. fasciatus* and *D. intermediosus* which both tended to specialize on arboreal (tree types) host plants, they further showed more specialization among the arboreal plants. *D. fasciatus* specialized more on Kapok and Baobab while *D. intermediosus* specialized on *Sterculia* species. Among the host plants identified, cotton was found to be the commonest host for all five species of *Dysdercus* found in Kilosa.

The finding was also reported by Heinrichs and Barrion (2004). A number of specific host plants and other feeding material mentioned above, which cotton stainers were specifically encountered feeding on them in Kilosa District during the survey, are described below:

4.1.1 *Hibiscus micranthus*

Figure 9 (a): *H. micranthus* open split bolls

***Figure 9 (b):* H. micranthus *hosting* Dysdercus cardinalis**

H. micranthus: These are wiry herbaceous plants under the family Malvaceae, 0.4 – 3 m tall (Fig. 9a and 9b). They have white corolla fading to pink. Their spherical capsules (small bolls) split open when mature enough and give cotton like seeded materials. Stainers were found feeding on flowers, young bolls, mature bolls and split open bolls. They were found on the host plant species for the whole year but in different populations' densities. *Dysdercus* species that were encountered feeding on the host plant species include: *D. cardinalis; D. nigrofasciatus*; *D. fasciatus*; *D. intermediosus* and *D. superstitiosus.*

4.1.2 Kapok (*Ceiba pentandra* L.) - Silk cotton tree

Kapoks (*Ceiba pentandra* L.) are very large majestic trees under the family Bombacaceae, with conspicuously buttressed trunks. The kapok tree grows more than

Figure 10: (a): Kapok tree

Figure 10 (b): Kapok split open pod with *D. nigrofasciatus* and *D. fasciatus* mating pairs and singles sucking on seeds.

61.6 m tall with widely spreading branches. The trunk can become more than 2.8m in diameter (Fig. 10a). The silk cottons of kapok consist of the hairs borne on the interior of the pods. The small, brown seed (Fig. 10b), on which cotton stainers feed on, is in betted within the fluffy kapok (Tropilab, 2003).

Most of the cotton stainers both mature and nymphs were found to feed on the dropped open split/ bored pods on the ground. Some (both mature and nymphs) were feeding on open split pods that were still attached on the tree, in which case for sure they dropped down together with these pods from the tree attachment. Cotton stainers mostly feed on seeds of dried split open mature pods, flowers and young pods/open green pods of this host plant. Some spend time on the truck of host tree as well as in barks and crevices of the tree itself especially when sufficiently fed on the ground. The following species of *Dysdercus* were observed: *Dysdercus fasciatus* were encountered throughout the year; *D. nigrofasciatus* were encountered throughout the year**;** *D. cardinalis* were observed on this host in December to April; *D. intermedius* were seen in January to May.

4.1.3 Baobab: *Adansonia digitata* L. Other common names include boab, bottle tree and monkey bread tree

Figure 11 (a): Baobab with green pods

Figure 11 (b): Split open baobab pod with* D. fasciatus *sucking on seeds

These are tree species of the family Bombacaceae which can reach heights of between 5–25 m (exceptionally 30 m) tall, and up to 7 m (exceptionally 11 m) in trunk diameter (Fig. 11a). Fruits are large, ovoid, containing large number of seed bean- shaped and dark brown seeds (Fig. 11b) embedded in a very light, floury pulp (Wikipedia, 2007). Most of the *Dysdercus spp* feed on the dropped open split/ bored pods on the ground rather than in the tree canopy. They mostly feed on seeds, flowers and young pods dropped on the ground. Cotton stainers cannot pierce the large globular indehiscent fruit with hard, woody shell but they feed on the seeds from the fruit that have fallen and been split open by impact or by man or baboons or damaged by other agents like termites (Pearson, 1958). There are many competing species than it is on the kapok and these include the termites, millipeds and Baobab weevils which were seen to be very aggressive in crushing the seeds of baobab thus more competitive than *Dysdercus spp* (Their feeding characteristic is like that of the larger grain borer in maize). Some stainers spend time on the trunk/ stem of the tree obviously when sufficiently fed. Species found during the survey were: *Dysdercus fasciatus* encountered throughout the year; *D. nigrofasciatus* encountered in October, November, March, April and June but *D. cardinalis* were encountered in November to January.

4.1.4 Cotton: *Gossypium hirsutum* (common name: Bourbon cotton)

Figure 12 (a): *G. hirsutum* field

Figure 12 (b): D. intermediosus on G. hirsutum

Cotton (*Gossypium hirsutum*) is a perennial shrub (herbaceous) of the family Malvaceae, usually cultivated as an annual, sub-shrub, 1- 3 m high (Fig. 12a). Fruits are spherical or ovoid with numerous pear-shaped seeds (Fig. 12b) (CAB International, 2007). During off-feeding session, Cotton stainers were found to camouflage themselves underside plant leaves. Matures and large nymphs were feeding on both open split bolls and green mature bolls while younger nymphs were mostly feeding on open split bolls on plant or dropped on ground. Occasionally they were found on squares and young bolls. Young nymphs that were feeding on the ground tended to camouflage under plant leaves and underground debris whenever disturbed. Species of *Dysdercus* encountered during the period of experimentation were: *Dysdercus fasciatus* and *D. nigrofasciatus* that were encountered on this host plant throughout the year; while *D. cardinalis* were observed on this host in October to January and May to July; *D. intermedius* were seen in March to September. *D. superstitious* were encountered in October only.

4.1.5 *Gossypium barbadense* L. (Common name: Gallini cotton)

Figure 13: *Gossypium barbadense* hosting *Dysdercus fasciatus*

Gossypium barbadense L. (Gallini cotton) is a perennial shrub of the family Malvaceae (Fig. 13). Fruits are spherical or ovoid capsule, with numerous pear-shaped seeds (CAB International, 2007). Cotton stainers were found to camouflage themselves under the plant leaves, feeding mostly on open split bolls and mature bolls, occasionally found on squares and young bolls. Mature and large nymphs tend to spend most of their time on the plant where their feed on bolls. Young nymphs feed on the seeds dropped on the ground and camouflage under plant leaves and underground debris. Species found during the survey were: *Dysdercus fasciatus* were encountered on this host plant throughout the year while *D. nigrofasciatus* were encountered in October to December and thereafter in June to September. *D. cardinalis* were observed on this host in October to January and

May to July while *D. intermedius* were seen in March to September. *D. superstitious* were encountered in November only.

4.1.6 Okra: Lady's Finger, (*Hibiscus esculentus* L. or *Abelmoschus esculentus* L. Moench)

Figure 14 (a): Okra hosting *D. nigrofasciatus*

Fig. 14 (b): Okra field (cultivated)

Okra is a stout, erect, annual herb of the family Malvaceae. Fruit a cylindrical to pyramidal capsule, green, greenish-purple or completely purple when young, brownish when mature. Its fruit contains numerous, blackish seeds (Fig. 14a and 14b) (CAB International, 2007). Cotton stainers were found to feed on mature intact or split open pods than young/ tender pods and feeding nipples are easily seen on the attacked pods. Species encountered on this host were: *D. nigrofasciatus* were encountered feeding on this host plant almost throughout the year; *D. fasciatus* seen in October to April while *D. cardinalis* were observed in this host on October to March; *D. intermedius* were seen in March and April only. *D. superstitious* were encountered on this host plant in November to February. The cotton stainers lower the quality of the fruits produced by inflicting a rusty appearance on the surface.

4.1.7: *Abutilon theophrastii* (velvet leaf):

Figure 15 (a): *D. cardinalis* on *A. theophrastii*

Figure 15 (b): *D. nigrofasciatus* on *A. theophrastii*

This is an annual plant in the family Malvaceae. Its fruit consists of a circular row of flattened seedpods (Fig. 15a and 15b). Each seedpod has greyish brown seeds (Wikipedia, 2008). In the survey, species encountered feeding on this host plant were: *D. nigrofasciatus, D. cardinalis* and *D. intermedius*.

4.1.8 *Hibiscus physaloides* Guill. & Perr.

Hibiscus physaloides is an annual herb in the family Malvaceae Fig. 16 (a and b) (Hyde and Wursten, 2008)**.** Species encountered during the survey were: *D. nigrofasciatus; D. cardinalis and D. intermedius*

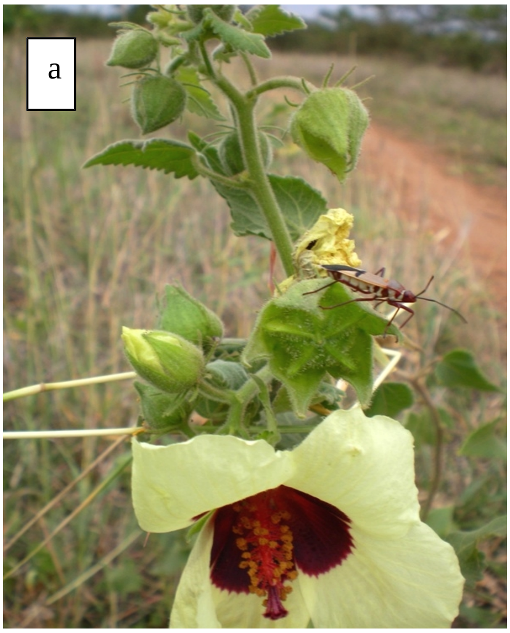

Figure 16: (a and b). ***D. cardinalis*** **on** ***H. physaloides***

4.1.9 Roselle: (*Hibiscus sabdariffa* L.)

Figure 17 (a): ***D. fasciatus*** **on** ***H. sabdariffa***

Figure 17 (b): ***D. intermediosus*** **on** ***H. sabdariffa***

The Roselle (*Hibiscus sabdariffa*) is a robust annual, erect, herbaceous plant species in the family Malvaceae (Fig. 17a and 17b) (Wikipedia, 2008). Fruit an ovoid dehiscent capsule containing blackish brown seeds (CAB International, 2007).

4.1.10 *Sida acuta* Burm. F. (Common name: Spinyhead)

Figure 18: *Sida acuta* hosting *Dysdercus* nymph

Sida acuta is a small, erect, much branched, perennial shrub or herb in the family Malvaceae (Fig. 18). The fruit is a capsule containing small seeds (PIER, 2007). Cotton stainers were found feeding on mature green fruits. Species encountered were: *D. nigrofasciatus, D. cardinalis* and *D. fasciatus* were encountered feeding on this host plant in heavy populations, particularly during October to December.

4.1.11 *Hibiscus cannabinus* "Kenaf"

Figure 19: *Hibiscus cannabinus* hosting *Dysdercus nigrofasciatus*

Hibiscus cannabinus is an annual or biennial herbaceous plant in the family Malvaceae (Fig. 19). The fruit is a capsule containing several seeds (Wikipedia, 2008). Cotton stainers were found feeding on mature intact or split open pods than young/ tender pods. Species encountered during the survey: *D. nigrofasciatus, D. cardinalis and D. intermedius* were commonly encountered feeding on this host plant particularly during April to August.

4.1.12 *Sida rhombifolia*

Figure 20: *Sida rhombifolia* hosting *Dysdercus* nymph

Sida rhombifolia (Arrowleaf Sida) is a perennial or sometimes annual plant in the family Malvaceae (Wikipedia, 2008). Cotton stainers were found to feed on mature intact green fruits than dry fruits (Fig. 20). Species encountered during the survey, especially during the months of October to December were: *D. nigrofasciatus* and occassionally *D. cardinalis* and *D. fasciatus* were encountered feeding on this host plant in high populations.

4.1.13 Banana: *Musa L.* (Musaceae: Zingiberales)

Figure 21 (a): Banana plant

Figure 21 (b): D. intermediosus on Banana finger

Banana plants are of the family Musaceae. They are the largest of all herbaceous plants. Each individual fruit (known as a banana or 'finger') has a protective outer layer (a peel or skin) with a fleshy edible inner portion (Fig. 21a and 21b). Cotton stainers were found feeding on remains of banana fingers and feeding on peels or skin. In October to December *D. intermedius* and *D. nigrofasciatus* were found feeding on these left over of banana. In January to September, *D. fasciutus* were seen several times feeding on the banana fingers and peels in the study area.

4.1.14 Jack fruits (*Artocarpus heterophyllus*):

Figure 22 (a): Jack fruit

Figure22 (b): Jack fruit sucked by Dysdercus fasciatus

Jackfruit (*Artocarpus heterophyllus*) (Fig. 22a) is a tree species of the mulberry family (Moraceae). Its fruit is the largest tree borne fruit in the world (Wikipedia, 2008). During the months of October to December, cotton stainers were found feeding on remains of the fruits of the jackfruit tree (Fig. 22b). Some of these insect pests were found under the tree wondering around while some were on the tree truck and barks resting after feeding. *Dysdercus fasciutus* were the species most commonly encountered feeding on this plant fruit remains. Others were the *D. intermedius* and *D. nigrofasciatus*.

4.1.15: Bread fruit (*Artocarpus altilis*):

Figure 23 (a): Bread fruit tree

Figure 23 (b): Bread fruit with Dysdercus spp

Breadfruit (*Artocarpus altilis*) is a tree and fruit species of the mulberry family (Moraceae). During the months of October to December, cotton stainers were found feeding on remains of the fruits of this breadfruit tree. Some of these insect pests were found under the tree wondering around while some were on the tree truck and barks resting after feeding. *Dysdercus fasciutus* were the species most commonly encountered feeding on this plant fruit remains. Other species encountered feeding on bread fruit were the *Dysdercus intermedius* and *Dysdercus nigrofasciatus.*

4.1.16 *Spondias cytherea* Sonn. –Ambarella (Anacardiaceae).

Figure 24 (a): *S. cytherea*

Figure 24 (b): *D. nigrofasciatus* on *S. cytherea* fruit

Ambarella (*Spondias cytherea*), is a fast-growing medium-sized dicotyledon tree species of the family Anacardiaceae (Fig. 24a). Fruits at maturity have a yellow to golden-orange skin (Fig. 24b) and an orangey-yellow pulp surrounding a single large spiny seed (Joyner, 2004). Many cotton stainers were found under this tree and on the tree itself, some were seen feeding on dropped rotting fruits particularly during the months of October to December. *D. intermedius* and *D. nigrofasciatus* were the species most commonly encountered feeding on this plant fruits.

4.1.17 Guava (*Psidium guajava* L.): Myrtaceae

Figure 25 (a): Guava tree

Figure25 (b): Guava fruit sucked by *D. fasciatus*

Guava is a genus of about 100 species of tropical shrubs and small trees in the myrtle family Myrtaceae (Fig. 25a). Guava fruit, is usually green before maturity, but becomes yellow, maroon, or green when ripe (Fig. 25b) (Wikipedia, 2008). Cotton stainers were found feeding on the fruit of guava. *Dysdercus fasciutus* were commonly seen feeding on these fruits particularly during the months of October to December.

4.1.18 *Carica papaya* L.

Common Names*:* papaya, papaw, fruta bomba, lechosa, melon tree

Figure 26 (a): *Carica papaya*

Figure 26 (b): *D. fasciatus* on *C. papaya* fruit remain

The papaya plant is an erect, fast-growing, usually unbranched tree (Fig. 26a) or shrub of the family Caricaceae (papaya family). Cotton stainers were encountered feeding on the *Papaya carica* left over and ripe pawpaw almost all the year around. The most commonly encountered species were *D. fasciatus* and *D. intermediosus.*

4.1.19 *Sterculia appendiculata* K.Schum. (Family: Sterculiaceae)

Figure 27 (a): *Sterculia appendiculata* trees

Figure 27(b): *Sterculia appendiculata* trees

Figure 27 (c): *S. appendiculata* seeded open split pod with *D. intermediosus*

Sterculia appendiculata is a tall tree up to 40 m. or even more. It is a tree plant species of the family Sterculiaceae (Fig. 27a) (Aluka, 2008). During the survey, cotton stainers were found feeding on seeds in open split *Sterculia appendiculata* pods. Some of these insect pests were found under the tree wondering around while some were on the tree truck and barks resting after feeding. *D. intermedius and Dysdercus fasciatus* were the species most commonly encountered feeding on this host plant especially in the months of October to April. Others were *Dysdercus nigrofasciatus* and *D. cardinalis*. The bugs were not present under sterile *S. appendiculata* trees.

4.1.20 *Tridax procumbens* L. Common names: coat buttons, tridax daisy

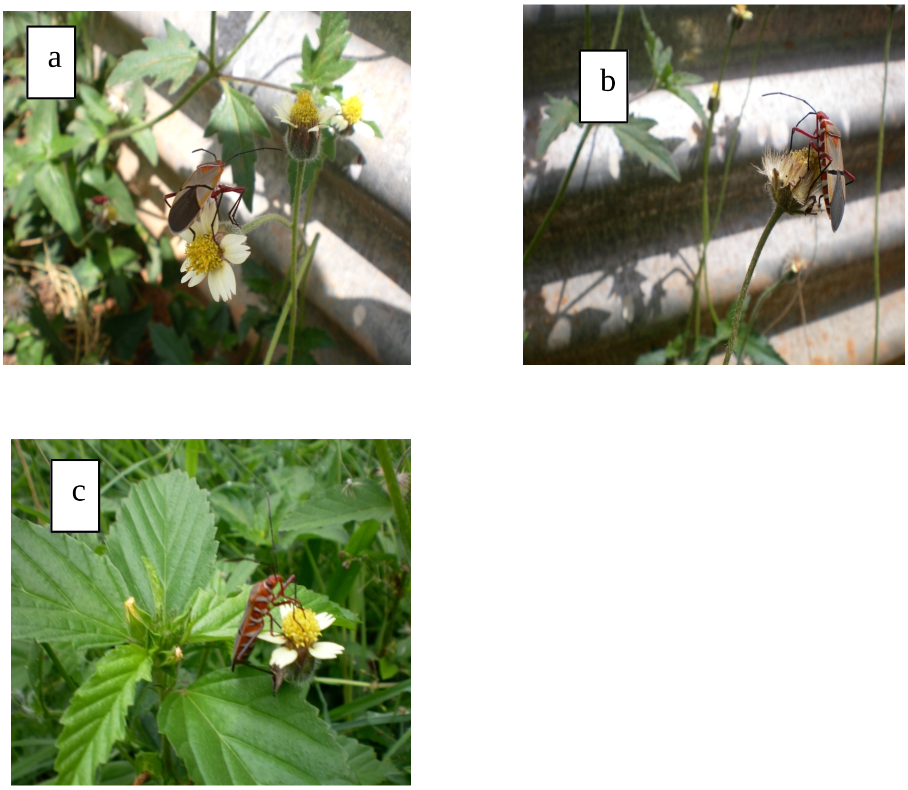

Figure 28(a, b, c): *D. intermedius* on *Tridax procumbens*

Tridax procumbens is a species of herbaceous flowering plant in the **daisy family** Asteraceae (Wikipedia, 2008). During the survey, cotton stainers were found feeding on seeds in open split *Tridax procumbens* flower head (capitulum). Some of these insect pests were found under the spreading plants of this species wondering around. *D. intermedius* were the only species that were most commonly encountered feeding on this host plant especially in months of May to December**.**

4.1.21 *Hibiscus vitifolius* L. (Family: Malvaceae)

Figure 29 (a): *Hibiscus vitifolius*

Figure29 (b): Hibiscus vitifolius and stainer

Hibiscus vitifolius is a low shrub, or scrambling herb in the family Malvaceae (Aluka, 2008). Cotton stainers were found to feed on mature intact or split open pods than young/ tender pods. They were found to camouflage themselves under the plant leaves, flowers and fruits and when in adverse condition or disturbed, in most cases they tended to drop on the ground. *Dysdercus nigrofasciatus, D. cardinalis and D. intermedius* were commonly encountered feeding on this host plant particularly during the months of April and May.

4.1.22 Sugarcane (*Saccharum officinarum*)

Figure 30 (a): Sugarcane plant

Figure 30 (b): Piece of sugarcane

Figure30 (c): Bits of sugarcane

Sugarcane is a large, perennial grass under the family Poaceae (Fig. 30a). *Dysdercus fasciatus* were found feeding on sugarcane and it's left over (Fig. 30b and 30c) particularly during the months of April to June.

4.1.23 Pineapple (*Ananas comosus*)

Figure 31 (a): Pineapple Plant

Figure31 (b): Pineapple fruit left over with *Dysdercus fasciatus* feeding on it

Pineapple is a perennial or biennial herb in the family Bromeliaceae. The flesh ranges from nearly white to yellow (Fig. 31a. and 31b.). *Dysdercus fasciatus* were found feeding on Pineapple (Fig. 31b).

4.1.24 *Ficus benjamina* (Common name: Weeping Fig)

Figure 32 (a): *Ficus benjamina* Tree

Figure32 (b): *Ficus benjamina* Seeds on which *D. intermediosus* feeds on

Ficus benjamina is a tree plant species of the family Moraceae (Fig. 32a). It bears red coloured fruits (Fig. 32b). Many *Dysdercus spp* were found under the tree feeding on red and browning dropped fruits, some were resting on the trunk / stem particularly in the months of October, November and December. *Dysdercus intermediosus* were the common species encountered feeding on this host plant (Fig. 32b).

4.1.25 *Sterculia quinqueloba* (Garcke) K. Schum Common name: Large-leaved star-Chestnut

Figure 33: *Sterculia quinqueloba*

Sterculia quinqueloba is an erect, medium-sized decidous tree species of the family Sterculiaceae (Gondwe *et al*., 2007). During the survey, cotton stainers were found feeding on seeds in open split *Sterculia quinqueloba* pods. Some of these insect pests were found under the tree wondering around while some were on the tree truck and barks resting after feeding. *Dysdercus intermediosus, D. cardinalis and D. fasciatus* were the species most commonly encountered feeding on this host plant especially in months of October to April. Others were the *D. nigrofasciatus*.

4.1.26 *Sterculia africana* (Lour.) Fiori Common name: African star-chestnut

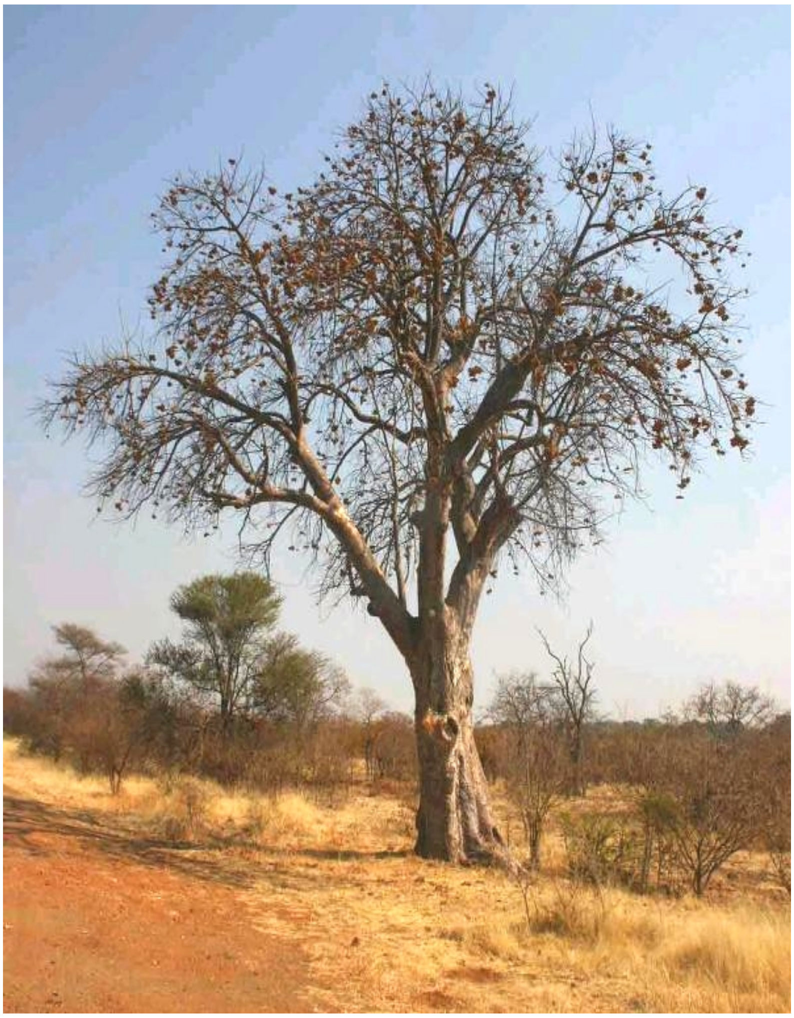

Figure 34: *Sterculia africana*

Sterculia africana is a fairly thick-stemmed, medium sized tree species of the family Sterculiaceae. Fruits contain blue-black/ blue-grey seeds (Hyde and Wursten, 2008). Cotton stainers were found feeding on seeds in open split *Sterculia africana* pods. Some of these insect pests were found under the tree wondering around and some were on the tree truck and barks resting after feeding. *Dysdercus intermedius, D. cardinalis and Dysdercus fasciatus* were the species most commonly encountered feeding on this host plant particularly in the months of October to April. Other species found feeding on the host plant were *D. nigrofasciatus*.

4.1.27 *Hibiscus panduriformis* Burm. F.

Figure 35: *Hibiscus panduriformis.*

Hibiscus panduriformis is a shrub-like perennial herb under the family Malvaceae. *Dysdercus nigrofasciatus*, *D. cardinalis* and *D. intermedius* were commonly encountered feeding on this host plant particularly during the months of April and May.

4.1.28 *Sida serratifolia* Wilczek & Steyaert

Figure 36: *Sida serratifolia*

Sida serratifolia is a suffrutex or shrub (herbaceous) plant species under the family Malvaceae. *Dysdercus fasciatus* were commonly encountered feeding on this host plant particularly during the month of December.

4.1.29 *Hibiscus calyphyllus* Cav.

Common names: hibiscus, sun hibiscus, lemon-yellow rosemallow (Eng.);

Figure 37: *Hibiscus calyphyllus*

Hibiscus calyphyllus is a dense herbaceous, perennial plant species under the family Malvaceae (Fig. 37) (Le Roux, 2008). *Dysdercus nigrofasciatus and D. cardinalis* were commonly encountered feeding on this host plant particularly during the months of April and May.

4.1.30 *Zea mays* L. Common names- English: maize, Indian corn, corn

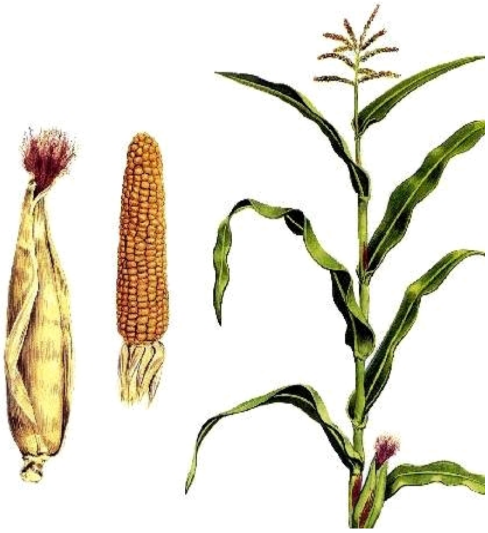

Figure 38 (a): Maize Plant

Figure 38 (b): *Dysdercus spp* feed on maize seed

Maize plant is a robust, monoecious, annual grass of the family Poaceae (Fig. 38a). *D. superstitious* and *D. nigrofasciatus* together with some nymphs were encountered feeding on the seed of this host plant, and this was during the month of December (Fig. 38b).

4.1.31 *Bidens pilosa* L.

Figure 39: Bidens pilosa with *D. intermediosus*

Bidens pilosa is an erect annual herbaceous plant species under the family Asteraceae. During the survey, cotton stainers were found feeding on seeds in open split *Bidens pilosa* flower heads (capitulums). Some of these insect pests were found under the spreading plants of this species wondering around. *D. intermedius* were the only species that was most commonly encountered feeding on this host plant especially in months of May to December (Fig. 39).

4.1.32 Unusual hosts /feedstuff

1. *Dysdercus spp* feed on remains of bun or doughnut, bread and the like e.g. *D. fasciatus* (Fig. 40a. and 40b).

Figure 40 (a): Cotton stainer on bun or doughnut

Figure 40 (b): Cotton stainer on bread

2. *Dysdercus spp* feed on remains of animal meat both fatty and muscular tissues, so dead wild and domestic animal remains can also support the life of stainers e.g *D. fasciatus* (Fig. 41a. and 41b).

Figure 41 (a): Stainer on muscular tissues.

Figure 41 (b): Stainer feeding on vertebrate fatty tissues.

3. Vices cannibalism: Cotton stainers (*Dysdercus spp*) have a habit to feed on their fellows that happen to be weak, dying and dead. Under such circumstances only the fittest do survive (Fig. 42a and 42b).

Figure 42 (a): Vices cannibalism

Figure 42 (b): Vices cannibalism

4.2 Population Dynamics of Cotton Stainers

4.2.1 Population dynamics of cotton stainers on cultivated cotton (bourbon cotton) (*Gossypium hirsutum*)

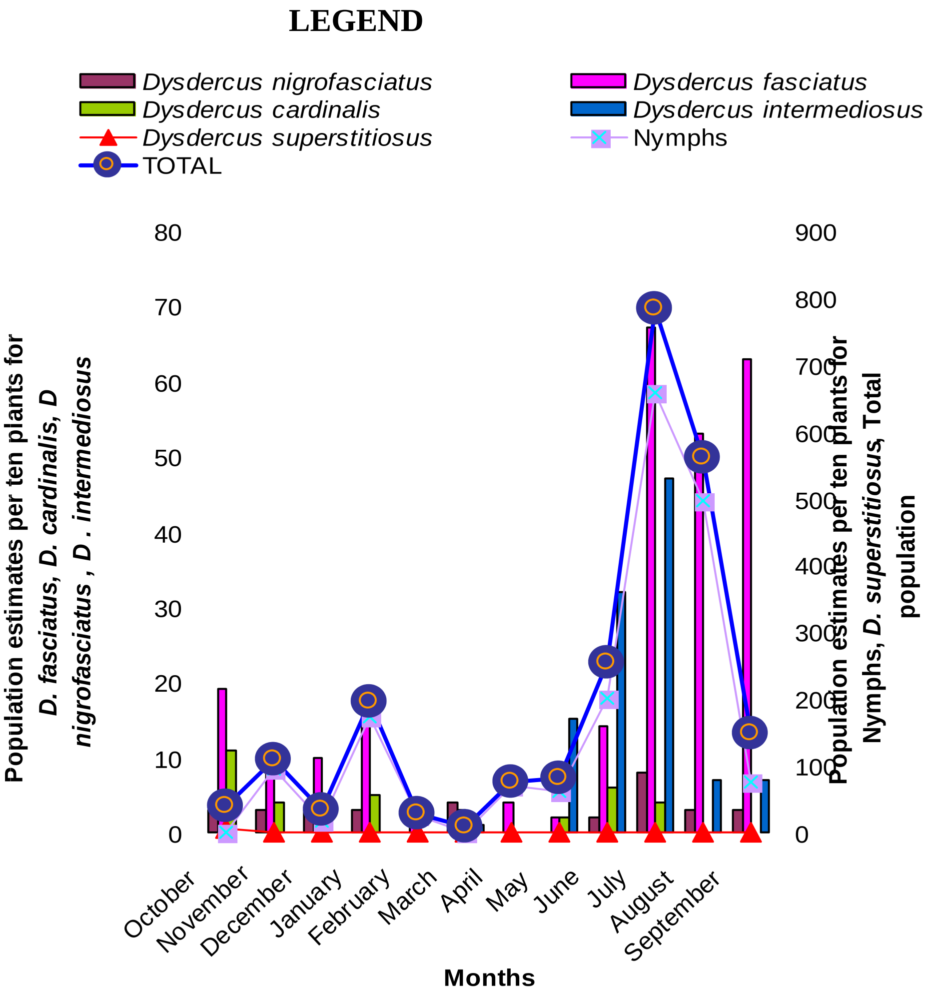

Figure 43: Population dynamics of cotton stainers on cultivated cotton (bourbon cotton) (*Gossypium hirsutum*)

Five African *Dysdercus* species, namely *D. fasciatus, D. nigrofasciatus, D. cardinalis, D. intermedius and D. superstitious,* were all encountered feeding on *Gossypium hisutum* at varying population levels at different periods of the year as seen from Fig. 43. Although nymphs were hardly seen during the month of October, their population tended to be higher than that of adults in almost all the other months. Generally, the total population of *Dysdercus spp* was fluctuating or tended to remain more or less constant over month(s). The highest population count on this host plant was observed in July and the lowest in March. Fluctuation patterns of the individual species varied greatly. Wolda (1992) stated that actual fluctuation patterns vary greatly between species suggesting the absence of some dominant environmental process affecting several species at the same time. The period from October to January is known to be off season in Kilosa whereby planting starts in February, thus the cotton plants that were not uprooted (for the sake of experiment) suffered from more or less stable cotton stainers attack up to the month April. The sprouted and newly planted cotton fields had their newly formed bolls approaching maturity. Clifford and Dawn (2006) observed that fluctuations in insect abundance appear to relate firstly to climatic factors such as length and severity of the dry season or amount and period of rainfall, and secondly to food availability such as an increase in the production of new leaves, flowers and fruiting periodicity.

However, during the month of May the population of *Dysdercus spp* tended to increase. This is the period when cotton stainers that were dispersing from alternative host plants started to invade the sprouted and newly planted cotton fields, which up to this period had maturing bolls. Fig. 44 shows two mature *D. intermediosus,* one mature *D. fasciatus* and many *D. intermediosus* nymphs, demonstrating that the level of infestation in cotton fields by *D. intermediosus* was higher than other species of cotton stainers as per May observation. The population of *Dysdercus intermediosus* was the highest in May because they were the first species to invade the cotton field in large numbers. Their infestation on cotton is demonstrated in Fig. 44. They breed and produce their progeny in later days such that, the June population of nymphs was largely composed of the *D. intermediosus* instars and the total population of cotton stainers kept on increasing as the number of nymphs equally increased.

Figure 44: Nymphs and two matures of *D. intermediosus* with one mature *D. fasciatus*

In July, *Dydercus fasciatus* gradually increased to large numbers than the other species. Fig. 45 shows many nymphs all of them being of *D. fasciatus* species as per July and August observations. *Dysdercus fasciatus* had the highest population in the field compared to the other species after July.

Figure 45: *D. fasciatus* nymphs in cotton field

In Fig. 43, it was observed that a decrease in population of *D. intermediosus* after July was due to the dispersion from the cotton fields to other alternative plant species like *Hibiscus micranthus* (Appendix 4), leaving domination of *D. fasciatus***.** The other three species, consistently maintained low populations in the field. Based on their individual occurrences, *D. cadinalis* and *D. nigrofasciatus* populations were almost in equal proportions. *Dysdercus cardinalis* tended to show a certain level of dominance over *D. nigrofasciatus. Dysdercus superstitious* had the least population count and was encountered in *G. hirsutum* field only during the month of October (Appendix 1). Tengecho and Khaemba (1998) reported that diet change in the cotton stainers, e.g *Dysdercus cardinalis* and *D. fasciatus*, as a result of their migration from cotton to alternate hosts, e.g *Sterculia spp* and *Adansonia digitata* was generally beneficial to their bionomics. Since insect damage is a function of insect population size, this study suggests that, currently *Dysdercus fasciatus* and *D. intermediosus* are the two major pest species in cotton as they tended to dominate the other species in different months while the other three namely; *D. nigrofasciatus, D. cardinalis* and *D. superstitiosus* are merely minor pest species as they tended to occur in lowest numbers (Fig. 43).

According to Pearson (1958), *D. intermediosus* are specialist migrants, and that, the adults of *D. intermediosus* have a very strong tendency to disperse from their breeding ground after their final moult, and this prevents the production of a large population in one site. They dispersed from cotton field at the end of cotton growing season while there was still enough food, leaving the resource for *D. fasciatus* after co-existing together in the same ecological niche for just a few months, a trend which seemed to be more or less similar to ecological segregation (Fig. 43). Similar tendency of dispersion was described by Dingle (1996). Kasule (1985) and Derr *et al.* (1981) reported that *D. intermediosus* specializes more on arboreal host plants than on herbaceous ones and is the largest sized of all five species mentioned above. Dingle (1996) described 'migrations' as changes of habitat, periodically recurring and alternating in direction, which tend to secure optimal environmental conditions at all times. The large species are restricted to arboreal resources by the requirement for oil-rich seeds in order to grow large, and will not break diapauses until food is in sufficient quantity (Derr *et al.*, 1981).

4.2.2 Population dynamics of cotton stainers on Gallini cotton (*Gossypium barbadense*)

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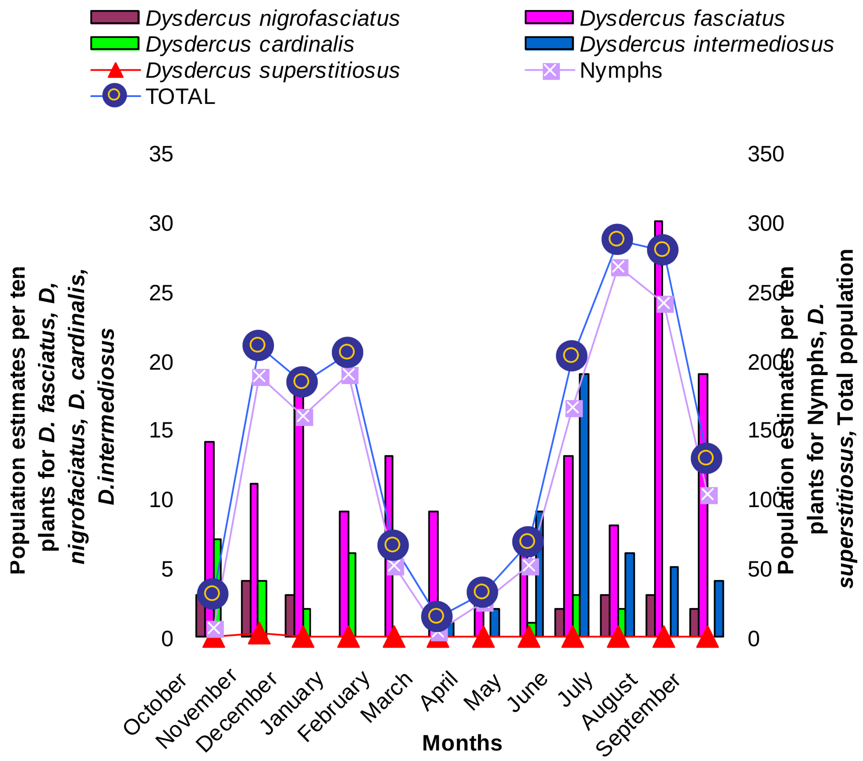

Figure 46: Population dynamics of stainers on gallini cotton (*Gossypium barbadense*)

Gallini cotton *(Gossypium barbadense)* is not cultivated by farmers in Kilosa District but rather was found grown by Ilonga Agricultural Research Institute for research purposes.

The plants served for the bugs' population estimates study in which case, five *Dysdercus spp* namely *D. fasciatus, D. nigrofasciatus, D. cardinalis, D. intermedius and D. superstitious,* were all encountered feeding on *Gossypium barbadense* at varying population levels during different periods of the year (Fig. 46). Nymphal population tended to be higher than that of adults in almost each month. Total population of *Dysdercus spp* was fluctuating or tended to remain more or less constant over month(s). Highest population of stainers was observed in July and August while the lowest population occurred in March. These results support the findings by Sengbusch (2008) that a population can never grow indefinitely, because no indefinite amounts of nutriments, energy, and habitat exist. The highest population count of the *Dysdercus spp* on this host plant was observed in July while the lowest count was in March. Individual species showed fluctuating patterns over month(s). *D. fasciatus* had the highest total mature individuals hence the dominant mature species throughout the year followed by the *D. intermedius. Dysdercus nigrofasciatus, D. cardinalis* and *D. superstitious* contributed a relatively small proportion of individuals in the total population. On monthly basis, individual populations fluctuated such that other species also dominated, especially *D. intermedius,* which showed dominance in June before *D. fasciatus* again took the lead in population level. *D. cardinalis* showed a certain level of dominance over *D. nigrofasciatus* while *Dysdercus superstitious* had the least population count and was encountered in *G. barbadense* field only during November. Fluctuations of populations of the individual species varied greatly and this conforms again to explanation by Wolda (1992). From the current study, *D. fasciatus* and *D. intermediosus* were the major pest species for this host plant species. The other species were regarded as minor pests.

4.2.3 Population dynamics of cotton stainers on Okra (*Abelmoschus esculentus*).

In Fig. 47, *D. fasciatus*, *D. nigrofasciatus*, *D. cardinalis*, *D. intermedius* and *D. superstitious* were sampled on the Okra, but population levels varied. *Dysdercus nigrofasciatus* had the highest population size of all species on okra. *D. cardinalis* population dominated only in January and May, while *D. nigrofasciatus* remained dominant for the rest of the year. The lowest population count was observed in October. Wallner (1987) reported that populations of organisms are never truly stable, but rise

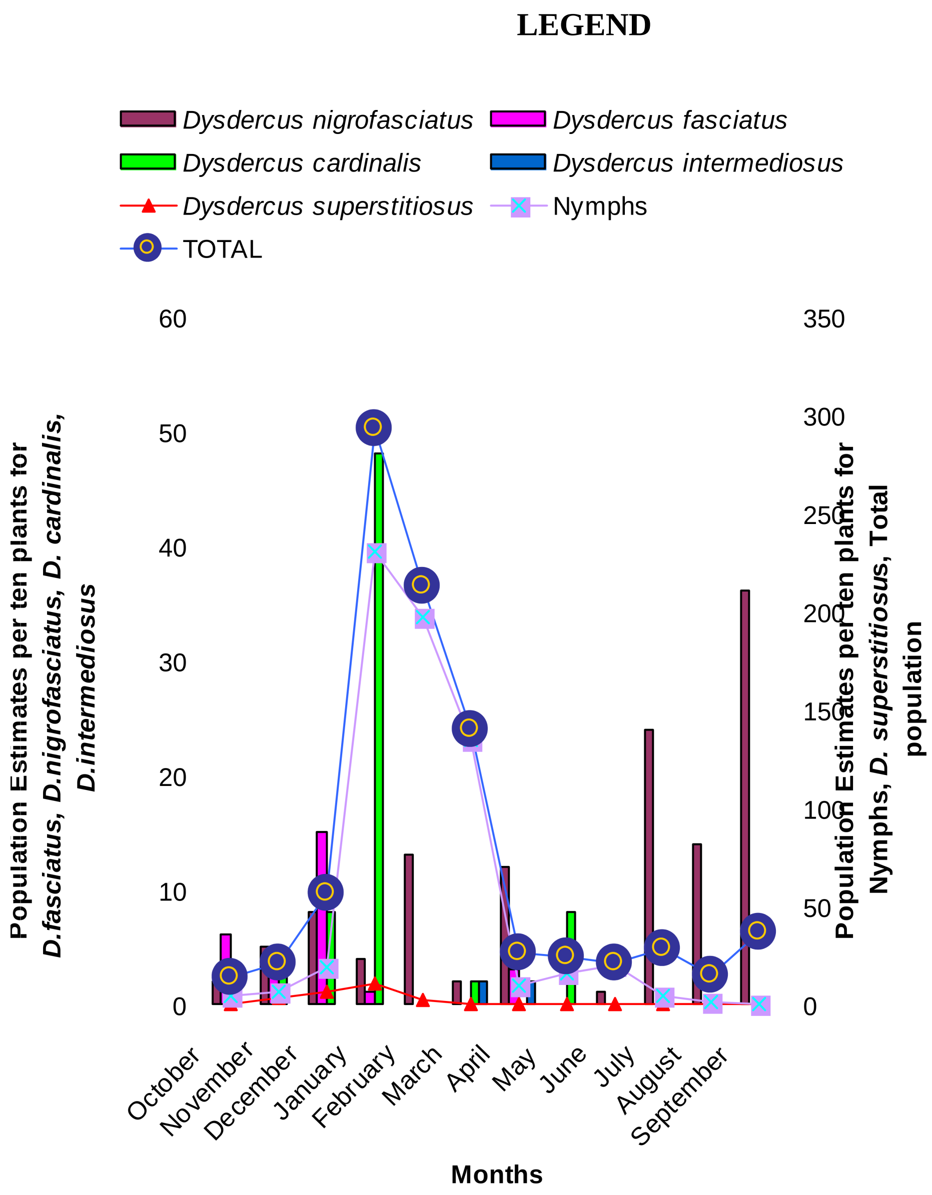

Figure 47: Population dynamics of cotton stainers on okra (*Abelmoschus esculentus*)

from some low density and then fall to approximately original size. They may exhibit stable equilibrium points, stable cyclic oscillations between two population points, stable cycles or a regime of aperiodicity. According to Pearson (1958), the fluctuations in numbers of the population of the dominating species, *D. nigrofasciatus*, on host plants are controlled by conditions acting indirectly, through their effect on the fruiting and eco-climate of the host plants, and directly, largely as a temperature-effect controlling breeding. Nymphal population remains almost consistently higher than that of the mature individuals. It is on this host plant where the rare *D. superstitious* was observed for four consecutive months, November to February. The findings from this study indicate that, although the two dominant species on this host plant are herein both considered as minor pest species of cotton and that the peak population of the bugs on the host plant occurs far away from cotton boll maturity period, still the host plant should not be overlooked in planning the control of *Dysdercus spp* through their host plants simply because even the smaller populations of *D. fasciatus* and *D. intermediosus* recorded on this host plant may disperse from *Abelmoschus esculentus* and invade and reproduce explosively in cotton fields. *Abelmoschus esculentus* is a cultivated herbaceous plant in Kilosa, thus the dominance of *D. nigrofasciatus* followed by *D. cardinalis* supports the findings by Kasule (1985) and Pearson (1958) that the two species are associated more with herbaceous than with arboreal host plants, though *D. nigrofasciatus* generally has a relatively wider host range and smaller body size than the *D. cardinalis,* and actually the smallest of all the five African cotton stainers.

4.2.4 Population dynamics of cotton stainers on *Hibiscus micranthus*

This host plant had no *Dysdercus spp* during October most probably because it had no fruits to support feeding after an excessive dry spell that left the plants with only a few leaves per plant while others completely dried. *D. cardinalis* showed dominance over all other species. *D. cardinalis* dominated in the population from December to June while *D. nigrofasciatus* dominated only in November and July. *Dysdercus fasciatus* dominance occurred in April and September, leaving *D. intermediosus* dominating only in August. Fluctuations in numbers of the individual species varied greatly. Communities are shaped by the interactions among species and among individuals, as well as interactions between the organisms and the environment (Ferry-Graham *et al*., 2002). It is the nature

of these interactions that ultimately leads to differences among species and separates

Legend

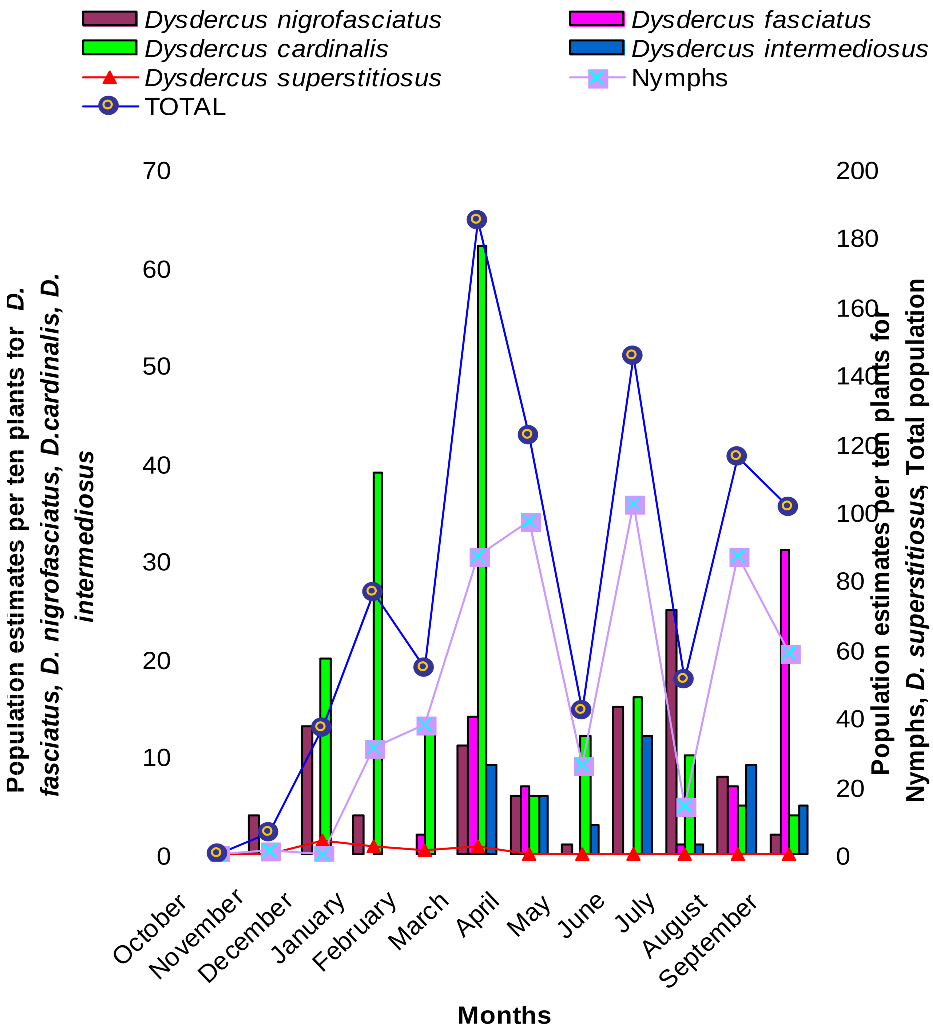

Figure 48: Population dynamics of cotton stainers on *Hibiscus micranthus*

them in both space and time, thus allowing them to coexist. Based on species counts, *D. nigrofasciatus* was the second dominant species on this host plant followed by *D. fasciatus* while *D. intermedius* was the fourth one leaving *D. superstitious* as the least dominant. On this host plant the rare *D. superstitious* was observed for four consecutive months (December to March only). With the nymphal population being higher than that of the matures, the total count of cotton stainers on this host plant fluctuated over month(s). The highest population was observed in March while the lowest population count was observed in October (Fig. 48). The total population of cotton stainers fluctuated and exhibited four major peaks, indicating that in a year the plant species is able to supply the bugs with sufficient nutrition in four different sessions thereby maintaining the potential sources of cotton stainers for invasion later when cotton bolls are mature in fields. This study further suggests that the host plant be considered as a dangerous species for the cotton Industry as it tends to keep a large population of cotton stainers in March, when newly planted cotton actually has bolls starting to mature. This plant species contributes a reasonable proportion of invasive cotton stainers to cotton fields.

4.2.5 Population dynamics of cotton stainers on silk cotton tree (*Ceiba pentandra*)

In Fig. 49, among the five species of *Dysdercus*, *D. superstitious* was not encountered feeding on *Ceiba pentandra*. However the other four species namely, *D. fasciatus, D. nigrofasciatus, D. cardinalis, D. intermediosus* were encountered feeding on this host plant. The tree hosted more *D. fasciatus* than the other species. The second dominant species was *D. nigrofasciatus* while *D. cardinalis* ranked third and *D. intermediosus* ranked fourth in population counts on *C. pentandra*. The highest population estimate on *C. pentandra* occurred in April while the lowest count was in October**.** According to

Froeschner (2007), in tropical regions, where heteropterans are most abundant, populations are influenced by factors such as rainfall, host plant development, and internal rhythms. The period of highest population of bugs on *Ceiba pentandra* (April to May) almost synchronized with the period of cotton boll maturity in fields. The current study suggests that *C. pentandra* carries a large number of *D. fasciatus* that disperse to invade cotton fields and thus, it coul be consindered one of the most serious pest species for the cotton industry. *Ceiba pentandra* being an arboreal type of host plant, tend to supply the bugs with food sources for a relatively longer period than herbaceous plants, making it possible for more than one generation of the bugs to be hosted by the tree in a year.

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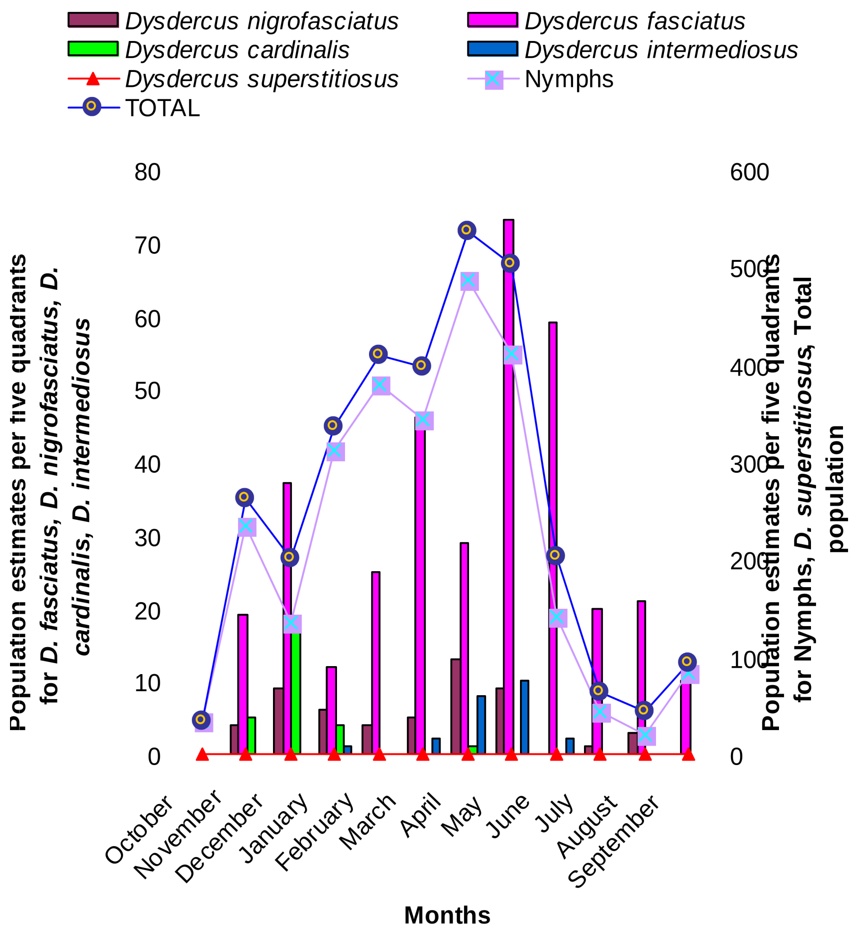

Figure 49: Population dynamics of cotton stainers on silk cotton tree (*Ceiba pentandra*)

4.2.6 Population dynamics of cotton stainers on baobab (*Adansonia digitata*)

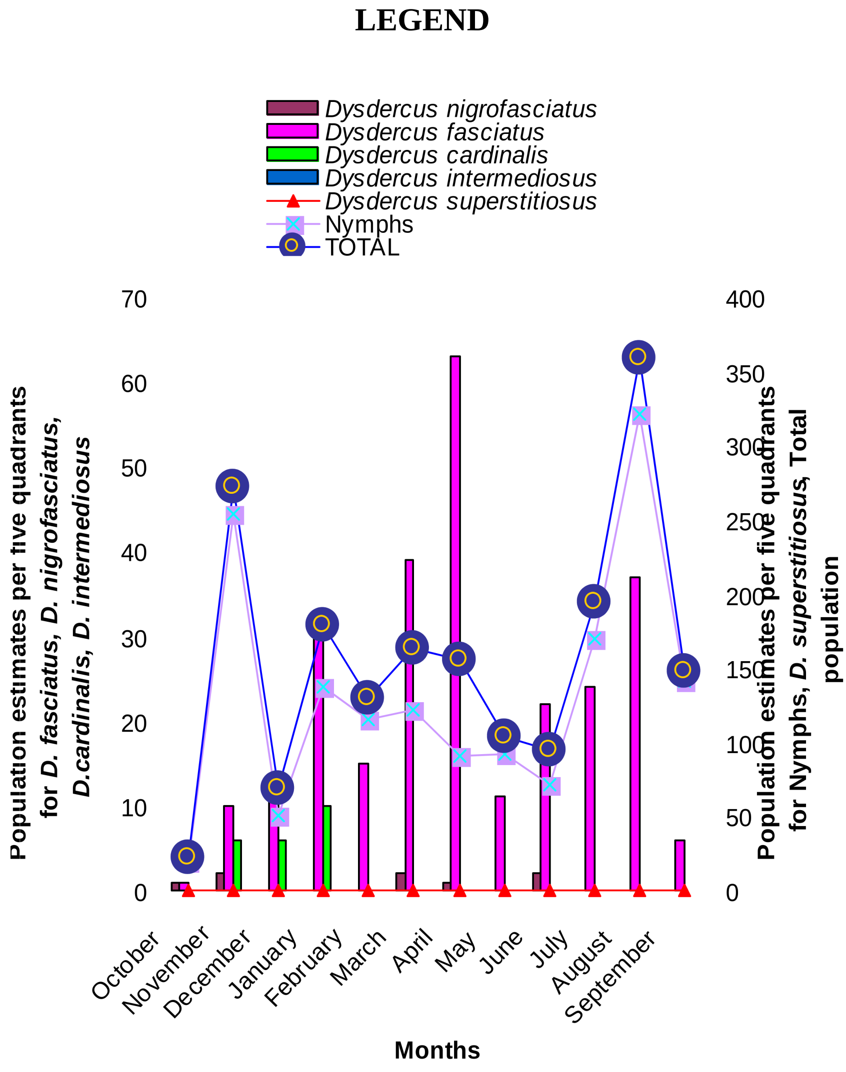

Figure 50: Population dynamics of cotton stainers on baobab (*Adansonia digitata*)

From Fig. 50, only three species namely *D. fasciatus*; *D. nigrofasciatus D. cardinalis* were encountered feeding on *Adansonia digitata* while the other two species (*D. superstitious* and *D. intermedius*) were not seen on this host plant during the study. *D. fasciatus* were the dominant species. The second more dominant species on this host plant was *D. cardinalis.* The highest nymphal population on this tree host plant occurred in August while the lowest count was in December. The highest population of adults was observed in April. According to Pearson (1958), all host plants are invaded by stainers as flying adults. The highest population of mature cotton stainers on *Adansonia digitata* occurred in April which almost synchronized with the period of cotton boll maturity in the fields. *Adansonia digitata* hosted more *D. fasciatus* than the other species.

4.3 Development and Survival of Cotton Stainers on Different Host Plants

Some developmental parameters that were recorded during the experiments in an insectary enabled observations on the effects of six host plants on *Dysdercus fasciatus. Gossypium hirsutum* (Bourbon cotton*), G. barbadense* (Gallini cotton), *Ceiba pentandra* (Kapok/silk cotton), *Abelmoschus esculentus* (Okra), *Adansonia digitata* (Baobab*)* and *Hibiscus micranthus* were selected among the plant hosts identified in Kilosa district for the laboratory rearing experiment. Their respective seeds were used as treatments in this experiment and the obtained results of the effects of feeding *D. fasciatus* with the seeds of the individual host plants are herein discussed.

4.3.1 Development of *D. fasciatus* during first instars stage

The results show that the mean duration taken by *D. fasciatus* to complete the first instars when supplied with the six different host plants to feed on, was not significantly different ($P > 0.05$) (Table 1a). The first instars are usually found congregating near the egg shells after emergence and spend much time underground ingesting bacteria which the female deposited on the eggs. This first instars behaviour was also reported by Mrosso *et al*. (2006) and Wilson *et al.* (2008).

4.3.2 Development of *D. fasciatus* during second instars stage

The durations of development of the second instars were not significantly different ($P>0.05$) (Table 1a), indicating that the effects of the six host plants on the second instars development were the same. A time lag that occurred before observing the effect of the different host plants, during the second instars, was expected because it is during this stage when the bugs just started to have their first feeding.

Table 1 (a): Mean durations of different nymphal development stages of *Dysdercus fasciatus*

Host plants	Developmental stages					
	First instars duration (days)	**Second instars duration (days**	**Third instars duration (days)**	**Fourth instars duration (days)**	**Fifth instars duration (days)**	**Total instars duration (days)**
H. micranthus	3.000a	8.0000a	6.3333b	7.000b	10.000b	34.333c
G. barbadense	3.000a	8.3333a	6.3333b	7.333b	10.667b	35.667c
G. hirsutum	3.000a	8.3333a	7.3333b	7.667b	11.333b	37.667bc
C. pentandra	3.000a	9.6667a	7.6667b	8.667b	11.667b	40.667b
A. digitata	3.000a	8.3333a	7.6667b	8.667b	12.000ab	40.000b
A. esculentus	3.000a	9.6667a	10.6667a	17.667a	16.667a	57.667a
C.V	0.000	12.8467	9.22313	20.7878	13.6859	3.69896
General mean	3.000	8.72222	7.66667	9.5000	12.0556	41.0000
LSD	0.000	3.1777	2.0053	5.6006	4.6791	4.3009
Pr > F	-	0.3310 NS	0.0002 ***	0.0005***	0.0072**	<0.0001***

Means with the same letter(s) in the same column are not significantly different at P ≤ 0.05 using Tukey's Studentized Range test.

NS = Not significant; (*) = Significant at 5%; (**) = Significant at 1% (very significant); (***) = Significant at 0.1% (highly significant)

4.3.3 Development of *D. fasciatus* during third instars stage

For the third instars, there were statistically significant differences (P< 0.001) in the developmental period (Table 1a). The host plants influenced the third instars development (duration in days) differently. The highly ranked *Abelmoschus esculentus* differed from all other hosts in a sense that it delayed the completion of the third instars for more days as compared to the other host plants. *Ceiba pentandra* and *Adansonia digitata* with very hard woody testa for the nymphs to penetrate their stylets (Pearson, 1958) also delayed the development although the bugs completed the third instars stage earlier than on *Abelmoschus esculentus*. The results suggest that, *Hibiscus micranthus* and *G. barbadense* are favourable diets influencing the bugs to complete the third instars stage earlier followed by *Gossypium hirsutum.* According to Wilson *et al*. (2008), once the third instars is reached the bugs are able to commence feeding on even the developing seeds within the bolls of cotton, something they hardly performed in earlier instars, implying that their capability in sucking from their hosts is more enhanced than in the former instars. This gives sufficient room for the diets to play their different roles in insect development. According to Pearson (1958), the state of development of the seeds and the nature of the host plants have marked effect upon the rate of development of the nymphs and fertility and fecundity of the resulting adults.

4.3.4 Development of *D. fasciatus* during fourth instars stage

Highly significant differences (P< 0.001) in mean duration of development were noted in this study. This indicates that, host plants again influenced the fourth instars development (duration in days) differently. The longest period taken to complete the fourth instars was on *Abelmoschus esculentus* seeds (Table 1a). Although ranked in the same order, *Ceiba pentandra* and *Adansonia digitata* also delayed development for one day compaired to the durations taken by bugs which were reared on *Gossypium hirsutum* or *G. barbadense*. The results revealed that, *Hibiscus micranthus* was the favourable diet for the fourth instars since it took fewer days to complete the stage. Prolonged developmental stage by some bugs raised on particular host plants is partly due to nutritional inadequacy of those host plants (Njau, 1984).

4.3.5 Development of *D. fasciatus* during fifth instars stage

Mean durations taken by fifth instars were significantly different (P< 0.01) for different host plants. They ranged from 10 to 16.667 days (Table 1a). *Hibiscus micranthus* remained superior to all other host species for it took the bugs the minimum number of days to complete fifth instars stage followed by *G. barbadense*, while *Abelmoschus esculentus* remained the poorest food source responsible for delaying the instars development. The results show that, bugs raised on *Gossypium hirsutum* and those kept on *Ceiba pentandra* had intermediate fifth instars duration.

4.3.6 Development of *D. fasciatus* during total nymphal stadia

The duration of total nymphal stadia of *D. fasciatus* when reared on seeds of six plant species differed highly significantly among the six food species provided (P< 0.001) (Table 1a). The duration taken to complete the nymphal stage was longest when fed on *Abelmoschus esculentus* and long when fed on *Ceiba pentandra* as well as on *Adansonia digitata*. However, bugs raised on *Hibiscus micranthus* took very short duration to complete the nymphal stadia while those kept on *G. barbadense* took short duration, and intermediate when kept on *G. hirsutum.* Means for the duration taken by *D. fasciatus* to develop through nymphal stage ranged from 34.3 to 57.6 days (Table 1a). Results presented here concur with other similar studies by Kohno and Ngan (2005), who reported that differences in diets affected the development of *Dysdercus cingulatus.* Results presented in this study also show that the minimum days taken by the bugs to complete successive nymphal stages were 3, 8, 6, 7 and 10 days for the First, Second, Third, Fourth and Fifth instars respectively. The study further supports the findings by Mead and Fasulo (2005) that the last instars takes longer duration than the rest of the instars. In this study, however, only bugs fed on *Hibiscus micranthus, G. barbadense, Gossypium hirsutum, Adansonia digitata* and *Ceiba pentandra* conformed to the range reported by Mead and Fasulo (2005) that all the five nymphal stages require from 21-41days before reaching the adult stage. *Dysdercus fasciatus* that were raised on *Abelmoschus esculentus* were out of the range of days stated above as it took them an average of 57 days before reaching the maturity stage. Despite the longest duration taken by the bugs raised on *Abelmoschus esculentus* to accomplish nymphal stages, however, it suffices to report here that they also consistently had extra ordinary smaller bodies in all stages compared to bodies of the bugs raised on the other food sources. This was especially observed during their third instars to fifth instars and the resultant adults. This study suggests that, during nymphal stages, *Hibiscus micranthus* and *G. barbadense* can be regarded as better than adequate host plants in influencing earlier completion of total nymphal stage development while *G. hirsutum* is just adequate. *Adansonia digitata* and *Ceiba pentandra* can be regarded as relatively poor, while *Abelmoschus esculentus* be regarded as nutritionally very poor diet for nymphal stadia development (Table 1a).

4.3.7 Development of *D. fasciatus* during maturity stage

Results of the laboratory rearing experiment show that the differences in the mean durations taken by *D. fasciatus* to maturity stage (herein considered as the period from the last moult to death) were highly significant (P< 0.0001) between host plants (Table 1b). The means durations ranged from 29.67 to 120.67 days for the individuals to live as mature stainer (Table 1b). The longest maturity period was observed in bugs reared on *G. barbadense* followed by those reared on *Adansonia digitata* and *G. hirsutum.* The shortest duration was observed on bugs reared on *Hibiscus micranthus*. This study indicates that nutrition had significant influence on *D. fasciatus* even after their final moult. The results support the finding of Pearson (1958) who reported that, after the final moult, nutrition continues to play an important part in *Dysdercus spp* development.

4.3.8 Development of *D. fasciatus* during pre-mating period

The significant differences in mean of durations before maturity taken by *D. fasciatus* after their final moult (P < 0.05) indicate that, nutritional qualities of different host plants

Table 1 (b): Mean durations for developmental stages of *Dysdercus fasciatus* during maturation

	Developmental stages						
	Maturity	Pre-	Pre-	Generation	Female	Male	Average

Host plants	duration (days)	mating duration (days)	ovipositio n duration (days)	period (days)	longevity (days)	longevity (days)	Number of Nymph s Per Female Per clutch
H. micranthus	56.00b	6.000b	11.333a	59.667b	78.000c	90.33b	64.333c
G. barbadense	120.67a	4.333b	8.000a	56.000b	96.333ab	156.33a	103.33a
G. hirsutum	118.33a	3.667b	8.000a	57.333b	110.667a	156.00a	102.00a
C. pentandra	94.67a	3.667b	6.667a	59.000b	103.67ab	135.33a	104.67a
A. digitata	119.00a	2.333b	9.667a	60.667b	89.333bc	159.00a	80.000b
A. esculentus	29.67b	10.67a	10.000a	87.000a	80.333c	87.33b	22.000d
C.V	14.20	31.48	24.38	3.182	5.621	9.585	6.723
General mean	89.722	5.1111	8.9444	63.278	93.056	130.72	79.389
LSD	36.135	4.5631	6.1844	5.7112	14.833	35.533	15.137
Pr > F	< 0.0001***	0.0011**	0.1993 NS	< .0001***	< 0.0001***	<0.0001 ***	< 0.0001 ***

Means with the same letter(s) in the same column are not significantly different at P ≤ 0.05 using Tukey's Studentized Range test.

NS = Not significant; (*) = Significant at 5%; (**) = Significant at 1% (very significant); (***) = Significant at 0.1% (highly significant)

have effect on pre-mating period. The durations ranged from 2.333 to 10.667 days. The shortest duration was observed in bugs kept on *Adansonia digitata* while those kept on *G. hirsutum, Ceiba pentandra and G. barbadense* had shorter durations. An intermediate duration was observed in bugs raised on *Hibiscus micranthus* but it took the longest duration before mating for the bugs kept on *Abelmoschus esculentus*. Njau (1984) reported that during moulting there is loss of weight of the moulted bugs caused by the loss of the old cuticle through ecdysis and partially due to water efflux through the unsclerotised newly formed cuticle. Sufficient quality nutrition is needed for the bug to re-gain sufficient weight and energy necessary for mating (Njau, 1984). Watanabe (2001) reported that some insect species are capable of mating soon after emergence as adults, the pre- mating period being non-existent. In other species there is a period during which the just emerged females are not sexually receptive, becoming so only when they begin to produce sexual pheromone to attract males. It suffices to mention that female of *Dysdercus spp* were observed to be one example in which pre-mating period normally exists.

4.3.9 Development of *D. fasciatus* during pre- oviposition period

Statistically, means for pre- oviposition periods, herein defined as the duration taken by the female bugs from first mating to first oviposition (Watanabe, 2001), were not significantly different (P > 0.05). The mean durations ranged from 6.667 to 11.333 days, indicating how relatively better were *Ceiba pentandra*, *G. hirsutum* and *G. barbadense* than the other food sources. *Ceiba pentandra* fed *D. fasciatus* oviposited relatively earlier than *Hibiscus micranthus* fed individuals. Njau (1984) reported that development of the oocytes took place only when there was adequate provision of nutrients to female *Dysdercus nigrofasciatus.* During his study, he added more that, even inter-ovipostion periods were influenced by the quality and quantity of food supplied to *D. nigrofasciatus.*

4.3.10 Generation time of *D. fasciatus*

Generation period as applied by Tang (1999) and defined by Weeden *et al*. (2000), is herein considered as the duration taken from day old nymphs (cohort generation) to occurrence of their immature (progeny of the cohort generation). The generation periods were highly significantly different (P< 0.001) when *D. fasciatus* were reared on different six host plant food sources mentioned earlier. The durations ranged from 56 to 87 days (Table 1b), indicating that day old nymphs grew and became mature to reproduce their own young in the shortest duration when raised on *G .barbadense* and longest duration when kept on *Abelmoschus esculentus*. The generation period for the bugs when reared on *G. hirsutum* was short while an intermediate duration was observed in bugs kept on

Ceiba pentandra or *Hibiscus micranthus*. Generation period on bugs raised on *Adansonia digitata* was relatively long. This has an implication on the number of generations to be produced per year. More generations will be expected when generation period of the individual raised on a given source of food is shorter.

4.3.11 Longevity of female *D. fasciatus*

The six host plants species had a highly significant (P < 0.001) effect on the longevity of female *D. fasciatus*. Among the six host plants, the survival duration by females of *D. fasciatus* ranged from 78 to 110 days (Table 1b). *Gossypium hirsutum* was the best host plant since female had longer longevity than on other food plants, followed by *Ceiba pentandra* on which the breeding (mating) individuals were initially collected. *G. barbadense* ranked third as best host plant leaving *Adansonia digitata* in fourth position. *Abelmoschus esculentus* and *Hibiscus micranthus* were the least favourable since individual females died in few hours to few days after the first oviposition. There was no second batch of eggs that was laid by females kept on *Abelmoschus esculentus* and *Hibiscus micranthus.*

4.3.12 Longevity of male *D. fasciatus*

The six host plants species had a highly significant (P < 0.001) effect on the longevity of male *D. fasciatus* (Table 1b). Males lived the longest duration when kept on *Adansonia digitata* and the shortest duration when raised on *Abelmoschus esculentus*. They lived longer when raised on *G. barbadense* and *G. hirsutum* as well as on *Ceiba pentandra*. Life of male *D. fasciatus* was shortened when raised on *Hibiscus micranthus*. The results support the finding of Pearson (1958) who reported that, after the final moult, nutrition continues to play an important part.

4.3.13 Average number of nymphs per female per clutch

The average numbers of nymphs per five females per clutch based on counts on each host plant species were statistically highly significant ($P < 0.001$). The highest average numbers of nymphs per five females per clutch were recorded in bugs kept on *Ceiba pentandra, G. barbadense* and *G. hirsutum.* The number of nymphs hatched from eggs of stainers raised on *Adansonia digitata* was moderately higher. Comparatively, few nymphs hatched from eggs of *D. fasciatus* that were raised on *Hibiscus micranthus* while the fewest nymphs were recorded from eggs laid by *D. fasciatus* kept on *Abelmoschus esculentus.* The mean numbers of nymphs ranged from 22 to 104.667 per female per clutch. This study suggests that *Ceiba pentandra, G. barbadense* and *G. Hirsutum* can be considered as highly suitable breeding host plants for *D. fasciatus.* However, *D. fasciatus* are moderately favoured for breeding on *Adansonia digitata,* less favoured for breeding on *Hibiscus micranthus* while *Abelmoschus esculentus* is the poorest breeding host plant for the same bug's species. The current results support the findings by Kabissa (1997) that, Kapok and cotton seeds are best attractants for *D. fasciatus* and that the host plants were favoured for breeding (Table 1b).

4.3.14 Survival of *D. fasciatus* during first instar

Survival of *D. fasciatus* on the six host plants was assessed by monitoring percentage death rates of the individuals. There were no significant differences in survival during the first instars (Table 2a). The first instars usually don't feed although they may drink (Mrosso *et al.*, 2006; Wilson *et al.*, 2008) hence no influence of food on deaths was expected during this stage of development of the bugs.

4.3.15 Survival of *D. fasciatus* during second instar

During the second instar, the mean mortality of the individuals reared on different six food sources were not significantly different (P>0.05) (Table 2a). This suggests that all the host plant species supplied as food sources affected the bugs' survival equally although, relatively more deaths were witnessed on bugs reared on *G. hirsutum* and *Abelmoschus esculentus* than on the other host plants. This was attributed to the fact that, it is during this stage when the bugs started to have their first feeding.

4.3.16 Survival of *D. fasciatus* during third instar

The survival of third instars when reared on the six host plants was not statistically significant (P> 0.05) (Table 2a), although relatively higher chances for survival were observed on *D. fasciatus* raised on *G. barbadense , G. hirsutum and Adansonia digitata* than those raised on the other host plant species. This suggests that, for the third instar, all food sources provided to the bugs to feed on were nutritionally equally sufficient atleast for the maintenance of the bugs.

4.3.17 Survival of *D. fasciatus* during fourth instars

Highly significant (P= 0.001) effect of host plants on the survival of the fourth instars was noted indicating that the six food sources contributed differently to the survival of

Table 2 (a): Survival of *D. fasciatus* on different host plants

	Survival of different stages					
Host plants	**First instars death rate**	**Second instars death rate**	**Third instars death rate**	**Fourth instars death rate**	**Fifth instars death rate**	**Total instars death rate**
H. micranthus	0.000	5.000a	11.667a	10.833b	9.17a	36.667cd
G. barbadense	0.000	1.667a	0.000a	10.000b	10.83a	22.500d
G. hirsutum	0.000	8.333a	5.000a	20.000b	17.50a	50.833bc
C. pentandra	0.000	4.167a	15.833a	9.167b	8.33a	37.500bcd
A. digitata	0.000	0.000a	6.667a	32.500b	19.17a	58.333b
A. esculentus	0.000	7.500a	10.000a	66.667a	4.17a	88.333a

C.V	0.000	163.57	80.268	48.074	107.68	15.031
General mean	0.000	4.444	8.194	24.86	11.53	49.03
LSD	0.000	20.616	18.654	33.895	35.204	20.899
Pr > F	-	0.7058 NS	0.1450 NS	0.001 ***	0.6748 NS	< 0.0001 ***

Means with the same letter(s) in the same column are not significantly different at P ≤ 0.05 using Tukey's Studentized Range test.
NS = Not significant; (*) = Significant at 5%; (**) = Significant at 1% (very significant); (***) = Significant at 0.1% (highly significant)

the bugs. The highest percentage death rate was observed on *Abelmoschus esculentus* fed bugs followed by *Adansonia digitata* fed bugs while those reared on *G. hirsutum* had an intermediate death rate percentage. The lowest percentage death rate was observed on bugs raised on *Ceiba pentandra* followed by *G. barbadense* and *Hibiscus micranthus* (Table 2a).

4.3.18 Survival of *D. fasciatus* during fifth instars

The mean death rates of the fifth instars were highly significantly different (P < 0.001) (Table 2a). The highest percentage death rate was observed on *Adansonia digitata* fed bugs followed by *G. hirsutum* fed bugs while those reared on *G. barbadense and Hibiscus micranthus* had intermediate death rates. The lowest percentage death rate was observed on bugs raised on *Abelmoschus esculentus* followed by those raised on *Ceiba pentandra* (Table 2a).

4.3.19 Survival of *D. fasciatus* during total nymphal stadia

During the end of the nymphal period (total nymphal stadia), mean death rates of individuals raised on different host plant food sources were highly significantly different (P< 0.001) (Table 2a). The results showed that host plants contributed differently to the survival of the bugs. The mean death rates ranged from 22.5 to 88.3% (Table 2a). The lowest nymphal survival was found in bugs raised on *Abelmoschus esculentus* in which only about 11.6% of the initial number reached maturity. Survival of the nymphs was highest when they were raised on *G. barbadense* followed by *Hibiscus micranthus* and *Ceiba pentandra.* Half of the individuals survived to the end of nymphal period when kept on *G. hirsutum* or *Adansonia digitata.*

4.3.20 Survival of *D. fasciatus* during Maturity stage

During maturity, the mean death rates of individuals raised on different host plant food sources were highly significantly different (P< 0.001). The results imply that host plants contributed differently to the survival of the bugs even after their final moult. The mean death rates ranged from 11. 6 to 77.5% (Table 2b). The lowest survival occurred when bugs were raised on *Abelmoschus esculentus* whereby only about 11.6% of the initial number reached maturity. The highest survival occurred when they were raised on *G. barbadense* followed by *Hibiscus micranthus* and *Ceiba pentandra.* About half of the individuals survived during maturity stage when kept on *G. hirsutum.* About 41.667% of the initial number kept on *Adansonia digitata* reached maturity.

Table 2 (b): Survival of *D. fasciatus* during maturity stage

Host plants	**Survival of different maturity stages**			
	Mature death rate	**Pre-mating period death rate**	**Pre-oviposition period death rate**	**Generation period death rate**
H. micranthus	63.333ab	0.000a	9.167a	57.50ab
G. barbadense	77.500a	5.000a	5.833a	43.33b
G. hirsutum	49.167bc	0.000a	2.500a	55.00b
C. pentandra	62.500abc	0.000a	1.667a	52.50b
A. digitata	41.667c	0.000a	3.333a	63.33ab
A. esculentus	11.667d	0.833a	0.000a	95.83a
C.V	14.457	291.92	182.97	22.269
General mean	50.97	0.922	3.750	61.25
LSD	20.899	8.0491	19.46	38.682
Pr > F	< 0.0001 ***	0.2758 NS	0.6451 NS	0.0121 *

Means with the same letter(s) in the same column are not significantly different at $P \leq 0.05$ using Tukey's Studentized Range test.
NS = Not significant; (*) = Significant at 5%; (**) = Significant at 1% (very significant); (***) = Significant at 0.1% (highly significant)

4.3.21 Survival of *D. fasciatus* during pre – mating period

The mean survival of *D. fasciatus* during the pre-mating period was not significantly different ($P > 0.05$) indicating that the effects of six host plant species on the survival of the bugs during the time taken by the bugs before copulating after their final moult were similar (Table 2b).

4.3.22 Survival of *D. fasciatus* during pre- oviposition

The mean survival of *D. fasciatus* during pre-oviposition period were not significantly different ($P > 0.05$), indicating that the effects of the six host plant species on the survival of the bugs before oviposition but after they had mated were similar (Table 2b).

4.3.23 Survivalof *D. fasciatus* during generation period

The mean survivals of *D. fasciatus* during the generation period were significantly different ($P < 0.05$) on different hosts. During the generation time, the death rates ranged from 43.3 to 95.8%. Those reared on *Abelmoschus esculentus* suffered the highest death rate followed by those fed on *Adansonia digitata*. *Dysdercus fasciatus* reared on *Gossypium barbadense* suffered the lowest death rate followed by those fed on *Ceiba pentandra*. Bugs kept on *Gossypium hirsutum* or *Hibiscus micranthus* suffered moderately less death (Table 2b).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion.

(a) From the field survey conducted in cultivated and uncultivated fields in Kilosa district's cotton growing areas to determine the host range of different *Dysdercus spp* (cotton stainers), five species of cotton stainers were identified and encountered feeding on different host plant species ranging from arboreal to both annual and perennial herbaceous plants. The cotton stainer species that were identified were *Dysdecus fasciatus* Sign; *D. intermediosus* Dist; *D. nigrofasciatus* Stål; *D. cardinalis* Gerst and *D. superstitiosus* (F).

(b) In the absence of cotton, cotton stainers feed on a wide range of plants. Atleast 31 plant species were found to host cotton stainers in Kilosa District cotton growing areas. Stainer attacks on cotton were consequently more common in areas where these wild and cultivated host plants are abundant and can support large stainer populations. Attacks can also originate from seed stores with poor sanitation where the stainers feed and breed on old cotton seed. Cotton left in the field either on plants or on the surface of the ground after harvesting has been completed can also provide food supply during the closed season. With the exception of the few plants, most of the host plant species identified belong to the order Malvales, particularly of the families Malvaceae, Bombacaceae, Tiliaceae and Sterculiaceae. Some few plants were potentially found to host the cotton stainers to a considerable degree, and these belonged to the families of Asteraceae, Moraceae, Myrtaceae, Caricaceae, Musaceae, Anacardiaceae, Bromeliaceae, and Poaceae. However, there were unusual hosts that were found to support the bugs with nutritional materials, and these included meat from vertebrates, left over of bread, buns or doughnuts. Cannibalism was found among the cotton stainers.

(c) This study revealed that *Dysdercus fasciatus, D. nigrofasciatus and D. intermediosus* have wide host ranges in Kilosa district, providing a greater potential for survival and playing a dominant role on some plants during certain period of the year. *D. cardinalis* has a relatively narrow host range and the rare *D. superstitiosus* has the narrowest host range. However, apart from cotton, *D. fasciatus* and *D. intermediosus* tended to specialize much on arboreal host plants while *D. nigrofasciatus* and *D. cardinalis* specialized much on herbaceous host plants.

(d) A field population dynamics of *Dysdercus spp* study on six host plants revealed that the five cotton stainer species, namely *D. fasciatus, D. nigrofasciatus, D. cardinalis, D. intermedius* and *D. superstitious*, do feed on cotton (*G. hirsutum*) in varying population proportions. Population fluctuations of the individual species varied greatly. The highest population count on *G. hirsutum* was observed in July and the lowest counted on March. *Dysdercus intermediosus* dominated only the months of May and June while for the rest of the year it was dominated by *D. fasciatus*. *Dysdercus intermediosus* and *D. fasciatus* are regarded as major pest species of bourbon cotton (*G. hirsutum*) as they are found in larger populations while *D. nigrofasciatus; D. cardinalis* and *D. superstitious* are minor pest species in Kilosa cotton growing Region.

(e) The populations of cotton stainers on *G. barbadense* (gallini cotton), *Ceiba pentandra* and *Adansonia digitata* were dominated by *Dysdercus fasciatus*, one of the major pest species of *G. hirsutum* (bourbon cotton). This renders the plant species to become more of a threat to the cotton industry than the other host plant species on which the field stainers' population estimates were conducted.

(f) The populations of *D. nigrofasciatus* and *D. cardinalis* dominated on *A. esculentus* and *H. micranthus* respectively. Since the insect pests were both considered as minor pests of *G. hirsutum* (bourbon cotton), the host plant species can be considered as relatively less threats to cotton industry.

(g) *D. fasciatus* undergo five instars and were able to complete their life cycle when reared on either of the following host plant species; *G. hirsutum, Ceiba pentandra, G. barbadense, Adansonia digitata H. micranthus* and *A. esculentus*. Generally, the development and survival of *Dysdercus fasciatus* were more favoured by feeding them on *G. hirsutum, Ceiba pentandra, G. barbadense* and *Adansonia digitata* than feeding them on *Hibiscus micranthus*. *Abelmoschus esculentus* was extremely not a favourable food source for *D. fasciatus*.

(h) Differences in diet affect the development and survival of the cotton stainers.

5.2 Recommendations

(a) From the present field study, wherever possible farmers should be encouraged to cultivate cotton far from arboreal and / or herbaceous cotton stainers' altenative host plants that have been mentioned in the results of the experiment.

(b) Further, from the results of field experiment, it is recommended that if cotton is cultivated where arboreal/herbaceous alternative host plants occur; farmers should be advised to spray the soil, trunks of host plants to kill the nymphs hatching from eggs laid around the stems/plants and make use of tanglefoot around tree trunks (destroy breeding sites).

(c) Once *Dysdercus spp* invade the cotton field they tend to multiply vigorously and their survival and development is highly favoured since cotton (*Gossypium hirsutum*) is one of their favourable diets as revealed from the laboratory study. Farmers should be advised to prevent the build up of larger populations of the stainers by use of several combinations of integrated methods including; shaking the small infestation of stainers into the bucket of soapy water. Small heaps of seeds, fruits, or bits of sugarcane can be used as baits to attract cotton strainers and then the insects can be killed with a spray of soapy or scalding hot water. Use of natural enemies e.g insects of the genus *Phonoctonus*; cultivation of trap crops; mixed or strip cultivation with repellent action plants and /or materials. Early sowing and regular picking.

(d) The pesent study has revealed that *D. fasciatus* and *D. intermediosus* are currently the major species of cotton stainers in Kilosa district, thus more similar studies on the species are necessary and much effort should be put on the control of these species in cotton fields by use of synthetic insecticides and botanicals.

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APPENDICES

Appendix 1: *Dysdercus spp* population dynamics on cultivated cotton (*Gossypium hirsutum*) as observed on a random sample of ten plants on monthly bases.

	Dysdercus nigrofasciatus	*Dysdercus fasciatus*	*Dysdercus cardinalis*	*Dysdercus intermediosus*	*Dysdercus superstitiosus*	Nymphs	TOTAL
October 2007	3	19	11	0	5	0	38
November	3	8	4	0	0	95	110
December	3	10	4	0	0	17	34
January 2008	3	16	5	0	0	172	196
February	0	4	0	0	0	25	29
March	4	3	0	1	0	0	8
April	0	4	0	0	0	70	74
May	0	2	2	15	0	62	81
June	2	14	6	32	0	200	254
July	8	67	4	47	0	657	783
August	3	53		7	0	497	560
September	3	63	0	7	0	75	148
Total per Spp per year per ten plants	**32**	**263**	**36**	**109**	**5**	**1870**	**2315**

Appendix 2: Trend of (*Dysdercus spp*) population dynamics on gallini cotton (*Gossypium barbadense*) as observed on a random sample of ten plants

	Dysdercus nigrofasciatus	*Dysdercus fasciatus*	*Dysdercus cardinalis*	*Dysdercus intermediosus*	*Dysdercus superstitiosus*	Nymphs	TOTAL
October 2007	3	14	7	0	0	6	30
November	4	11	4	0	2	188	209
December	3	19	2	0	0	159	183
January 2008	0	9	6	0	0	190	205
February	0	13	0	0	0	52	65
March	0	9	0	1	0	4	14
April	0	4	0	2	0	25	31
May	0	6	1	9	0	52	68
June	2	13	3	19	0	165	202
July	3	8	2	6	0	267	286
August	3	30	0	5	0	241	279
September	2	19	0	4	0	103	128
Total per Spp per year per ten plants	**20**	**155**	**25**	**46**	**2**	**1452**	**1700**

Appendix 3: Trend of (*Dysdercus spp*) population dynamics on okra (*Abelmoschus esculentus*) as observed on a random sample of ten plants.

	Dysdercus nigrofasciatus	*Dysdercus fasciatus*	*Dysdercus cardinalis*	*Dysdercus intermediosus*	*Dysdercus superstitiosus*	Nymphs	TOTAL
October 2007	2	6	2	0	0	4	14
November	5	4	3	0	3	6	21
December	8	15	8	0	6	19	56
January 2008	4	1	48	0	10	230	293
February	13	0	0	0	2	197	212
March	2	0	2	2	0	134	140
April	12	3	0	2	0	9	26
May	0	0	8	0	0	16	24
June	1	0	0	0	0	20	21
July	24	0	0	0	0	4	28
August	14	0	0	0	0	1	15
September	36	0	0	0	0	0	36
Total per spp per year per ten plants	**121**	**29**	**71**	**4**	**21**	**640**	**886**

Appendix 4: Trend of *Dysdercus spp* population dynamics on *Hibiscus micranthus* as observed on a random sample of ten plants

	Dysdercus nigrofasciatus	*Dysdercus fasciatus*	*Dysdercus cardinalis*	*Dysdercus intermediosus*	*Dysdercus superstitiosus*	Nymphs	TOTAL
October 2007	0	0	0	0	0	0	0
November	4	0	1	0	0	1	6
December	13	0	20	0	4	0	37
January 2008	4	0	39	0	2	31	76
February	0	2	13	0	1	38	54
March	11	14	62	9	2	87	185
April	6	7	6	6	0	97	122
May	1	0	12	3	0	26	42
June	15	0	16	12	0	102	145
July	25	1	10	1	0	14	51
August	8	7	5	9	0	87	116
September	2	31	4	5	0	59	101
Total per Spp/ year perTen plants	**89**	**62**	**188**	**45**	**9**	**542**	**935**

Appendix 5: Trend of *Dysdercus spp* population dynamics on kapok/ silk -cotton tree (*Ceiba pentandra*) as observed under the tree in five quadrants

	Dysdercus nigrofasciatus	*Dysdercus fasciatus*	*Dysdercus cardinalis*	*Dysdercus intermediosus*	*Dysdercus superstitiosus*	Nymphs	TOTAL
October 2007	0	0	0	0	0	34	34
November	4	19	5	0	0	234	262
December	9	37	18	0	0	136	200
January 2008	6	12	4	1	0	312	335
February	4	25	0	0	0	380	409
March	5	46	0	2	0	344	397
April	13	29	1	8	0	486	537
May	9	73	0	10	0	411	503
June	0	59	0	2	0	142	203
July	1	20	0	0	0	43	64
August	3	21	0	0	0	19	43
September	0	10	0	0	0	83	93
Total per Spp/ year perTen plants	**54**	**351**	**28**	**23**	**0**	**2624**	**3080**

Appendix 6: Trend of *Dysdercus spp* population dynamics on baobab (*Adansonia digitata*) as observed under the tree in five quadrants

	Dysdercus nigrofasciatus	*Dysdercus fasciatus*	*Dysdercus cardinalis*	*Dysdercus intermediosus*	*Dysdercus superstitiosus*	Nymphs	TOTAL
October 2007	1	1	0	0	0	20	22
November	2	10	6	0	0	254	272
December	0	13	6	0	0	50	69
January 2008	0	31	10	0	0	137	178
February	0	15	0	0	0	115	130
March	2	39	0	0	0	122	163
April	1	63	0	0	0	91	155
May	0	11	0	0	0	92	103
June	2	22	0	0	0	71	95
July	0	24	0	0	0	170	194
August	0	37	0	0	0	321	358
September	0	6	0	0	0	141	147
Total per spp per year per ten plants	**8**	**272**	**22**	**0**	**0**	**1584**	**1886**

Appendix 7: The GLM Procedure

Class Level Information

Class	Levels	Values
Rep	3	1 2 3
Treat	6	Baobab Barbade Hirsutum Kapok Okra Sida

Number of observations 18

The GLM Procedures

Dependent Variable: First (First instars development duration ➔ days)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	0	0	.	.
Treat	5	0	0	.	.

Dependent Variable: Second (Second instars development duration ➔ days)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	14.77777778	7.38888889	5.88	0.0205
Treat	5	8.27777778	1.65555556	1.32	0.3310

Dependent Variable: Third (Third instars development duration ➔ days)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	1.00000000	0.50000000	1.00	0.4019
Treat	5	38.00000000	7.60000000	15.20	0.0002

Dependent Variable: Fourth (Fourth instars development duration ➔ days)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	16.3333333	8.1666667	2.09	0.1739

Treat	5	247.1666667	49.4333333	12.68	0.0005

Dependent Variable: Fifth (Fifth instars development duration ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	1.44444444	0.72222222	0.27	0.7722
Treat	5	84.27777778	16.85555556	6.19	0.0072

Dependent Variable: Total (Total instars development duration ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	10.333333	5.166667	2.25	0.1564
Treat	5	1088.666667	217.733333	94.67	<.0001

Dependent Variable: Maturi (Maturity stage duration ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	539.11111	269.55556	1.66	0.2384
Treat	5	22204.94444	4440.98889	27.35	<.0001

Dependent Variable: Premat (Pre-mating period ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	15.4444444	7.7222222	2.98	0.0964
Treat	5	132.4444444	26.4888889	10.23	0.0011

Dependent Variable: Preovip (Pre- oviposition period ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	8.44444444	4.22222222	0.89	0.4416
Treat	5	42.94444444	8.58888889	1.81	0.1993

Dependent Variable: Gperiod (Generation period ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	41.444444	20.722222	5.11	0.0296
Treat	5	2067.611111	413.522222	101.96	<.0001

Dependent Variable: Flongev (Female longevity ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	133.777778	66.888889	2.45	0.1366
Treat	5	2507.611111	501.522222	18.33	<.0001

Dependent Variable: Mlongev (Male longevity ➔ days)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	486.77778	243.38889	1.55	0.2591
Treat	5	16888.94444	3377.78889	21.52	<.0001

Dependent Variable: Anfclut (Average number of nymphs per female per clutch)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	55.11111	27.55556	0.97	0.4130
Treat	5	15732.27778	3146.45556	110.45	<.0001

Dependent Variable: Fdeath (First instars death rate ➔ percentage)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	0	0	.	.
Treat	5	0	0	.	.

Dependent Variable: Sdeath (Second instars death rate ➔ percentage)

Source	DF	Type I SS	Mean Square	F Value	Pr > F

Rep	2	21.5277778	10.7638889	0.20	0.8190
Treat	5	156.9444444	31.3888889	0.59	0.7058

Dependent Variable: Tdeath (Third instars death rate ➔ percentage)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	154.8611111	77.4305556	1.79	0.2166
Treat	5	460.0694444	92.0138889	2.13	0.1450

Dependent Variable: Fodea (Fourth instars death rate ➔ percentage)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	521.527778	260.763889	1.83	0.2110
Treat	5	7480.902778	1496.180556	10.47	0.0010

Dependent Variable: Fideat (Fifth instars death rate ➔ percentage)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	42.3611111	21.1805556	0.14	0.8732
Treat	5	493.4027778	98.6805556	0.64	0.6748

Dependent Variable: Totde (Total instars death rate ➔ percentage)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	11.111111	5.555556	0.10	0.9037
Treat	5	7872.569444	1574.513889	28.99	<.0001

Dependent Variable: Madeat (Maturity stage death rate ➔ percentage)

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	11.111111	5.555556	0.10	0.9037

Treat	5	7872.569444	1574.513889	28.99	<.0001

Dependent Variable: Premde (Pre-mating period death rate ➔ percentage)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	11.11111111	5.55555556	0.69	0.5241
Treat	5	60.06944444	12.01388889	1.49	0.2758

Dependent Variable: Povide (Pre- oviposition period death rate ➔ percentage)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	8.3333333	4.1666667	0.09	0.9160
Treat	5	161.4583333	32.2916667	0.69	0.6451

Dependent Variable: Gpdeath (Generation period death rate ➔ percentage)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	2	52.083333	26.041667	0.14	0.8711
Treat	5	4953.125000	990.625000	5.32	0.0121