EFFICACY OF PESTICIDES USED ON COTTON IN THE WESTERN COTTON GROWING AREAS OF TANZANIA

JEREMIAH JOE KABISSA

A DESSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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EXTENDED ABSTRACT

Complaints against the ineffectiveness of pesticides currently distributed by the Tanzania Cotton Board (TCB) and private dealers in the Western Cotton Growing Areas (WCGA) have persisted for nearly a decade which has rendered some famers abandoning the crop. Technically, the reasons for the low efficacy could be associated with insecticides or poor application techniques. A series of studies were conducted between September 2014 and September, 2015 in the WCGA to document the commonly used pesticides on cotton, examine their authenticity with reference to the registrar's article and evaluate their effectiveness. Documentation of the commonly used insecticides, accessibility and perceived efficacy were studied through a survey conducted using structured questionnaires in five districts in Mwanza and Simiyu Regions. A total of 175 respondents were interviewed. Authenticity of the commonly used pesticides was examined through sampling among the commonly used pesticides, obtaining small volumes in screw-capped bottles, re-packaging and labelling by numbers to disguise the identity, after which they were sent to the Tropical Pesticide Research Institute (TPRI) laboratories for determination of active ingredients. The effectiveness of the commonly used pesticides was determined through a field experiment set at Ukiriguru Agricultural Research Institute. Cotton insect pests against which the pesticides were tested included; *Helicoverpa armigera* (Hubner), *Aphis gossypii* (Glover), *Pectinophora gossypiella* (Sound), *Dysdercus* sp (Herrich- Schaeffer) and *Earias* sp (Walker/Boisduval). The results indicated that most of the approved and few of unapproved insecticides are used in controlling cotton pests in the WCGA. About 70% of insecticides used by farmers in all five Districts surveyed were supplied through CDTF and the remaining 30% were sourced from private agro-shops and open markets. About 40% of the insecticides sold in agro-shops and local market centres had expired but cotton farmers being unaware

purchased them for use. About, 85% of agro-shop owners employed unskilled shopkeepers to sell pesticides. The confirmatory test at TPRI laboratories proved the collected insecticides to conform to the registrar's records in terms of contents and active ingredients. The field tests showed that all insecticides were effective against target insect pests provided the proper dosage was applied at the right time and appropriate pests threshold. Pyrethyroids such as lambdacyhalothrin and cypermethrin when used in combination with organophosphates controlled both endocarpic and exocarpic boll worms and other insect pests very effectively but when lambdacyhalothrin was used singly, the effectiveness was compromised particularly on aphids. Likewise the endocarpic and exocarpic boll worms could not be effectively controlled using cypermethrin alone. The findings from this study resolved the long-standing doubt on efficacy of insecticides distributed to cotton growers through the CDTF. Ineffectiveness reported by farmers are mostly caused by use of inadequate amounts of insecticides (low dosages), mixing insecticides with poor quality water (dirty water) and poor coverage of the crop canopy during spray. Wrong timing of the day to first spray and poor knowledge of pest threshold also contribute to the limited efficacy of the insecticides in small farmers' setting. Therefore, the Tanzania cotton sector should take concrete steps to educate growers on proper use of insecticides and avoid the risks of insect pests developing resistance to the used insecticides particularly the Pyrethroids.

DECLARATION

I Jeremiah Joe Kabissa, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted to any institution.

26.09.2016

Jeremiah Joe Kabissa (Date)

(MSc. Crop Science Candidate)

The above declaration is confirmed by

26.09.2016

Gration M. Rwegasira, (PhD) (Date)

(Supervisor)

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DEDICATION

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LIST OF ABBREVIATIONS

ABW	African Boll Worm
A/Pacs	Acre Packs
BT	*Bacillus thurungiensis*
ANOVA	Analysis of Variance
ARI	Agriculture Research Institute
CABI	Centre for Agriculture and Biosciences International
CDTF	Cotton Development Trust Fund
CV	Coefficient of Variation
DAE	Days after crop emergency
DALDO	District Agriculture and Livestock Development Officer
DAFS	Days After First Spray
DAICO	District Agriculture Irrigation and Cooperative Officer
DF	Degrees of Freedom
ET	Economic Threshold
EIL	Economic Injury Level
EC	Emulsifiable concentrate
ECGA	Eastern Cotton Growing Area
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FID	Frame Ionization Detector
GAP	Good Agricultural practices

GC	Gas Chromatography
GDP	Gross Domestic product
GURT	Government of United Republic of Tanzania
INDS	Insecticides
LSD	Least Square Difference
IPM	Integrated Pest management
MALFC	Ministry of Agriculture Livestock, Fisheries and Cooperatives
MAFAP	Monitoring and Analysing Food and Agricultural Policies
MSS	Mean Sum Square
N	Nitrogen
n	Sample size
P	Probability
PBW	Pink Boll Worm
PRC	Pesticides Registration Centre
RCBD	Randomized Complete Block Design
Resp	Respondents
SBW	Spiny Boll Worm
SC	Soluble Concentrate
SPSS	Statistical Package for Social Science
SPW	Spiny Boll Worm
SS	Sum Square
SUA	Sokoine University of Agriculture
SV	Source of variation
TACOGA	Tanzania Cotton Growers Association

TCB	Tanzania Cotton Board
TCL&SB	Tanzania Cotton Lint and Seed Board
TCA	Tanzania Cotton Growers Association
TPRI	Tropical Pesticides Research Institute
MSUES	Mississippi State University Extension Services
Ops	Organo phosphates
Ps	Pyrethroids
UK M	Ukiriguru Cotton Variety M
ULV+	Ultra Low Volume plus
URT	United Republic of Tanzania
WCGA	Western Cotton Growing Area
WP	Wettable powder
WHO	World Health Organisation
UK	United Kingdom
UK 91	Ukiriguru Cotton Variety developed in 91

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Cotton, *Gossypium* Spp of the family Malvaceae is a cultivated annual shrub with broad three-lobed leaves and seeds in capsules or cotton bolls (Jenkins, 2003). Each seed is surrounded with white downy fibre which is easily spun. The crop is domesticated independently as source of fibre (Brubaker*et al.*, 1999). The different cotton species known include; *Gosypium hirsutum* L., *G. barbadense* L., *G. herbaceum* L, and *G. arboretum* L. (Edward and Mirza, 1979; Enderizzi *et al.*, 1985;Stewart, 1995).The species *G. hirsutum* is the commonly cultivated in Tanzania (TCB, 2005).

Cotton is an economically important cash crop in Tanzania. Available data for 2009 indicates that the crop contributed up to US$ 92 million per annum of the GDP (TCB, 2005). It is cultivated on about 0.5 million ha which is approximately 9% of the total arable land in Tanzania (TCB, 2010). The crop is mainly grown in the Eastern and Western parts of the country. These are designated as Eastern cotton growing areas (ECGA) comprised of Manyara, Kilimanjaro, Tanga, Coast, Morogoro and Iringa regions, and Western cotton growing areas (WCGA) comprised of Shinyanga, Mwanza, Simiyu, Mara, Geita, Kagera, Kigoma, Tabora and Singida regions from which more than 95% of the cotton is produced (TCB, 2005).

In Tanzania, the crop is faced by many production constraints; which include insect pests, weed, diseases, low soil fertility, poor agronomic practices and irrational policies (Poulton and Maro, 2009). According to Kabissa (1989) the most damaging pest species on cotton are *Helicoverpa armigera* (Hubner), *Aphis gossypii* (Glover) and *Dysdercus spp* (Walker). In order to minimize the impact of cotton pests and improve yield, farmers are usually advised to use cultural, host plant resistance and chemical methods of control. Chemical control tends to be preferred due to ease of application and immediate effects on pests.

FAO (2002) described a pesticide as any substance or mixture of substances that are intended for preventing, destroying, controlling and mitigating any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substance which may be administered to animals for the control of insects, arachnids or other pest in or on their bodies. The term includes substances intended for use as plant growth regulators, defoliants, desiccants or agents for thinning fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. Cooper and Dobson (2007) considered that, pesticides are defined as poisons used in certain circumstance to kill specifically targeted pests. Despite their effectiveness and being often preferred, insecticides are hazardous to humans and to the environment particularly when misused (Key and Mungereza, 1988).

1.2 Justification

Cotton productivity in Tanzania is grossly low (0.46 - 0.69 ton/ha) when compared to the world standard of 2.5 - 4 tons/ha (FAOSTAT, 2013). The limited productivity is often attributed to abiotic and biotic stresses (TCL and SB, 2002). While former is accounted for by poor soil fertility, drought and limited mechanization, the latter is mainly associated with insect pests, weeds and to a lesser extent diseases and low productivity of the grown varieties. The major cotton pest particularly in the WCGA includes *Helicoverpa armigera* (Hubner), *Aphis gossypii* (Glover) and *Dysdercus* sp (Herrich-

Schaeffer) (Kabissa, 1989). There are other pests but of minor significance such as stink bugs, thrips, loppers and jassids. Collectively, these insects contribute to significant yield losses in Tanzania of up to 60% (Mrosso *et al.*, 2006). Such losses often compel farmers' interest into using insecticides as first line of defence. Most of the recommended insecticides are synthetic pyrethroids for example (Fenkil- Fenverelate, Furry, Karate-Lambdacyahalothrin, Ninja-Lambdacyahalothrin, Insectido-Lambdacyahalothrin and Lambdex super-Lambdacyahalothrin) (TCB, 2005). These insecticides are preferentially used due to their quick knock down effect (Jenson *et al.*, 2010). Others are organophosphates for example Chlorpyrifos, Profenophos and Dimethoate.

In WCGA there has been some growing concern about the ineffectiveness of insecticides that are currently being distributed to farmers for control of cotton pests. Crop failure has become a common phenomenon often leading to great socio-economic and political problems. Some products like Duduall-Cypermethrin and chlorpyrifos which is manufactured and supplied by Hangzhou Agrochemicals and others that were used by farmers in 2009-2013 were not supplied through the Cotton Development Trust Fund (CDTF) and had never at all been tested and approved for use in cotton but found their way to farmers through unscrupulous dealers (TPRI, 2011).

Available information with the CDTF indicates that cotton insecticides in general are centrally procured through tenders (Salum, J. P, personal communication). However, there is always no post acquisition authentication of pesticides prior to distribution to farmers unless they raise grievances. Checking for authenticity is rarely done as was the case for Bamethrin in 2010/2011 farming season (found with several counterfeits in acre-packs, filled less than the required volumes of insecticide) and Lambdex super (found expired but double branded to conceal expiry dates) (TCB, 2010). While insecticide suppliers tend to blame the ineffectiveness of insecticides and irresponsiveness of insect pests to pesticides on limited farmers' knowledge on proper use of insecticides, lack of appropriate application equipment's and poor timing of insecticide sprays, no research has been conducted to justify the claims.

Moreover, these problems were never experienced previously in 1950s through late 1990s when cotton insecticides were centrally procured by the government. It was not clear whether the cause for ineffectiveness is due to inauthentic insecticides being used, poor application techniques or build-up of resistance to the insecticides by the target insect pests. The present study aimed at assessing whether the reported ineffectiveness of insecticides being used in the WCGA is insecticide borne or user related. The outcome of this study would help TCB, CDTF; GURT and policy makers to take appropriate action as remedy for the dwindling cotton production in Tanzania. Steps to rationalize the procurement and distribution of cotton insecticides for the socio-economic welfare of cotton growers and the cotton industry would have scientific base.

1.3 Objective

1.3.1 Overall objective

The overall objective of the study was to find out, the contribution of pesticide use and misuse under smallholder farmers on the pest status of major cotton insect pests.

1.3.2 Specific objectives

i. To identify different pesticides currently used by farmers to control the major pests of cotton in the WCGA.

ii. To examine effectiveness of five most commonly used insecticides in the WCGA against major cotton pests in the field.

iii. To determine the authenticity of the commonly used insecticides in the WCGA.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Cotton Production in Tanzania

Cotton is mainly grown in WCGA and ECGA (TCB, 2005). In WCGA there are 32 districts in 9 regions which produce cotton. The varieties currently used are UK 91, UK 08 and UK M08 (TCB, 2010). Cotton farming is a major source of livelihoods as it provides employment to about 500 000 rural households as well as a source for both direct and indirect benefits to more than 40% of the Tanzanian population (FAO and MAFAP, 2013). Today, the world uses far more cotton than any other fibre. This stimulates business activities for factories and enterprises throughout the country. Processing and handling of cotton after it leaves the farm generates even more business activity.

Cotton is a part of our daily lives from the time we dry our faces on a soft cotton towel in the morning until we slide between fresh cotton sheets at night. It has hundreds of uses, from blue jeans to shoe strings. Clothing and household items are the largest uses, but industrial products account for many thousands of bales. All parts of the cotton plant are useful (Deussen, 1992). However, the most important cotton by-product is the fibre or lint, which is used in making cotton cloth. Linters – the short fuzz on the seed provide cellulose for making plastics, explosives and other products. Linters also are incorporated into high quality paper products and processed into batting for padding mattresses, furniture and automobile cushions.

The cotton seed is crushed in order to separate its three products: -oil, meal and hulls. Cotton seed oil is used primarily for shortening, cooking oil and salad dressing. The meal and hulls that remain are used either separately or in combination as livestock, poultry and fish feed and as fertilizer (Cherry *et al.*, 1981). The stalks and leaves of the cotton plant are ploughed under to enrich the soil. Some cotton seeds also are used as high-protein concentrate in baked goods and other food products.

2.2 Abiotic and Biotic Constraints to Cotton Production

Abiotic factors include: reliance on rain-fed growing conditions, insufficient use of fertilizer and chemicals, drought, high temperatures and salt affected soils (Bursi *et al.*, 2008). Biotic factors includes; low yielding varieties, diseases (such as Fusarium wilt, Bacterial blight, Alternaria leaf spot), insect pests (African bollworm, Pink bollworm, Spiny bollworm, Aphids, Stainers, Jassids, Lygus), nematodes and weeds. After planting, cotton requires 8 weeks of weeds free growth to allow optimum yields. Good yields require greater than 95% efficient weed control. Excellent yield requires 99% or better control of weeds (Cotton incorporated, 2016). Such near perfect control is needed to avert difficulties with picking, excessive trash in the harvested lint and recurring cycle of heavy weed seed rain followed by high population of weed particularly *Amaranthus* spp, *Conyza canadensis*, *Cida acuta*, rye grasses and goose grasses (Bunyecha, 1995).

2.3 Policy Constraints to Cotton Production

Tanzania's textile industry was started in the early 1970's as part of the government's efforts to industrialize the economy. More than 80% of mill capacity was under state ownership (URT, 1999b). When the government support came to an end, the industry was unable to survive international competition and some textile mills went out of business (Shepherd, 1999).

Constrains which are associated with cotton production relate to the escalation of input prices by 25% in annual nominal terms following trade liberalization and small holders becoming increasingly exposed to producer price uncertainties. So apart from the necessity to access inputs and new technologies, smallholders needed policy safety nets to safeguard them against exposure to competitive markets (Kabissa and Myaka, 2000).

The cotton sector is heavily taxed in United Republic of Tanzania. Taxation in cotton sector was being administered centrally by the Prime Minister's Office in consultation with the Ministry of Agriculture, Livestock and Fisheries (MALF) and the Cotton Board before the reforms in the 1980s. The structure of taxation includes several taxes, levies and fees administered at both local and central government levels. A study on the tax structure in 1998/99 by the Government of the United Republic of Tanzania found that the tax burden on cotton was more than 13% of the producer price, distributed between local government (districts) (7.7%) and central Government (5.1%) taxes (Baffes, 2002).

In addition, the cotton sector has other fees, such as Cotton Development Fund. Cotton Development Trust fund fee and fees payable to cooperative unions and primary societies, that when included in the equation raised tax burden to over 20% of the producer price (URT, 1999a). Cotton taxes during the 2000s remained high in Tanzania (Poulton and Maro, 2009) with taxing basis both fixed (20 TZS/kg of seed cotton as contribution to the Cotton Development Fund and variable (5% of seed cotton price as District levy) components.

Other encompassed rampant contamination with deleterious effects on farm gate prices and fibre competitiveness (Poulton and Maro, 2009). Limited extension services, research services, budget, and fall in prices for small producers; exporters in developing countries, competition from synthetic fibres, cotton price subsidy and inputs subsidy (TCB, 2010). In 1991, Ukiriguru Research Station released a new cotton variety, UK91, which was superior (in both yield and diseases resistant) when compared to both UK77 and UK82. However, achieving higher yields at farmers' fields requires multiplication and release of enough UK91 seed to replace the older varieties so as to avoid mixing with existing varieties. Since the release in 1991, there have never been enough seeds produced to cover the WCGA (Shepherd, 1999) due to limited financial support and lack of investments in cotton seed sector.

Poor infrastructure has also impeded the development of cotton sector. Transportation by rail would have meant a great relief on cost incurred by growers or primary processors in transporting cotton to harbor and ports. Unfortunately the quality of rail services has continued to deteriorate contributing to poor performance of the cotton sector. Moreover, the road network particularly in rural areas of Singida, Mwanza, Shinyanga and Mara regions, where most cotton is produced, requires considerable upgrading. As with rail transport, road improvements would have increased efficiency and reduced costs, short of which has led to higher production costs (Baffes, 2002).

Limited access to input caused by removal of input price subsidies at farmer level (mainly insecticides and fertilizers) led to poor quality cotton and low yields. Quality decline in produce due to reduced input use reflects relative prices and hence market forces (Bunyecha and Tamminga, 1995).

Following reforms, as cotton prices raised in the late 1990's, price competition and over capacity in ginning caused abandonment of zoning, leading to the mixing of fusarium infected and fusarium uninfected cotton seeds with ultimate reduction in cotton fibre quality. The northern and southern area varieties, which were released for specific agro-climatic conditions were also mixed up and contributed to lower productivity of cotton (URT, 1999a; TCL and SB, 2002).

2.4 Insecticides Commonly Used for the Control of cotton Pests

Currently insecticides used on cotton in the WCGA come as water based formulations. Examples Bamethrin 2.5% E. C (deltamethrin 25g/L), Karate 5% E. C (lambdacyhalothrin 50g/L), Zetabestox 10% E. C (zeta-cypamethrin100g/L), Agrothrin 10% E. C (lambdacyhalothrin 100g/L), Delta plus 250 E. C (deltamethrin 100g/L), Insectido 5% E. C (lambdacyhalothrin 50g/L), Perfecto 175 W. D. G (lambda cyhalothrin 75g/L + imidacloprid 100g/L), Attakan C 350 S. E (imidacloprid 350g/L), Lambdex super 315 E. C (lambdacyhalothrin 115g/L + chlorpyrifos 200g/L), and Lambdex 5% E. C (lambdacyhalothrin 50g/L).

An acre-pack of any of these pesticides is enough for a single spray on an acre of cotton (Mrosso and Temu, 2008). Insecticides are either sprayed in the morning after dew has dried up or in the evening provided there is no rain. Knapsacks sprayers (from Fambase, Solo and Matabi) as well as ULV + sprayers are used to apply these water based formulations (Kabissa and Myaka, 2000).

2.5 Insecticide Acquisition-Delivery Chain and Regulation

Insecticides are centrally acquired by Tanzania Cotton Development Trust Fund (CDTF) which delivers all chemicals to farmers indirectly by way of cooperative societies and ginners on the basis of instructions given to them by district council's cotton task forces

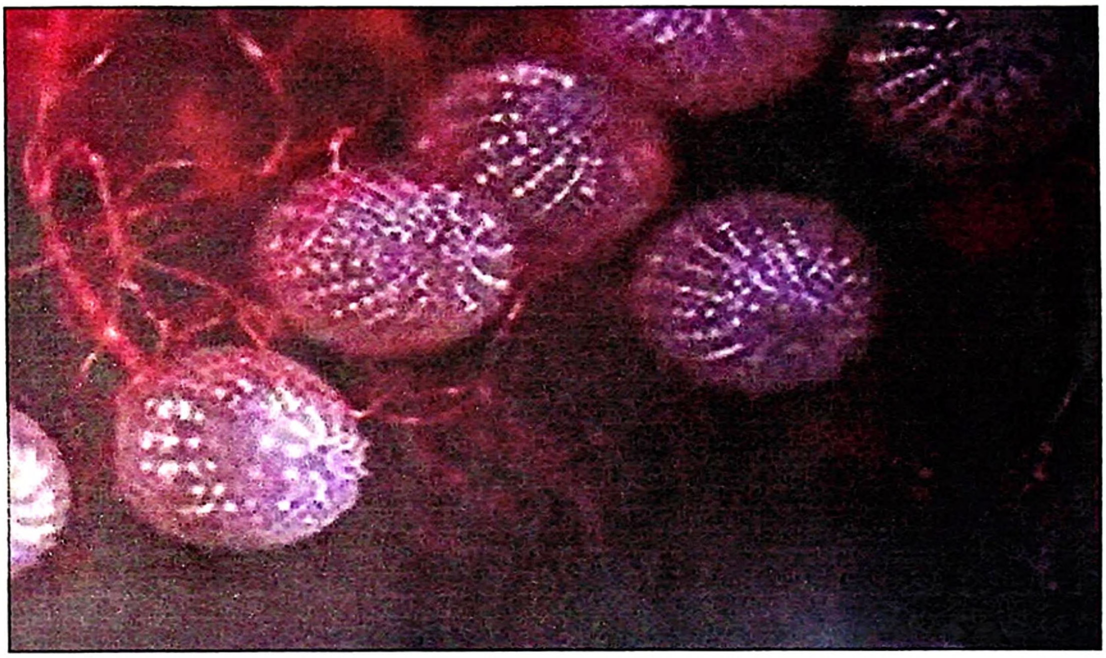
(Mwalukasa E. Personal communication). Moreover, agro-dealers can also acquire insecticides from their own sources and sell them directly to farmers.

2.6 Common Pests of Cotton

According to Mrosso and Temu (2008), the important insect pests of cotton in the fields in Tanzania include; African boll worm - *Helcoverpa. armigera* (Hubner); aphids - *Aphis. gossypii* (Glover) and cotton stainers - *Dysdercus* sp (Herrich- Schaeffer). Other insect pests include spiny bollworms, *Earias.* sp (Walker and Boisduval), pink bollworm - *Pectinophora. gossypiella* (Sounders), jassids - *Jacobiasca.* spp (Jacobi), blue seed bug - *Calidae* spp, Lygus -*Taylorilygus vosseleri* (Popp), Helopeltis *Helopeltis schoutedeni* (Ret), cotton seed bugs - *Oxycarenus hyalinipennis* (Costa), spider mites -*Tetranychus* spp, Tea mite - (*Hemitarsonemus latus* (Banks)) now *Polyphagotarsonemus latus* (Banks), Termites - (*Microterms* spp).

2.6.1 The African bollworm

The adult *H. armigera* (Hubner) can lay several hundred eggs in just 10 days from emergence which are spherical shaped, 0.4 to 0.6mm in diameter and have a costate surface, white coloured (Pate 2.1) later becoming greenish (Agro Atlas, 2013). The eggs usually are distributed on various parts of the plant. Under favorable conditions, the eggs can hatch into larvae (Plate 2.2) within three days and the whole life cycle can be completed in just over a month (CABI, 2013).



Source: Agro Atlas (2013)

Plate 2.1: Eggs of *H. armigera*

The larvae take 12 to 22 days to develop, reaching up to 40 mm long in the sixth instars. Their colouration is variable but mostly greenish and yellow to red-brown. The head is yellow with several spots. Three dark stripes extend along the dorsal side and one yellow light stripe is situated under the spiracles on the lateral side. The ventral parts of the larvae are pale (Agro Atlas, 2013). They are rather aggressive, occasionally carnivorous and may even cannibalise each other. If disturbed, they fall from the plant and curl up on the ground. The pupae develop inside a silken cocoon over 7 to 15 days in soil at a depth of 4–10 centimeter or in cotton bolls or maize ears (Tay *et al.*, 2013; Agro Atlas, 2013). The life cycle of *H. amigera* has been presented (Figure 2:1).

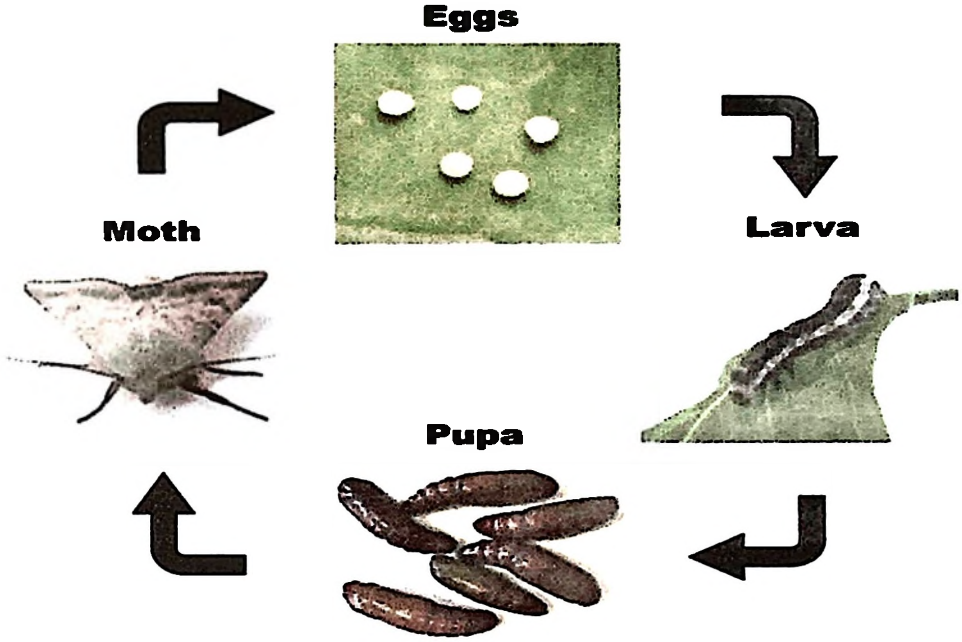


Figure 2:1Life cycle of *H. armigera*

The Larva of African boll worm is a serious pest on outdoor crops (cotton in particular). Serious damage has been reported from both WCGA and ECGA (Mrosso and Temu, 2008). Damage to cotton plants occurs through feeding of the larvae on the plant parts. Single larva of *H. armigera* consumes 6.00-6.26 fruiting bodies of cotton during its larval stage and the damages are very high during larva instars 3, 4 and 5 (Garcia, 1980). As larva feeds on leaves, buds, growing points, flowers, square and fruit (Plate 2.2) leaves are damaged and slows down plant growth because the leaf area index for effective photosynthesis is reduced as results, assimilates partitioning to the sink is reduced and consequently productivity of the cotton. Feeding on flowers prevent fruits formation and feeding on fruit causes the main economic damages to cotton productivity as seed cotton will not be produced and if any then the quality of lint is affected (Mrosso and Temu, 2008).

The holes serve as entry points for secondary infection by pathogens causing diseases that lead to fruit decay. Once bollworms burrow into the fruits endocarp are difficult to reach and to control with insecticides (Kibata, 2002). Damage can be serious with total loss of bolls in heavily infested plants. Yield losses reported due to bollworms in Ghana in the absence of an efficient management intervention range from (39 to 55%) worldwide exceed USD 2 billion, and the cost of insecticides used to control these pests is over $1 billion annually (Salifu, 1996).

Plate 2.2: *H. armigera* larva feeding on cotton boll

H. armigera is pervasive in central and southern Europe, temperate Asia, Africa, Australia and Oceania, and has recently been confirmed to have successfully invaded Brazil (Tay *et al.*, 2013). It is a migrant species, able to reach Scandinavia and other northern Countries. In Tanzania the insect pest is widely spread all over the country and it has extensive primary and secondary host range for its survival (CABI and EPPO, 1996).

The success of cotton bollworm is geared by its highly polyphagous behavior, high fecundity and migratory behavior. The most important crop hosts are Cotton, Vegetables, Pigeon pea, Chickpea, Maize, Rice, Sorghum and Cowpea (Robinson *et al*., 2010). Other hosts include Groundnut, Okra, Peas, field Beans and Soybeans. Tobacco, Potatoes, Flax, Dianthus, Pelargonium and Chrysanthemum are likewise infested by the pest. In Russia and neighboring countries, the larvae populations are found in more than 120 plant species, favouring *Solanum, Datura, Hyoscyamus, Atriplex*, and *Amaranthus* genera (Agro Atlas, 2013).

2.6.2 Biology and importance of *Aphis gossypii*

Aphis gossypii Glover (Hemiptera: Aphididae) is a polyphagous small, soft-bodied and slow moving yellowish or dark green insects that uses their piercing sucking mouth parts to feed on plant sap. They usually occur in colonies on the undersides of tender terminal growth the adult aphid varies in colour from light to dark green and those which has dark siphunculi (Slosser *et al.,* 1989). At high temperatures and in crowded environments, adult aphids are pale yellow in colour (Blackman and Eastop, 1984). The length of an adult cotton aphid is approximately two millimetres, and the insects are pear shaped. Mrosso and Temu (2008) eluded that; there are both winged and wingless asexual adult (Plate 2.3) aphids that can be seen in Tanzania. According to Miyazaki (1987), alate cotton aphids have well-developed and larger compound eyes as compared to the apterae.

First-instar cotton aphids have four segments in the antenna, whereas second-instars nymphs have five segments. There is not much visible difference between the second and third instars with the exception that, the second instars have developing wings and third-instars have small wing pads. The fourth instars have developing wings that are distinctly visible. Third instars have no setae whereas fourth-instars have setae on the margin of the genital plate (Ebert and Cartwright, 1997).

The role of reproductive male cotton aphids might be to mate with oviparous females to produce eggs that are able to over season (Kid, 1995). It is believed that male cotton aphids are produced late in the season through sexual reproduction with oviparous female and production of eggs that can survive the over seasoning (Parajulee *et al.*, 2003).

Plate 2.3: Cotton parthogenetic aphids CABI, EPPO (1996)

Aphis gossypii (Grover) suck juice from the plants and cause young leaves to curl downward at the edge and to crinkle turn yellow and fall off (Plate 2.4), growing tips are attacked and become stunted during heavy attack.

Source: CABI, EPPO (1996)

Plate 2.4: Cotton aphids damage

The honeydew, a sugary solution excreted by the aphids is noticed as a shiny deposit on leaves, making them dark green (Plate 2.5A). The appearance of sooty mold on plants may be the first time that an aphid infestation is noticed. The drops can attract other insects such as ants that will feed on the sticky deposits (Bergamin, 1954; Compos, 1960; Vendramin and Nakano, 1981). Honey dew that falls onto exposed lint in open bolls (Plate 2.5B) causes serious problems at the textile mill (Slosser *et al.*, 1989; Leser *et al.*, 1992).

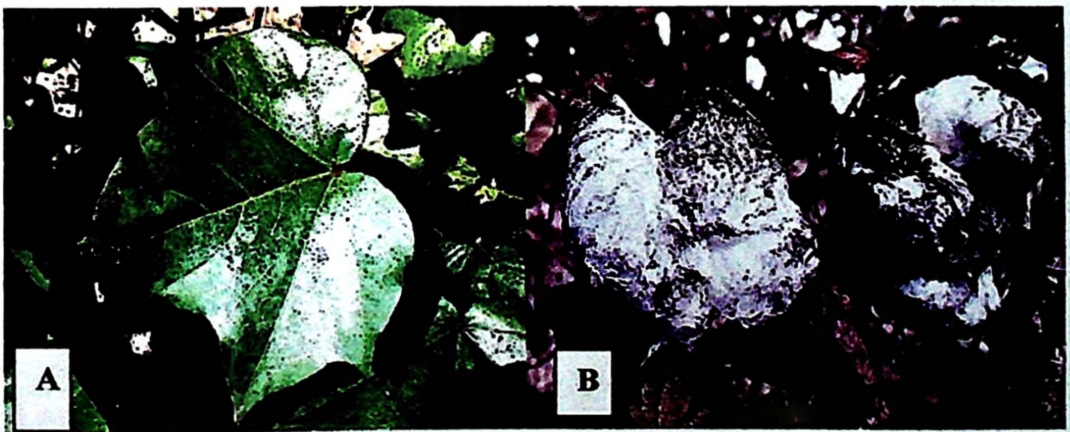
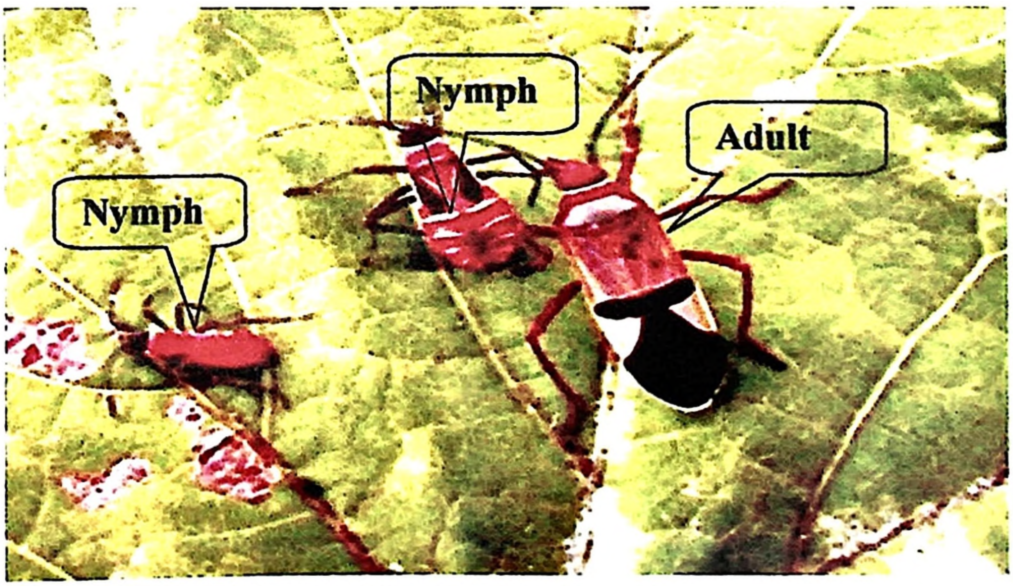


Plate 2.5: Cotton aphids sticky honey dew on leaves (A) and sooty mould on the lint (B)

During the spinning process sugars in the honey dew on contaminated lint accumulate on machinery which interferes with the processing. Aphid infestation causes foliar alterations and delay of the plant growth. Such negative effects interfere with the physiology of the cotton plants (Cacagnolo and Sauer, 1954). Sand particles trapped by the honey dew abrade and cause premature wear to machine parts. In addition *A. gossypii* is a virus vector, thus through virus transmission and subsequent infection cotton yield can be reduced 30 - 40% of the total yield anticipated (Costa, 1972).

2.6.2 Biology and importance of cotton stainers, *Dysdercus* spp

Pyrrhocoridae is a family of insects with more than 300 species world-wide. Many are red coloured and are known as red bugs (Plate 2.6). Some species of cotton stainers are "true bug" with piercing and sucking mouthparts, the head and pronotum are bright red; the remainder of the body is dark brown crossed with pale yellow lines. Immature stages are smaller but resemble adults without wings (Schaefer and Ahmed, 2000).



Source: BAYER (2013)

Plate 2.6: Nymphs and adult of cotton stainer

Dysdercus spp (true bugs) feed by sucking the juice from cotton bolls, this feeding activity also infest cotton lint with nematospora fungi and it is the secondary effect of this fungi which leaves an indelible yellow-brownish stain on cotton crops (Freeman, 1974; Ahmad and Schaefer 1987; Yasuda, 1992; Kohno and Bui Thi, 2004) (Plate 2.7).

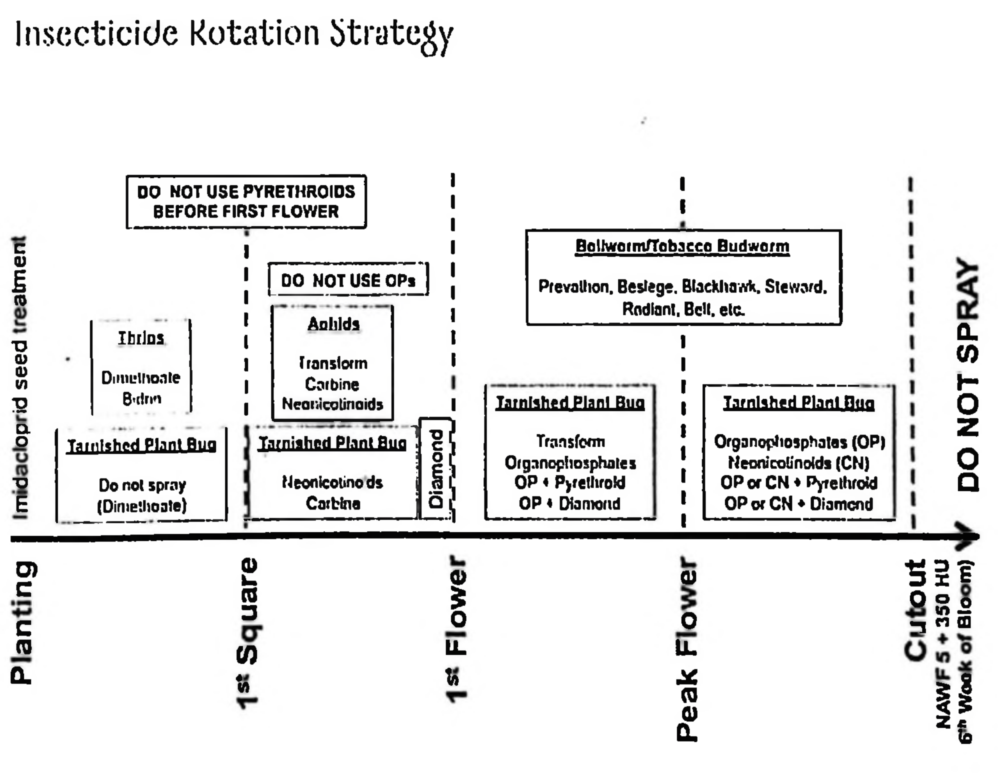
Plate 2.7: Yellowish seed cotton as a result of cotton stainers

2.7 Management of the Major Pests of Cotton

2.7.1 Chemical control

In both WCGA and ECGA just like anywhere else in the world where cotton is grown pesticides are used as the most effective first line of defense against *H. armigera* (Hubner), *Earias*. spp (Walker and Boisduval), *P. gossypiella* (Saund), *A. gossypii* (Glover), and *Dysdercus*. sp. Among these insect pests bollworms are said to be most highly susceptible to synthetic pyrethroid insecticides such as deltamethrin, lambdacyhalothrin, zetacypamethrin, alphacypermethrin and many others. Nevertheless, pyrethroids are relatively ineffective against cotton field pests such as aphids which often occur concurrently with bollworms. Thus synthetic pyrethroids are often mixed combined with organophosphates insecticides such as profenofos, dimethoate, chlorpyrifos and some others synergist to buttress its efficacy (Golob *et al.*, 1985; Golob and Hanks, 1990).

Insect control recommendations often include the use of treatment thresholds, insecticides and suggested rates for specific pest. The recommendations are divided into three distinct section (Figure 2.2) based on stage of plant development (emergence to first square; first square to first bloom and after first bloom mainly because populations of important pests tend to vary in relation to the stage of plant development (MSUES, 2015).



Source Angus (2015)

Figure 2.2: Insecticide Rotation Strategy

2.7.2 Biological control

Predators and parasites can often prevent a pest population from reaching unmanageable levels, and the control they provide is often cheaper, better, and longer-lasting than that provided by insecticides (Pedigo, 1989). However, one has to beware of population levels of naturally occurring predators and parasites and recognizing that treatment thresholds can often be increased when predator's population levels are high. Fortunately, cotton producers in Western Tanzania have a wide range of naturally occurring biological control agents that play an important role in managing pest populations (Kabissa, 1989). Collectively, these biological control agents are alternative methods of controlling cotton insect pests in WCGA because most cotton farmers do not use insecticides due to high prices and unreliable supplies. However often times the full economic value of these biological agents is not recognized or even appreciated. Severe outbreaks resulting in high levels of crop loss or unusually high control costs seldom occur unless natural control has been disrupted (Mrosso and Temu, 2008).

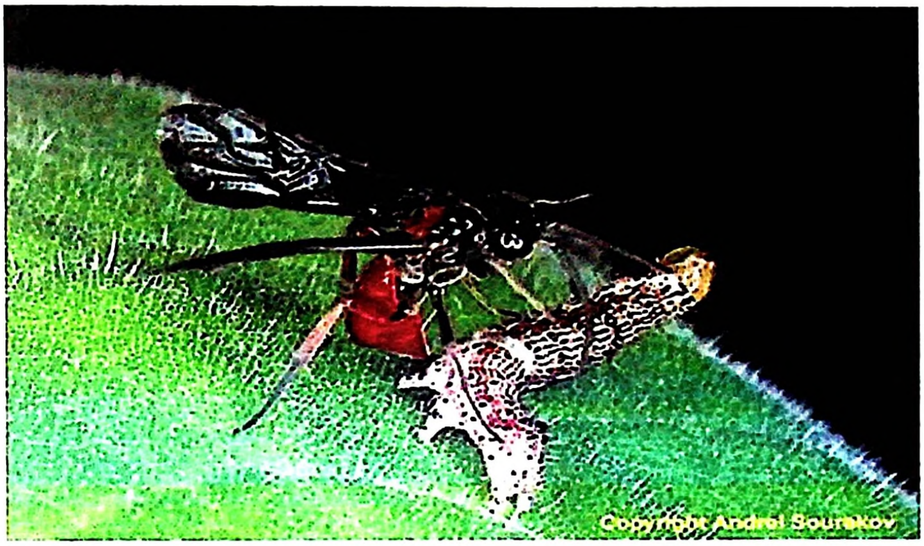
To gain the maximum economic benefit from the control provided by these natural control agents, growers need to know which species are beneficial, how to identify them and insect herbivory they attack, what factors enhance their usefulness, when they are most useful, and when they may not provide effective control (Waterhouse and Sand, 2001) Some of biological agents include predators such as Assassin bugs (*Phonoctonus* spp.), Ladybird beetles (Coccinellids) (Figure 2.3), both Green and Brown Lacewings in the family of Chrysopidae and Hemerobiidae (Figure 2.4), different spp. of Spiders (Araneae) (Figure 2.5), Hover fly - *Cardiochile nigriceps* (Plate 2.8) and others different spp of birds, Lizards and Frogs.

Figure 2.3: **Assassin bugs (*Phonoctonus spp.*) left and lady bird beetles (Coccinellids) right**

Figure 2.4: **Adult green lacewing (left) and brown lacewing (right) courtesy Bugwood network**

Source: Waterhouse (2001)

Figure 2.5: Predaceous spiders



Source: Waterhouse (2001)

Plate 2.8: Adult *Cardiochile nigriceps* ovipositing eggs in the bollworm larva

Most species of insect pests are susceptible to one or more known diseases. In some cases, the impact of the disease is relatively subtle and slows population development. In other cases, the disease is quite dramatic, providing quick, almost total control of a pest population that has neared or exceeded damaging levels examples are Hoverflies (Diptera: Syrphidae) (Plates 2.8), *Cardiochiles nigriceps* a wasp that parasitizes and cause neozygites fungal disease which attacks bollworms, and loopers (Waterhouse and Sand, 2001).

2.7.3 Cultural practices

No-till planting has most significant features of establishing fire ants which are very aggressive predators of bollworm eggs, larvae, and pupae but the risks associated with is, fire ants will tend to protect certain sucking pests, such as aphids and three-cornered alfalfa hoppers, causing their numbers to be higher (Angus *et al.*, 2015).

Bollworms over season as pupae, 1 to 3 inches deep in the soil thus dry season tillage destroys some pupae and disrupts exit tunnels, reducing numbers that emerge from over seasoning. Rain season tillage destroys weeds and/or cover crops by tillage or spraying herbicide at least 3 weeks before planting minimizes risk of cutworm problems (Nyambo, 1989).

Early maturing, short-season varieties are more likely to escape attack/damage from late-season infestations of bollworms, tarnished plant bugs. Aphids and whitefly populations tend to be reduced on smooth leaf varieties while bollworms tend to deposit fewer eggs than on hairy varieties (Angus *et al.*, 2015). Varieties with okra leaf trait allow improved canopy penetration of foliar insecticide treatments. This trait also has been associated with resistance to whiteflies (Nyambo, 1989) Nectariless varieties tend to lower plant bug populations by reducing egg production capacity of most moth species because of reduced nectar availability. High glanding varieties have additional gossypol glands which increases resistance to bollworms whereas dual gene transgenic varieties (Bollgard II and Widestrike) provide better suppression of bollworms and other caterpillar pests than Bollgard cotton did (Bacheler *et al.*, 2004).

Early sowing, appropriate spacing and proper plant stand density will reduce insect pest infestation . In years when early African bollworm attack occurs, early sown cotton may lose some of its bottom crop but can later compensate for this loss by producing a crop later in the season, provided the soil moisture and nutrients are not limiting while in years of late African bollworm attack, early sown cotton will have already set its main crop and so will escape serious damage (Angus *et al.*, 2015). Regular border vegetation management and weeding of *Hibiscus, Sida, Soda, Solanum* and *Corchorus*, which alternative hosts for such pests as jassids, aphids, lygus and cotton seed bug, late season pests such as spiny bollworm, pink bollworms, cotton stainers, blue bug are prevented from building up to damaging numbers (Mrosso and Temu, 2008). Cotton is a poor competitor to weed for soil moisture, nutrients and sunlight. In a field full of weeds cotton will suffer from atrophy dwarfing and becomes less able to withstand the attacks of jassids or aphids, which commonly occur on young cotton crop and result in a delay in maturity and harvesting (Angus *et al.*, 2015).

Cotton seed and seed cotton left in or around buildings and stores can be dangerous source of infestation by pink bollworm, stainers, seed bugs, blue bugs and other pests as it enables them to survive when no other supply of food may be available Cotton should always be picked regularly so that the open bolls are less likely be attacked by cotton stainers and seed bugs (Mrosso and Temu, 2008). Regular picking will always escape rains and dirt that can also spoil the cotton of open bolls, the sooner cotton is picked the greater the percentage of grade "A" and the easier it is to grade. In Tanzania the uprooting and destruction of cotton stalks as soon as possible after harvest helps to reduce populations of pests such as stainers, spiny and pink bollworms quite dramatically. The uprooting and burning dates for the different cotton growing areas in Tanzania are as shown (Table 2.1).

Table 2.1: Recommended dates for plant uprooting and destruction

Area	Optimum time for sowing	Last date for uprooting and burning
WCGA		
Mwanza, Shinyanga, Mara, Geita, Simiyu, Kagera, Tabora, Singida and Kigoma	November to December	Mid – September
ECGA		
Iringa and Manyara	December to January	Mid – September
Coast, Morogoro, Kilimanjaro and Tanga	Mid February to Mid – March	Early – November

Source Mrosso and Temu (2008)

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CHAPTER THREE

3.0 EFFECTIVENESS AND AUTHENTICITY OF INSECTICIDES USED IN WESTERN COTTONG ROWING AREAS OF TANZANIA

Jeremiah J. Kabissa[1] and Gration M. Rwegasira[1]
[1]*Department of Crop science and Production, P.O Box 3005 SUA, Morogoro, Tanzania*

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3.1 Abstract

A series of farmer's interview were conducted using structured questionnaire from September 2014 to June 2015 to assess the cotton grower's perception of the effectiveness of insecticides currently distributed for the control of cotton pests in the Western Cotton Growing Areas of Tanzania (WCGA). A total of 175 respondents (35 in each of Itilima, Kwimba, Maswa, Meatu and Misungwi districts) were interviewed. Samples of insecticides that had been supplied to farmers through either Tanzania Cotton Development Trust Fund (CDTF) or private agrochemical-dealers were randomly selected and collected for authenticity tests at the Tropical Pesticides Research Institute (TPRI). Obtained results indicate that of the 18 samples collected (44.44%) of the products (Agromethrin, Bamethrin, Duduall, Duducyper, Karate and Lambdex super) supplied through CDTF and (55.56%) of the products (Agrithiote, Akrimactin, Duducyper, Duduthrin, Mupacron, Select plus Supercron and Sume) were supplied through Agro shops, out of which (Agrithiote, Akrimactin, Banofos, Duducyper, Mupacron, Sume, Twigathiote and Supercron) were re neither registered nor approved by TPRI for use in cotton.

Over (65%) of the collected samples had expired already despite being on the market. Most of agro-dealers never worried about selling expired products. Vendors in several outlet shops were unskilled and lacked basic training in pesticide handling and appropriate use. Most of, the pesticides were sold at open markets without any shelter to protect them from rain, direct sunlight and dust. Most important is that timing of the first spray, frequency of spray, lack of knowledge on scouting and estimation of damage threshold were critically translated to the insecticides inefficacy.

Key Words: Cotton, pests, Insecticides accessibility and users perception.

3.2 Introduction

Cotton is Tanzania's second most important cash crop after coffee. However, its productivity remains low relative to the area of 0.5 million ha under cultivation (TCB, 2010). The 2012/2013 crop recorded the highest ever production of 578915bales (181kg each). Government provision of subsidies on both cotton seeds and insecticides which allowed access by farmers to sufficient inputs has been cited as the reason for such yield gain (TCB, 2013). Apart from subsidies, limited adoption of improved technologies has also been cited as a cause for low productivity (Cox, 1985). Cotton marketing in Tanzania was liberalized and ginning privatized in early 1990s to overcome declining productivity which was associated with low price payable per unit sale (Mbilinyi, 1996). Privatization led to removal of farm input subsidies leading to escalated input price with limited profitability. The cost of 15 litres of endosulfan for instance (a spray requirement for 1ha/season) rose from US$26 in 1992 to 112 US$ in 1996, and from 112US$ in 1996 to US$201.15 in 2015. The price of seed cotton also tremendously increased from 150TZS/kg past 2009 to 600TZS/kg in 2015 (Mwalukasa E. unpublished data).The lower cost but limited availability of pesticides supplied through CDTF stimulated farmers to look for alternative sources, some of which are agro-shops and auction markets in Meatu, Kwimba, Maswa, Misungwi and Bariadi (Bariadi, Itilima and Busega) Districts (Kabissa *et al.*, 1998).

Changes in input acquisition procedures led to demand for production technologies with lower cash input requirements which triggered a shift from the use of oil based (ULV) insecticides to water based ones (E.C, S.C and W. P) and consequently changes in the dosage rates and insecticide application equipment's (Mbilinyi, 1996). The recommendation of insecticide spray regimes based on cotton phenology is divided into four distinct stages. a) From emergence to first square were by seeds are dressed by using Imidaclopid, bronocot and nordox, after emergence organophosphates (Ops) are recommended for the control of thrips but not bugs, b) First square to first bloom do not use pyrethroids (P) and Ops as the two will kill both pest and natural enemies. Carbamate (C) and Neonicotinoids (CN) are recommended for the control of aphids and bugs, c) After first bloom it is recommended to spray pyrethroids for the control of bollworms complex, soft bodied insects and bugs. Other insecticides which are also recommended at this stage are Ops, CN, CN or Ops + Pyrethroids, Ops or CN + Diamond (Novaluron), d) 6thweek after bloom (Cutout) do not spray so that the crop can become refuge (MSUES, 2015). The current study aimed at identifying the different types of insecticides that are commonly used in managing the cotton insect pests in the WCGA to examine the farmers' perception of the efficacy of the used insecticides against cotton insect pests and to determine the potential loopholes that might be compromising the efficacy of the insecticides being used. Here we report the findings from the study conducted from September 2014 to September, 2015 which went a. further mile into re-examining the authenticity of commonly used insecticides.

3.3 Materials and Methods

3.3.1 Survey study

Structured questionnaires with closed and open ended type of questions were administered to a total of 175 respondents (thirty five respondents each of the districts namely; Itilima, Maswa and Meatu of Simiyu Region; Kwimba and Misungwi of Mwanza Region. Of the 35 respondents in each district, 30 were cotton growers and 5 were key informants in cotton sector at different levels such as agricultural extension officers, cooperatives officers and cotton inspectors. Ten villages were randomly selected in each district and the number of respondents/village varied by ± 2 depending on the availability of farmers and key informants (Appendix 1).

The collected data were analyzed using the Statistical Package for Social Science (SPSS-version 18.0 Inc. Chicago, 2008) to examine; which are the commonly used pesticides, user's perception of pesticide effectiveness, farmers' knowledge about the pesticides they commonly use on cotton (status and recommended uses inclusive of expiry and validity date, timing of spraying, spray intervals, dosage rates, and spray coverage), availability and accessibility of the recommended insecticides. The knowledge of the shop keepers/ pesticide vendors were also assessed particularly their education level.

In order to authenticate the active ingredients, samples from five most commonly used out of the more than twenty insecticides in the five districts were collected, labeled using numbers and sent to the Tropical Pesticides Research Institute (TPRI) laboratories for chemical analysis. Samples sent for analyses with their corresponding numbers in brackets were; Ninja (1), Bamethrin (2a), Bamethrin (2b), Agrothrin (3), Zetabestox (4) and Duduall (5).

3.3.2 Determination of active ingredients

Active ingredients in the collected samples were analyzed through computerized Gas Chromatography (Varian CP 3800), equipped with Flame Ionization Detector (FID). The column used was Megabore column 1.83m * 2m (i.d) packed with 5% Silcone 30, 3-5μm capacity.

Using analytical balance 4 grams of pesticides (E.C) samples were accurately weighed into 10mls solution volumetric flask of appropriate solvent; Acetone for Lambdacyhalothrin and Deltamethrin, Chlorypyrifos for Alphacypermethrin and Zetacypermethrin (Worthing and Hence,1991). The samples were mounted on mechanical shaker for five minutes cold extraction then syringe micro filtered to remove particles as per protocol (Franco and Jasionowska, 2013).

Before analysis, two injections were performed to equilibrate the system and then carried out duplicate injections of calibrations standard. Using a syringe needle, 3 μl analytes were injected into the Gas Chromatography, the operating conditions for the stationary phase was; injector (250 ^{0}C), detector (280 ^{0}C) and (270 ^{0}C, programmed at 80 ^{0}C initially held for 1 minute, then 270 ^{0}C at the rate of 5^{0}C/minute and held for 10 minutes) the mobile phase (carrier) was Nitrogen gas, where Hydrogen gas and Oxygen gas were used for FID combustion (Karthikeyan and Srinivasan, 2010; Rusibamayila *et al.*, 1998). The concentrations of the active ingredients were computed by comparing the peak retention time and area of the sample of unknown concentration against that of the known concentration of standard. Obtained data for active ingredients were computed as:

$$A.I\%\ content = \frac{(Area\ of\ a\ sample \times Dilution\ factor \times purity\ of\ the\ standard) \times 100}{(Slope \times weight\ of\ sample \times conventional\ factor)} \quad \ldots\ldots (1)$$

The results were evaluated using FAO/WHO standards

3.3 Results

3.3.1 Most damaging insect pest in the study districts

Most respondents, 90% (165/175) indicated the pest, *H. armigera* as most dominant and destructive pest followed by *A. gossypii*, 7.5% (12/175) while *P. gossypiella* and *Earias* spp were least accounting for 1.3% (2/175) and 0.6% (1/175) respectively (Table 3.1).

Table 3.1: Most damaging insect's pest as indicated by cotton farmers

Insect pest	Respondents	Percentage
H.armigera	165/175	90.6
A gossypii	12/175	7.5
P. gossypiella	2/175	1.3
Earias spp	1/175	0.6

n=175

3.3.2 Commonly used pesticides

It was established that only insecticides are used by cotton growers in WCGA and no cases reported of mixing shown in pesticides for the control of insect pests. The commonly used insecticides are indicated (Figure 3.1). These included; Banofos 720E. C (Profenofos 720g/L), Agrithiote 40 E. C (Dimethoate 400g/L), Duducyper 5% E. C (Cypermethrin 50g/L), Supercron 500 E. C (Profenofos 500g/L), Sume dimethoate 40 E C (Dimethoate 400g/L), Select plus 315 E. C (Profenofos 115g/L + Lambdacyhalothrin 200g/L), Twigathiote 40E. C (Dimethoate 499g/L), Mupacron 500 E. C (Profenofos 500g/L), Akrimactin 1.8 E. C (Abamectin 18g/L) and Duduthrin 5 E. C (Lambdacyhalothrin 50g/L. Follow up to research stations with national mandate on cotton research (ARI-Ukiriguru and ARI- Ilonga) indicated that none of the researchers was informed about the use of unregistered insecticides despite being traded on and used by farmers in cotton production. Such pesticides have been registered for use on other crops mainly fruits, vegetables, tobacco and coffee but not cotton.

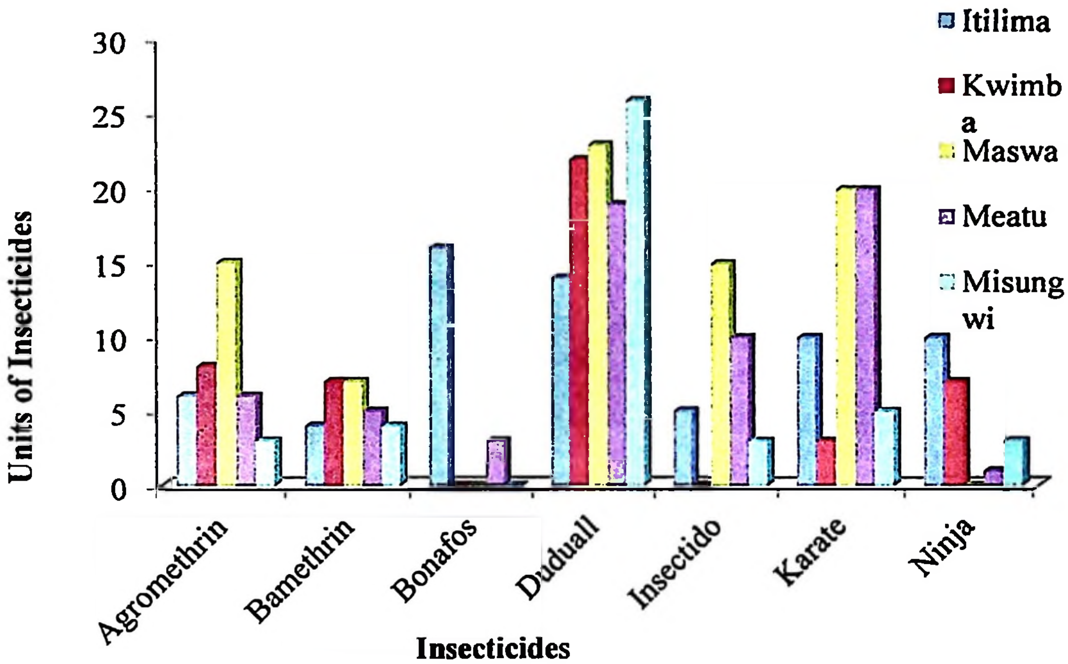

Figure 3.1: Commonly used insecticides in surveyed Districts

3.3.3 User's perception of effectiveness of insecticides

Based on farmers' perception all insecticides were fairly effective against the key pests *H. armigera* and *A. gossypii* despite the limited variation on knock down time and residual effect and some products being used but not tested and approved for the control of cotton pests, Collected data suggest that most cotton farmers had no understanding on when spraying should , which insecticide to use, against which pest, at what stage of cotton growth stage and how to spray correctly and effectively. Other irregularities included limited knowledge on scouting, spraying interval, frequency of insecticide application and dosage in all five districts covered (Figure 3.2A and 3.2B).

Figure 3.2: Itilima district Officials inspecting pesticide in one of agro-shops

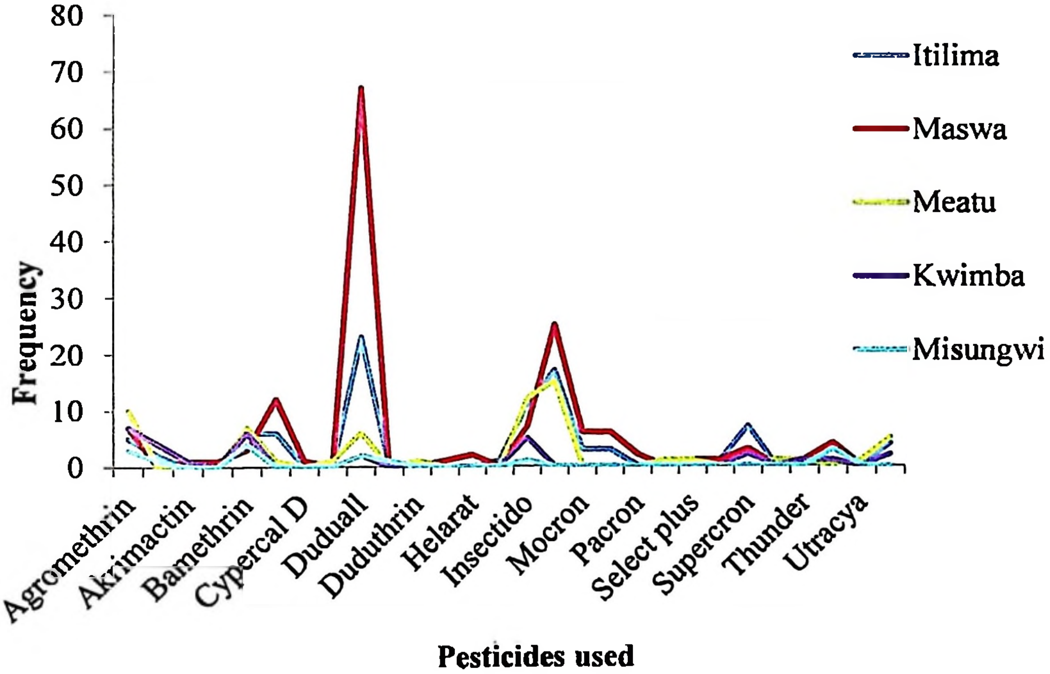

Figure 3.3: User's perception of pesticide effectiveness

3.3.4 Pesticide procurement and distribution channels

Pesticides are generally procured centrally by CDTF through tenders and dispensed to farmers through cooperative societies and ginners. However, there have been delays in dispensing pesticides to farmers and unclear way in which the pesticides are distributed leading to many farmers resorting to nearby agro shops (Table 3.2). Many of the agro shops visited sold assortment of pesticides some of which are either inauthentic or unregistered for control of cotton insect pests and a few of which were expired. Shockingly, about 95% of separately interviewed shopkeepers were not well informed about pesticides they were selling.

It is very unfortunate that, currently TPRI does not have District pesticides inspectors the enforcement of the pesticides act and regulations as stipulated by the MAFSC. Because of that, the quality and authenticity of the traded products is compromised and such products are sold at the expense of cotton growers ignorance, always results into cotton growers ending up buying expired products, counterfeits and products which are neither tested nor registered for use on cotton

Table 3.2: Pesticides Distribution Channel

District	Unit of cotton pesticides sold per dealer				
	Agro-shop		CDTF		Total Units
	Units	Percentage	Units	Percentage	
Itilima	72	45	16	10	88
Misungwi	9	5.7	53	33.3	62
Meatu	59	36.9	36	22.5	95
Maswa	9	5.7	36	22.5	45
Kwimba	1	0.6	57	35.8	58

n = 175

1 Unit of insecticide is equivalent to1 Acre pack sold

3.3.5 Availability and accessibility the insecticides

The survey revealed that almost all recommended insecticides were available at both CDTF outlets and agro shops. However, accessing insecticides from CDTF was the problem. Apart from bureaucratic procedures, access to information by growers was a big setback. Respondents indicated that in most cases ginners and cooperative society leaders do not inform cotton farmers about the availability of insecticides in their respective villages. Moreover, lack of credit facilities or subsidies for inputs undermines farmers' ability to timely purchase insecticides as most of cotton farmers did not seem to have saving for next season's input purchases. The high price of cotton inputs and lack of subsidies meant that cotton famers often left their fields unsprayed at mercy of natural enemies alone.

3.3.6 Agro shops vendor knowledge of pesticides

It was established that most of the agro shops owners employ unskilled personnel who never attended any training on pesticide handling and uses. As such the sales personnel could not provide sufficient instructions to cotton farmers on pesticide dosages, timing of applications and dilution ratios. Figure (3.3) shows the percentage and frequency of agro shop vendors who have the knowledge of pesticides viz those who do not have that knowledge.

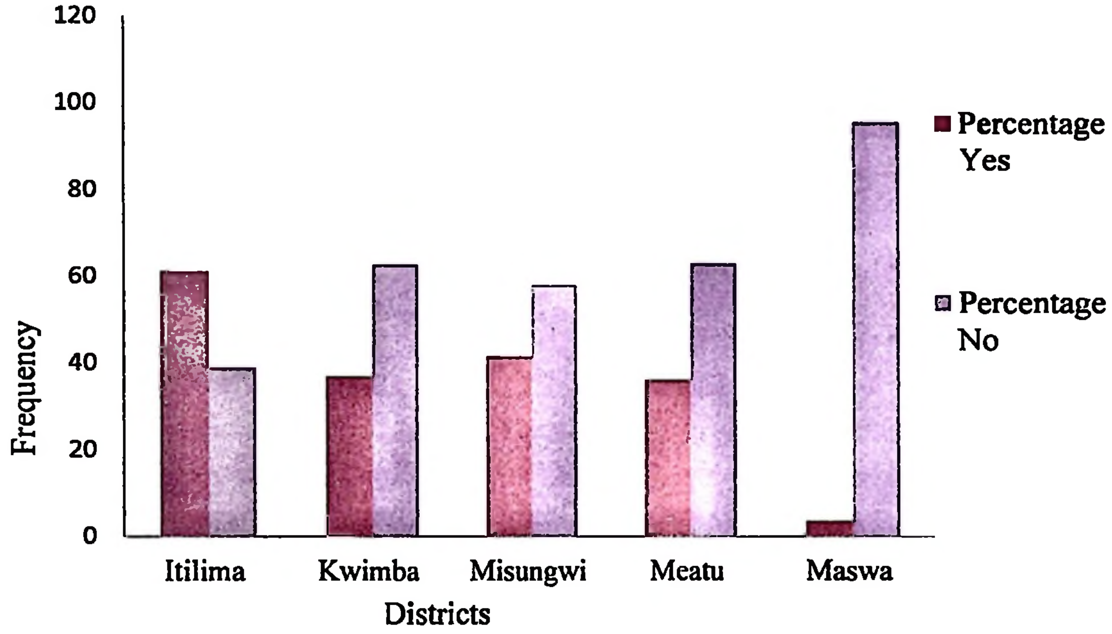

Figure 3.4: Assessment of vendor's knowledge of Pesticides and their uses

3.3.6 Number of days to first round of insecticide spray

Collected data suggest that (31%) of farmers start spraying within 14- 30 days after emergency (DAE), (66%) start spraying within 31-60 DAE and (3%) of farmers start spraying 61-90 DAE but based on the cotton phenology 14-35 days is the vegetative growth of cotton, 40-80 DAE is the reproductive stage where by growers real need to closely inspect their fields for insects pest. According to Mrosso and Temu (2008), spraying should commence at 40 DAE unless there is an outbreak of insect pests just before the recommended time (Table 3.3).

Table 3.3: Number of days to 1st spray

District	No of days to 1st round of insecticide spray		
	1 – 30 (%)	31 – 60 (%)	61 – 90 (%)
Itilima	7 (19.4)	27(75)	2(5.6)
Misungwi	31(86.1)	4(11.1)	1(2.8)
Meatu	1(5 (3)	32(97.0)	0(0.0)
Maswa	5(17.9)	22(78.6)	1(3.6)
Kwimba	8(29.6)	18(66.7)	1(3.7)

n= 175

3.3.7 Insecticide spray intervals and application frequency

It was learnt that an average frequency of (61%) of farmers from Kwimba and Maswa, (16.7%) of farmers from Itilima, (33.3%) of farmers from Meatu and (100%) of farmers from Misungwi re-spray their fields within seven days; (44%) Of Itilimas farmers, (27.8%) of Kwimba farmers,. (33.3%) of Maswa farmers resprayed their cotton fields within eight to fourteen days; (16.7%) Itilima farmers, (11.1%) of Kwimba farmers and (66.7%) resprayed their field within 16 to 21 days; (13.9%) of Itilima farmers and (5.6%) of Kwimba farmers were the extremist and resprayed their field within 22 to 44 days, (Table 3.4).

Table 3.4: Insecticide spray intervals and application frequency

	Days			
	3-7	8-15	16-21	22-44
District	(%)	(%)	(%)	(%)
Itilima	16.7	44.4	16.7	13.9
Kwimba	56.6	27.8	11.1	5.6
Maswa	66.7	33.3	0.0	0.0
Meatu	33.3	0.0	66.7	0.0
Misungwi	100	0.0	0.0	0.0

In all the five districts covered, spraying of insecticides was being irregularly done because farmers neither scouted for pests nor assessed the damages caused. Instead, farmers were more reliant on the amount of rainfall, i.e. the more the rainfall the more the frequency of spraying and vice versa. Generally, insecticide spraying was dependent on farmers' liquidity as it would dictate when insecticides would be bought and applied. Generally (84.72%) of farmers sprayed once on average, (18.9%) sprayed twice or thrice while (3.9%) sprayed four times. Thus most cotton growers spray their cotton fields once or twice per season. Majority of farmers either did not have access to pesticides or prevailing weather conditions, rains in particular did not warrant spraying to be done. In general farmers tend to believe that insect abundance on cotton and hence the damage caused tends to be linked to the amount of rain falling during the season and vice versa.

3.4 Laboratory Chemical Analysis for Active Ingredients (a.i)

The outcome of laboratory analysis for the active ingredients are as presented (Table 3.5). All active ingredients of the eighteen insecticides samples were similar to what was indicated on the label and the registration documents affirmed to the tolerance limit stipulated jointly by WHO and FAO (Costa, 1997).

Table 3.5 Outcomes of the Laboratory analysis of Insecticides active ingredients

Lab No	Batch No.	Trade Name	Compound Name	Official Declared Active Ingredient	Lab Analytical Results of Active ingredients	Emulsion Stability (physical test)	Solvent for extraction	Remarks
1	KR 14-0043	NINJA 5E	Lambdacyhalothrin 50g/l	Lambdacyhalothrin	5.5%w/v	Uniform	Acetone	Meet required Specification
2a	201210	BAMETHRIN 2.5EC	Deltamethrin25g/l	DELTAMETHRIN	2.4%w/v	Uniform	Acetone	Meet required Specification
2b	AS 20111030	BAMETHRIN 2.5EC	Deltamethrin25g/l	DELTAMETHRIN	2.458%w/v	Uniform	Acetone	Meet required Specification
3	S 20131218	ZETABESTO X 10EC	Zeta-Cypermethrin100g/l	Zetacypermethrin	Zetacypermethrin 10.32%w/v	Uniform	Acetone	Meet required Specification
4	25112012	DUDU-ALL 450EC	Chloropyrifos 350g/l Cypermethrin 100g/l	Chloropyrifos Cypermethrin	Chloropyrifos :34.48%w/v Cypermethrin: 10.64%/w/v	Uniform	Acetone & chlorpyrifos	Meet required Specification
5	SHQI 2011H1011	AGROMETHRIN 10EC	Alphacypermethrin 100g/l	Alphacypermethrin	10.7%w/v	Uniform	Acetone	Meet required Specification

3.5 Discussion

Based on the obtained results, *H. armigera* was indicated by most of the respondents as most dominant and destructive pest. The rapid buildup in number of this pest due to its high fecundity (one female bollworm moth can lay 250-1500 eggs), mobility and multiple hosts (1stgeneration on legumes crops, 2nd generation on corn/maize and 3rd generation caterpillars generally are the first infestation of cotton), ability to enter facultative diapauses all allows the pest to adapt to different climate condition (Clearly *et al.*, 2006).

Feeding habit of *H. armigera* causes damage on the squares, buds, flowers and fruits of the most valuable crops like cotton and thus high economic damage can be caused even at low population densities (Cameron, 1989; CABI, 2007; Rahman, 2012). This pest has for long been considered to be the most damaging insect pest in WCGA due to the costs used to control the pest which is approximately TZS 12 000 per acre and TZS 30 000 per acre for the insecticides such as Banofos and Supercron enough to cover 4 sprays supplied through CDTF and private Agro-shops respectively. Such expense is unbearable by most of Tanzanian farmers who are largely subsistent farmers.

Other cotton agronomic practices like weeding are also costly. Clearly *et al.* (2006) reported that, in Australian Agriculture, control of *H. armigera* costs approximately USD 225.2 million/year. According to Plantwise knowledge bank (2012) two to three larvae on cotton plant can destroy all bolls within 15 days. Ting (1986) reported that young larvae (second and third instars) can cause up to (65%) loss to cotton yield. The prevalence of high damages caused by of *H. armigera* on cotton could be associated with repeated use of insecticides in the past (McCaffrey *et al.*, 1989; Trowell *et al.*, 1993; and Fitt, 1994). A prolonged use of insecticides by farmers in the WCGA could have led to resistance of particularly *H. armigera* to pyrethroids. However this supposition needs purposeful study on the efficacy of pyrethroids on *H. amigera* for tangible conclusions to be made.

Aphis gossypii was indicated as the second most important cotton pest. Similar report has been made in the Eastern Cotton Growing Areas of Tanzania (Mrosso *et al.*, 2006).Aphids feed by sucking cell sap from their host plants harbouring the underside of the leaves, inside of flower and on buds but in some occasions the entire plant might be covered at high population densities which is the intrinsic biotic characteristic of the insect (Vanemden and Harrington, 2007). Such rapid development and parthenogenetic mode of reproduction in the tropics is enhanced when coupled with high temperatures and plants under water stress (Godfrey *et al.*, 2000; Vanemden and Harrington, 2007), both of which are common conditions in WCGA. The infested leaves become curled downward and appear wrinkled, mottled and chlorotic. Heavy infestation might result into wilting of matured plants while young plants suffer from atrophy dwarfing (Ebert, 2008; Leclant and Degue, 1994).

Like any other soft bodied insect such as leafhoppers, mealy bugs and scales, aphids produce copious amount of honeydews a sweet and watery excrement which serves as medium on which sooty mould grows. The sooty mold blackens the leaf and decrease photosynthetic efficiency (Elmer and Brawner, 1975). In addition, the respondents observed *A. gossypii* as the second most damaging insect pest due to the ineffectiveness of some pyrethroids which are the most commonly used insecticides in cotton production. Being contact insecticides, the pyrethroids are generally ineffective in preventing Aphids' damage because the insect hide themselves on the underside of cotton leaves and flowers. As reported by Casey (1997), the leaf curling, poor spray technique, inadequate coverage or high pH in the spray tank could contribute to the insect pest being difficult to control.

Pectinophora gossypiella is one of the most destructive pests of cotton in many areas of the world, including India, China, Brazil and Western USA (Kabissa *et al.*, 1998). However in WCGA of Tanzania, it is a potentially serious pest which is often under check by the regular destruction of crop residues and easily killed by insecticides (Mrosso and Temu, 2008). This could be the reason as to why it was not observed by respondents as a real problem to cotton growers.

Earias spp is known worldwide as spiny bollworm which is a major culprit that causes tip boring in cotton despite being seldom a serious pest (Vannilla *et al.*, 2007). The spp is considered sporadic in terms of their occurrence in one place and not another, and on one season but not the next or within a season (Vannilla *et al.*, 2007). Such characteristics make it a pest of limited significance as observed in the current study. However, since the larvae damages at all stages of cotton plants, it can at any time become a serious pest particularly in the first 20-30 DAE because the young plants have only one to several terminals which are killed. This could be of serious impact to growers' economy hence the pest should not be ignored.

Access and availability of insecticides by cotton growers was one of greatest challenges in WCGA. Following market liberalization, pesticides are imported directly from manufacturers like Rentokil, Syngenta, DVA Agro and BAYER by different local chemicals trading companies such as MUKPAR, MERU AGRO, SUBA AGRO, POSITIVE, BASF Agro, BALTON, HANGZOU and BAJUTA ENTERPRISE. Under such a free trade, quality control becomes compromised. Unfortunately, unscrupulous traders use this void of free market and farmer's ignorance to sell outdated inauthentic pesticides.

Insecticides supplied through CDTF were not easily accessible by cotton growers due to series of bureaucratic measures. CDTF uses ginners and cooperative societies to dispense insecticides to cotton growers but the inefficient distribution system in place does not cater for insecticides demand. Farmers are not informed of the availability of insecticides and sometimes insecticide prices are hiked not because of insccticide dearth but rather unnecessary reluctance of ginners to distribute them to the respective villages probably because they want to side sell insecticides or avoids the associated costs.

The poor synchrony between cotton crop growth and insecticide availability forces growers to look for alternative sources of insecticides from the agro-shops some of which are not tested and approved for use in cotton by TPRI. Such insecticides were in use and sourced from agro shops included Banofos, Mupacron, Supercron, Agrithiote, Duducyper, Sume dimethoate, Select plus, Twigathiote, Duduthrin and Akrimactin. Yet some products were found expired. The fact that cotton is highly valued crop in WCGA, the feared destruction of the crop by insect pests and the truth that high economic yield cannot be attained without effectively controlling the pest, cotton growers seek to buy insecticides from any available source including open markets regardless of the authenticity.

The delays in dispensing insecticides to farmers was due to poor planning of the ginners for the transport, selling points and lack of dedicated personnel to sell the insecticides to cotton growers. Most ginners remit insecticides to cotton growers in small quantities as they worry of losing their money.

On the other hand, the District councils inclusive of Ward and village executive and agricultural extension officers do not play their part in informing cotton growers about the availability of insecticides supplied through CDTF. Consequently, the cotton growers resort to available alternatives like agro shops and open markets. For instance, in Itilima and Meatu districts 45% of insecticides units (equivalent to 72 acre packs) were bought from agro shops whereas only 10% of insecticides units (equivalent to 16 Acre packs) were bought from CDTF via ginners agents.

Generally, the unreliable availability of insecticides supplied through CDTF, lack of subsidies, higher price of cotton inputs from agro shops caused many farmers to abandon their cotton fields unsprayed. The practice totally undermines growers' economy and compounds the pest's problem consequently affecting growers' livelihood and the economy of the country. The knowledge of vendors and agro shop keepers on pesticides was limited and scanty except Itilima district where most growers confirmed getting sufficient instruction from vendors.

Respondents in the rest of the districts (Maswa, Meatu, Kwimba and Misungwi) reported limited knowledge of vendors that often leaves growers unsatisfied and with the service provide not knowing what to do. Most of the agro shops employed unskilled personnel who never attended any training on pesticides handling and use. Lack of understanding of English language was particularly a barrier in translating information on pesticide labels to illiterate users. Surprisingly a good proportion of venders could not even read in Kiswahili. The fact that some of cotton growers are illiterate, finding vendors who are likewise illiterate compounded the problem. Consequently the use of insecticides by cotton growers was a blind operation. As such much of claimed inefficacy of insecticides in cotton is due to lack of knowledge dosage and application techniques.

Insecticides including Agromethrin, Bamethrin, Banofos, Duduall, Insectido, Karate and Ninja were the most commonly used by cotton growers. Duduall and Insectido had the highest score because they were supplied to the cotton growers in all five Districts for large quantities and sold at a cheaper price of TZS 2500/Acre pack as opposed to agro shops in which the same products were sold at TZS 3000/Acre pack. Karate ranked second probably because of its acquaintance to the farmers since 1980's: its effectiveness is based on quick knock down effect. Its active ingredient (Lambdacyhalothrin) has for long been known to be very efficacious against bollworm complex and other chewing and sucking pests except aphids.

Banofos was the most preferred of insecticides sourced from the agro shops in Itilima because of being relatively cheaper compared to Supercron, Sume, Abamectin and Select plus. Banofos was said to be very effective against bollworm complex and other insect pests of cotton. The multiple uses of Banofos in controlling vegetable pests make it a favorite for farmers in Itilima District. Most of cotton growers in Itilima district also engage themselves in horticultural crops production particularly vegetables. Ninja, a variant of Karate was as effective as Karate but being relatively new in the market led to most farmers doubting about its efficacy. Thus farmers wanted to test the quantities bought for efficacy and hence acceptability by the cotton farmers. Agromethrin and Bamethrin were least preferred by the cotton growers because of the past history when some insecticides sold along with them proved ineffective against cotton pests. Large stocks of Agromethrin and Bamethrin were stocked agro shops and most had expired. Cotton growers had become tired of them and wanted to test new products found in the market.

Effectiveness of particular insecticides varied greatly among respondents depending on cotton phenology, previous experience, pest species, dosages and many other factors. Within a group of insecticides there are recommendations for control of a specific pest at different growth stages and there is often considerable variability in cost, effectiveness against the primary target pest and secondary pest being controlled. Limited knowledge on pesticide use also affected farmers' choices and the effectiveness of the applied insecticides hence a varied perception of the given insecticides. Poor knowledge on recommended agronomic practices like the need to rotate among different insecticide classes, recommended insecticide for the given pest problem and unavailability of insecticides on time compelled farmers to use whatever is brought to them from either CDTF or the agro shops.

It was established that misuse of insecticides was rampant amongst cotton growers particularly based on poor dosages (sub-lethal doses), wrong timing of application, and poor coverage of plants during application. Many of these were related to the lack of knowledge on how to do scouting and make use of damage thresholds (recommended threshold is eight Larva/100 plants before bloom, four larvae/100 plants after bloom). Moreover, it is recommended that the insecticide be applied before larvae of *H. armigera* are half inch long. In principle, damage (fruit or boll) count threshold based treatment should be deployed when damage fruit count exceeds 5% or number of larvae about one-eighth inch long exceeds 8 Larvae/100 plant (MSUES, 2015). Regardless of size of larvae treatment may be warranted if damaged boll counts exceed 2% and significant numbers of Larvae are present and continuing to cause damage) (MSUES, 2015).

During survey, it was noted that canopy coverage and spraying interval in all five surveyed districts were compromised on several instances. The common observation was that 98% of cotton growers use Matabi super green 16 knapsack sprayer which is equipped with pressure regulator valve which makes the pesticides droplets very fine but spraying during windy weather caused drift the droplets affecting coverage of 4 rows swath expected. Since most pyrethyroids are contact insecticides, limited coverage allows pests to escape from insecticides. Partial dosages have been documented to be detrimental as it does not only allow adjustment of the pest to resist the insecticide but also resurgence risking the inefficacy of used insecticides (Rummel *et al.,* 1995).

The recommended number of days to the first round of insecticide spray is 40 days after emergence (Mrosso and Temu, 2008) although there is no rule of thumb as to when spraying should start because it is mostly reliant on economic threshold. The first spray at 40 DAE must be followed by intense insect pest control of *H. amigera* and lygus become major fraction in cotton insect pest management to be assured of optimum square retention prior to bloom. Since the most effective fruiting period is the first three to four weeks of flowering proper scouting becomes the first line of defense against insect pests in cotton. Therefore attention to established action threshold is essential during this period to avoid misuse or overuse of pesticide application (NCCA, 2007).

Cotton growers who re-sprayed their field in between 7-21 days had the knowledge of proper scouting programs to warrant chemicals application at ET, those who resprayed their field from 22 - 44 Days after first spray (DAFS) were forced to do so by higher levels of damages of pestiferous insects or just because they have learnt, it is a routine to spray their cotton field without scouting techniques.

According to Mrosso and Temu (2006), in WCGA pest control needs at least 4 times/round of spray but insofar the study revealed that only (3.9%) of cotton growers sprayed their cotton field four times, thus the complaints of the inefficacy could be attributed to poor scouting for pestiferous insect and single or twice sprays not because of the insecticides ineffectiveness.

The outcome of laboratory chemical analysis for active ingredients (a.i) showed that, the composition and quantities of all the active ingredients of the five commonly used insecticides samples were similar to what was indicated on the label and in accordance with the registrar's portfolio at TPRI. As such, the registered products were with respect to tolerance limits as stipulated jointly by WHO and FAO (Costa, 1997). Thus the findings suggest that insecticides sample brought by the manufacturer for testing and registration by the TPRI are indisputable, despite the fact that one of the products, (Zeatabestox) was found expired.

Conclusively, the inefficacy of the insecticides in the WCGA should not be blamed on pesticides but rather the user's illiteracy that contributes to misuse. Inappropriate choices of insecticides, wrong timing of application, poor dosages and limited knowledge on scouting pests and decision making largely contribute to the ineffectiveness of insecticides. Given the prolonged use of pyrethroids, Tanzania cotton body and agencies such as URT, CDTF, TCA and TACOGA should work through Research institutes ARI (Ukiriguru and Ilonga) and SUA to develop a better strategy of using insecticides in the IPM context for efficient control of insect pests in cotton.

3.6 Acknowledgements

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CHAPTER FOUR

4.0 EFFICACY OF THE COMMONLY USED INSECTICIDES IN CONTROLLING COTTON PESTS IN WESTERN COTTON GROWING AREAS OF TANZANIA

Jeremiah J. Kabissa[1] and Gration M. Rwegasira[1&2]

[1]Department of Crop Science & Production, Sokoine University of Agriculture, P. O Box 3005 Chuo Kikuu, Morogoro

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4.1 Abstract

Farmers' complaints about ineffectiveness of the currently supplied insecticides on cotton insect pests in Western Cotton Growing Areas of Tanzania have persisted on for more than ten years 2005. Five commonly used insecticides namely; Agromethrin (Alfa-Cypermethrin 5% E.C) Bamethrin (Deltamethrin 2.5% E.C), Duduall (Cypermethrin 150g/L + Chorpyrifos 300g/L E.C), Ninja (Lambdacyhalothrin 50g/L E.C) and Zetabestox (Zeta-Cypermethrin 5% E.C) were tested for their effectiveness in controlling cotton pests on variety UK M08, in a field experiment conducted at Ukiriguru Agricultural Research Institute. A randomized complete block design was used with 4 replicates, each with six plots sized 10m*10m planted at a spacing of 0.9m*0.4m. The most abundant among the recorded insect pests were; *Aphids gossypii* (Glover) (31.07%), *Helcoverpa armigera* (Hubner) (25.99%), *Dysdercus spp* (17.98%), unidentified beetle (13.81%) and *Pectinophora gossypiella* (Saunder) (11.14%) and *Earias* sp (>1%). All insecticides were effective against the target pests.

Lambdacyhalothrin was not effective against *A. gossypii* and *Dysdercus spp* while cypermethrin and/or chlorpyrifos were not effective against exocarpic and endocarpic bollworms. Laboratory tests of the insecticides' active ingredients were in conformity with registration standards. Thus, the reported ineffectiveness was due to misuse rather than the insecticides.

Key Words: Abundance, Cotton pests, Control, Efficacy, Insecticides, Pest damage

4.2 Introduction

Cotton is grown on an estimated 3% of cultivated area in the World. About (25%) of all insecticides applied for pest control programs are used in cotton fields. Moreover about (50%) of the cotton yield in the world is attributed to the use of agrochemicals (ICAC, 1998). In the United Republic of Tanzania, cotton has been grown by subsistence farmers since 1904 when it was introduced by the German settlers (Baffes, 2002). Infestation by insect pests particularly Jassids triggered researchers' interest in developing varieties with resistance to serious pests (Reed, 1982). Despite the efforts to control pest since the 20th century, cotton farming in Tanzania experience yield losses of up to 60% due to insect pests damage (Mrosso *et al.*, 2006).

The nature of losses varies ranging from feed holes on leaves (which reduces effective leaf area index for photosynthesis) to enormous damages on squares and bolls caused by chewing pests. Leaf curling, mottling, chrorosis and sooty mould caused by succulent sapping pests like aphids reduce photosynthetic efficiency and the exudates stains the lint. Transmission of fungal, bacterial, and viral diseases is among secondary outcome of insect pest damages (Yoshida and Toscano, 1994).

In 1960s to 1980s, the major pests of cotton in WCGA included; False codling moth, *Cryptophlebia leucotreta* (Meyer), Cotton lygus, *Taylorilygus vosseli* (Pop), Cotton jassid, *Empoasca lybica* (Berg), Spiny bollworm, *Earias insulate* (Boisd) and *E. biplaga* (de Berg). Cotton jassid was a serious pest in the past although insecticides and host plants resistance proved to be effective against it (Reed, 1982; Sekamatte, 1994). To date, the African bollworm, *Helicoverpa armigera* (Hubner), Aphids, *Aphis gossypii* (Glover) and Cotton stainers, *Dysdercus* spp which are not yet amenable for control by host plant resistance as in the case for Jassids, have attained increased importance in WCGA of Tanzania. Pest management in cotton has been a prime subject to cotton farmers, researchers, extension workers and policy planners. The changes in pest status of the former to the current ones and their significance have been critically analysed (Rodriquez *et al*., 1960; Mrosso and Temu, 2006).

Pest damage and subsequent yield losses in cotton increase with plant growth stages, notably from seedling by cutworms, vegetative stage by aphids and jassids through flowering by bollworm and by the cotton stainers (Mrosso and Temu, 2008). The most notable loss is caused by the damage from bollworm which exhibits sequential attack on plants (Yoshida and Toscano, 1994). Despite the recent efforts by researchers to introduce integrated pest management (IPM), the use of pesticide on cotton in the WCGA has been long and a solely dependable option by farmers.

Various insecticides have been used by farmers to control African bollworm, aphids and cotton stainers and other pests in WCGA of Tanzania. Among the organophosphates (OP); Dimethoate, Imidacropid, Chlorpyrifos and Profenophos are very common, whereas Carbosulfan, Flucythriate, Primicarb, Aldicab, Methomyl and Menazon also constitutes the Carbamate group frequently used (ICAC, 1998). Synthetic pyrethroids are probably the most widely and oldest used insecticides used by farmers in the WCGA. Insecticides in this group include; Cypermethrin, Lambdacyhalothrin and Deltamethrin.

In nearly a decade cotton farmers have raised concerns against insecticides procured and distributed through CDTF that they do not offer the desired level of control of cotton pests (TCB, 2010). Suspicion of existence of counterfeits and expired products, misuse of the insecticides and the occurrence of resistance to the commonly used pesticides have been common claims from cotton growers and some workers in the cotton sector. Ineffectiveness of particularly Organophosphates and Pyrethroids against African bollworm, aphids and stainers has for long compromised the image of CDTF. Whether the ineffectiveness of the used insecticides was user-borne or insecticide borne the actual reason had not been examined previously.

The current study aimed at bridging the knowledge gap on the ineffectiveness of insecticides used to control cotton pests in Tanzania. Field experiment were undertaken at Ukiriguru Agricultural Research Institute from 2014 to 2015 to examine the efficacy of the five most commonly used insecticides on cotton pest in WCGA coupled with laboratory assessment of the active ingredients.

4.4 Materials and Methods

A field study on efficacy of five commonly used insecticides in the WCGA was conducted in a randomized complete block design (RCBD) at ARI Ukiriguru station. Plot sizes were 100 m^2 (10 m length by 10 m width) for each treatment replicated four times in a 2400 m^2 area. A distance of 4 m separated the plots to minimize the drift effects of insecticides. The crop was basal dressed with Diamonium Phosphate fertilizer (18% N and 46% P), planted at the spacing of 0.9 m x 0.4 m. Delinted UK M 08 seeds treated with nordox (a copper fungicide) were used. Thinning was done three weeks after planting leaving two plants per stand. Urea (46% N) was applied as top dressing four weeks after emergence.

The five insecticides tested includes; Duduall 450 E.C (Chrolopyrifos 300g/L + Cypermethrin 150g/L), Ninja 55 E.C (5% Lambda Cyhalothrin 50g/L), Zetabestox 10 E.C (Zetacypermethrin 100g/L), Agromethrin 10 E.C (Alphacypemethrin 100g/L), and Bamethrin 2.5 E.C (Deltamethrin 25g/L). Control plot was included in each treatment for comparison. Each insecticides spraying regime comprised of three phases namely; i) pre-spray scouting to determine pest abundance levels using a peg board method (Kabissa *et al.*, 1998); ii) application of the respective insecticides on cotton using Matabi (Super green 16) knapsack sprayers based on scouting decision, and iii) post-spray sampling done after four days to determine the extent to which the abundance of pests was suppressed after insecticide application.

4.5 Insecticide Application

Scouting for insect pests was done weekly starting from flowering to when 50% of bolls were open. Decision to spray insecticides was made at 50% spray threshold at the following dosages; (1) Duduall 450 E.C (Chrolopyrifos 300g/L+ Cypermethrin 150g/L) at 31.2525 mls/400 m^2, (2) Ninja 55 E.C (5% Lambda Cyhalothrin 50g/L) at 40 mls/400 m^2, (3) Zetabestox 10 E.C (Zetacypermethrin 100g/L) at 15 mls/400m^2, (4) Agromethrin 10 E.C (Alphacypemethrin 100g/L) at 15 mls/400 m^2, and (5) Bamethrin 2.5 E.C (Deltamethrin 25g/L) at 40 mls/400 m^2. Each insecticide or insecticide mixture was admixed with 7L of water. Five Matabi (Super Green 16) knapsack sprayers were marked (Zetabestox, Duduall, Bamethrin, Agromethrin and Ninja) and subsequently used for the respective insecticide to avoid mixing up.

A spray volume of 120 lt/ha at a walking speed of approximately 1m/s was used. Spraying commenced with the start of cotton flowering and was repeated every time a 50% damage threshold was reached following scouting. A minimum of three rounds of spray was attained for each insecticide. Thorough washing of sprayer using detergent soap was made before or after each insecticide application. Due to pest pressure in the field, the spray interval did not exceeded one week.

Sampling for insect pests to determine the effect of insecticides was undertaken four days after each spray. A total of 30 randomly selected plants in the six middle rows of every plot were inspected. At each sampling occasion, the abundance of *H. armigera*, *P. gossypiella*, *Earias* spp, *A. gossypii*, and *Dysdercus* spp was determined. Sampling of aphid infestation was done by counting colonies of aphids on the lower surface of 30 leaves taken at random from top, middle and bottom section of 12 infested plants per plot, collected leaves with aphids were kept in plastic bags and taken to the laboratory for counting.

4.6 Data Collection

Data were collected on types and abundance of insect pests, insect pest species, numbers counted before and after each spray, crop damage, seed cotton yield and grade of seed cotton harvested. Other data such as germination percentage, plant density at flowering and weed control were also noted. Assessment was by visual examination of the entire plants as described by Wilson and Room (1982).

4.7 Data Analysis

Insect counts were subjected to logarithmic stabilizing transformation in order to take care of heteroscedssticity among treatments prior to ANOVA.

$$[\log] \ 10 \ \lceil (x) + 1] \ \ldots\ldots (1)$$

Where

(x) = Number of observed insects pest

1 = Constant when all other factors are assumed to be variable.

A GEN-Stat software 10th Edition (VSN International 2014) was used to analyse and compare the efficacy of five insecticides against unsprayed check. Mean separation test was done using Least Significant Difference (LSD) at 95% efficiency (P>0.05). The abundance of each insect pest species was calculated as described by Thomas, (2005).

Abundance of species % = $\frac{\text{Number of individuals of the same species}}{\text{Total number of insects}}$ x100%. ....(2)

4.8 Determination of the Insecticides' Active Ingredients

Samples from insecticides to be tested were collected in duplicate, labeled by numbers and sent to TPRI for determination of the active ingredients. A computerized Gas Chromatography (Varian CP 3800), equipped with Flame Ionization Detector (FID) was used. The Megabore column 1.83 m*2 m (i.d) was considered packed with 5% Silcone 30, 3-5 μm capacity.

Using analytical balance 4 grams of pesticides (E.C) samples were accurately weighed into 10mls solution volumetric flask of appropriate solvent; Acetone for Ninja, Deltamethrin and Chlorypyrifos and Hexane for Alpha and Zetacypermethrin (Worthing and Hence, 1991). The samples were mounted on mechanical shaker for five minutes cold extraction then syringe micro filtered to remove particles (Franco and Jasionowska, 2013).

Before analysis, two injections were performed to equilibrate the system and then carried out duplicate injections of calibrations standard. Using a syringe needle, 3 μl analytes were injected into the Gas Chromatography. The operating conditions for the stationary phase was: injector (250 ^{0}C), detector (280 ^{0}C) and (270 ^{0}C, programmed at 80 ^{0}C initially held for 1 minute, then 270 ^{0}C at the rate of 5^{0}C/minute and held for 10 minutes) the mobile phase (carrier) was Nitrogen gas, where Hydrogen gas and Oxygen gas were used for FID combustion (Karthikeyan and Srinivasan, 2010; Rusibamayila *et al.*, 1998). The concentrations of the active ingredients were computed by comparing the peak retention time and area of the sample of unknown concentration against that of the known concentration of standard. Obtained data were computed as follows;

$$\textbf{A.I\% content} = \frac{\text{(Area of a sample x Dilution factor x purity of the standard)}}{\text{(Slope x weight of sample x conventional factor)}} \quad \text{(3)}$$

The units were evaluated using FAO/WHO standards

4.9 Results

4.9.1 Abundance of major cotton pests

Insect's pest sampling was done as described by (Mathews, 1993) for the period of Nov 23rd, 2014 - June 23rd 2015. Obtained data show that, the most abundant insect pest was *A. gossypii* (31.07%) followed by *H. armigera* (25.99%), a certain unidentified beetle (13.81%), *Dysdercus* spp 17.98%, *P. gossypiella*), (11.14%) and *Earias* sp (>8%), the least significant in causing damages to cotton (Table 8.4).

Table 4.1: Mean Abundance (%) of major cotton pests

Insect pest	Agromethrin	Bamethrin	Check	Duduall	Ninja	Zetabestox
A. gossypii	4.90a	27.90b	85.50c	3.53a	10.59ab	10.06a
Dysdercus spp	12.56a	21.30a	14.11ab	10.66a	9.45a	14.11a
Earias spp	8.37a	16.31b	8.18a	5.83a	5.90a	6.52a
H. armigera	4.82a	7.82ab	39.85c	13.96ab	8.44ab	8.42a
Jassid	12.11ab	11.52ab	21.83c	3.48a	9.11ab	14.28bc
P. goysspiella	3.89a	3.71a	14.56b	4.72a	3.93a	5.08a
Unidentified beetle	7.90a	10.78ab	16.32c	9.17ab	7.35a	11.8ab
Lygus	10.52ab	6.87a	19.06b	6.79a	11.52ab	19.43b
LSD	8.91	12.78	30.39	9.48	5.12	8.43

Values with a same letter in a column are not significantly different ($P < 0.05$)

4.9.2 Effectiveness of the commonly used insecticides

Field experiments were undertaken at Ukiriguru Agricultural Research Institute from 2014 to 2015 to examine the efficacy of the five most commonly used insecticides on cotton pests in WCGA coupled with laboratory assessment of the conformity of insecticides' active ingredients and the results shows that when the attack of major cotton insect pests was 50% threshold in the first spray, all insecticides gave similar control of the pests (Table 4.2). The unsprayed check had more insect pests, more damaged buds, leaves and bolls than all other treatments. In the second spray when the insect pests attack was heavier, Duduall 450g/L E.C gave best control for aphids and bollworms followed by Ninja 5% E.C and Bamethrin 2.5 E.C) which gave the best control of all major pests except for *A. gossypii* ($P<0.05$). Application ofagromethrin100 g/L E.C, Zetabesto x 100g/L, gave best control of aphids and poor control of boll worms ($P<0.05$). Likewise in the third spray when the insect pests attack was heavier, Duduall 450g/L E.C gave best control for aphids and bollworms followed by Ninja 5% E.C and Bamethrin 2.5 E.C) which gave the best control of all major pests except for *A. gossypii* ($P<0.05$).Application ofagromethrin100g/L E.C, Zetabestox 100g/L, gave best control of aphids and poor control of bollworms ($P<0.05$).

Table 4.2: Comparative Effectiveness of the most commonly used insecticides on the percentage score of insects

Spray Round	Spp	Control	Registered name and Chemical name				
			Zetabestox® (Zeta-cypermethrin)	Ninja® (Lambdacyhalothrin)	Duduall® (Lambdacyhalothrin + chrolopyrifos)	Bamethrin® (Deltemethrin)	Agromethrin® (Alpha-cypermethrin)
1st	*Helcoverpa armigera*	3.63b	0.00a	0.00a	0.00a	0.00a	0.00a
	Aphis gossypii	7.19a	6.83ab	5.80a	6.97a	7.28a	7.51a
	Beetles	2.82a	0.33c	0.00c	0.00c	0.25c	0.25c
	Pectinophoro gossypiella	2.23b	0.00a	0.00a	0.00a	0.00a	0.00a
	Earias sp	0.00a	0.00a	0.25a	0.00a	0.00a	0.00a
	Dysdercus spp	0.75a	0.33a	0.50a	0.33a	0.00a	0.25a
2nd	*H. armigera*	7.80b	0.37a	0.33a	0.00a	0.00a	0.25a
	A. gossypii	3.59a	0.32c	4.11a	0.00c	0.61c	0.00c
	Beetles	4.99a	0.00e	1.44a	0.00e	2.40a	0.75cb
	P. gossypiella	4.22b	0.00a	0.25a	0.25a	0.25a	0.25a
	Earias. spp	0.32a	0.00a	0.00a	0.00a	0.25a	0.25a
	*Dysdercus.*spp	0.00a	0.00a	0.00a	0.00a	0.25a	0.00a
3rd	*H.armigera*	1.84a	0.46a	0.00a	0.00a	0.00a	0.00a
	A.gossypii	4.89a	0.82b	4.75a	0.00b	5.89a	0.57b
	Beetles	5.91a	0.83b	1.64b	0.33b	4.25a	1.08b
	P.gossypiella	/2.91b*	0.00a	0.00a	0.32a	0.00a	0.75a
	Earias spp	4.96 b*	0.83a	1.19a	0.25a	1.15a	1.37a
	Dysdercus spp	5.24 a*	0.50ab	0.33c	0.58ab	0.87ab	2.00a

Means followed by the same letter in a row are not significantly different ($P < 0.05$)

4.9.3 Implication of insecticides on seed cotton yield

The results show that, all plots treated with insecticides to control pests gave relatively higher yield than unsprayed checks. With reference to the control plot, the plot sprayed by Ninja had (22.38%) fewer insect pests, fewer damaged buds, leaves and bolls; Bamethrin had (20.05%) fewer insects pests, fewer damaged buds, leaves and bolls; Zetabestox had (19.06%) fewer insect pests, fewer damaged buds, leaves and bolls; Duduall had (19.04%) fewer insect pests, fewer damaged buds, leaves and bolls; Agromethrin had 18.2% fewer insect pests fewer damaged buds, leaves and bolls. The unsprayed control had (>67%) insect pest, large number of damaged buds, leaves and bolls (Table4.3).

The results also showed that, Duduall 450 E.C at (50%) action threshold was efficacious against aphids and bollworms albeit with lower yield of seed cotton, Ninja 5% E.C and Bamethrin 2.5% E. C was not very effective against aphids ($P<0.05$) particularly at 50% action thresholds but gave relatively higher yield of seed cotton than the rest of the treatments. Likewise, spraying of Agromethrin 10% E.C, Zetabestox 10% E. C was not effective for the control of bollworms but gave good results for the control of aphids at ($P<0.05$). However the difference in seed cotton among pyrethroids and Ops treatments was not significant. Seed cotton yield from control treatment was significantly lower than the rest of all other treatments.

Table 4.3: Effect of spraying on seed cotton yield in WCGA

Exp season	Treatments	Percentage score of insects	Scouted rounds	Threshold reached	Number of sprays	Seed cotton Yield
2014/2015	Ninja	22.38	6	3	3	13.06c
	Zetabestox	20.05	6	3	3	11.14ab
	Duduall	19.06	6	3	3	11.11ab
	Bamethrin	19.04	6	3	3	12.38bc
	Agromethrin	18.2	6	3	3	10.63a
	Check	>67	6	3	3	7.66
	F probability					<.001
	CV					8.6
	LSD					1.46

4.9.4 Conformity of the used insecticides

Laboratory analysis of the active ingredient (a.i) showed that, the composition and quantities of all the active ingredients of the five insecticides were similar to what was indicated on the label (Table 4.4) and was in accordance to what was registered by TPRI with respect to tolerance limits jointly stipulated by WHO and FAO (Costa, 1997).

Table 4.4: Conformity of Active Ingredient of the used insecticides as determined by TPRI

Trade Name	Compound Name	Label a.i	Registered product a.i	Lab Analytical Results of a.i
Ninja	Lambdacyhalothrin 50g/l	50g/L	5w/v	5.5%w/v
Bamethrin	Deltamethrin 25g/l	25g/L	2.5 w/v	2.4%w/v
Bamethrin	Deltamethrin 25g/l	25g/L	2.5 w/v	2.458%w/v
Zetabestox	Zeta-Cypermethrin100g/l	100g/L	10 w/v	Zetacypermethrin 10.32% w/v
Dudu-all	Chloropyrifos 350g/l Cypermethrin 100g/l	150g/L: 300g/L	35:10 w/v	Chloropyrifos :34.48%w/v Cypermethrin: 10.64%w/v
Agromethrin	Alphacypermethrin 100g/l	100g/L	10w/v	10.7%w/v

4.10 Discussion

The effectiveness of a particular insecticide varies greatly from one field to another depending on previous insecticide use, pestiferous insect's spp and level of tolerance to insecticide classes (Mulroney and Elmore, 2000). The decision to control key cotton insect pests in the current study was greatly influenced by damage thresholds, type of insect pest and type of insecticide used. Duduall gave best results for the control of both bollworm and sucking pest complex because it contained cypermethrin which is a contact insecticide with the immediate knock down effect and chlorpyriphos which is a systemic insecticide, The combination of two insecticides gave it increased potency to control insect pests, Ninja, and Bamethrin gave good results for the control of bollworm complex and sucking pest other than aphids.This could be due to their high knockdown effect that kills natural enemies which would have otherwise preyed on aphids and consequently reducing the populations. Zetabestox and Agromethrin gave best results of controlling aphids but to lesser extent bollworms, which could be due to its prolonged use though under different trade names example Ninja, Karate, Insectido and Fastac.

Control of all major insect pests in the first spray gave similar result at (50%) threshold because insect pest population was not that much high to warrant significant difference at ($P<0.05$), after chemical application however the unsprayed check had more of the damaged buds, bolls, leaves and insect pestsbecause spraying onto the rest of all other plots killed most of the insect pests. The results from this study have shown that the insecticides deployed were active ingredient and/or combinations dependent effect on *H. armigera, Earias* spp, *P. gossypiella, A. gossypii* and *Dysdercus* spp abundance. This is buttressed by the synergistic effect of Duduall 450E. C which is both systemic and contact translocated poison through the plant sap, the translocation delayed its degradation under field conditions, this account for its high efficacy in controlling bollworms complex, aphids, unidentified beetle, and stainers (Adebayo, 2003), which is an advantage over Ninja, Bamethrin, Agromethrin and Zetabestox. However there are several factors which affect insecticides efficacy on leaf surface, the most important being insecticides persistence, foliage growth and the prevailing weather condition during and after application (Mulrooney and Elmore, 2000).

Ninja and Bamethrin were most effective pyrethroids for the control of bollworm complex when compared to Zetabestox and Agromethrin probably due to CYP9A12, and CYP9A14 , GSTs and elevated cytochrome P450 oxidative metabolism which has been shown to be a major resistance mechanism to pyrethroid in *H. armigera* against cypermethrin (Chen *et al.*, 2005; Ventas *et al.*, 2001; Young *et al.*, 2005).

Studies elsewhere indicated that esterase mediated detoxification played an important role in Esfenvelerate, Permethrin, Alpha and Zeta cypermethrin, Deltamethrin, Flucythrinate and Phoxim resistance in a Laboratory selected strain of *H. armigera* (Gunning *et al*., 1996, 1999 and 2007; Zheng *et al*., 2008). This wide variation in efficacy justifies the significance of careful selection of insecticides in case of both chewing and sucking insect's pest management.

Foliage structure might also have affected the efficacy of insecticides. Wilson *et al.* (1983) reported that foliage growth not only dilute non-systematic insecticides deposits on the leaf surface but also results in some insecticides free leaves playing refuges to pests which could also decrease the mean efficacy of the insecticides. Rainfall, temperature and sunlight intensity have also been reported to cause insecticides degradation under field conditions, but given the fact that all insecticides were applied under same condition, the effects of weather parameters was assumed to be uniform.

The cotton aphid emerged as an imperative cotton pest since late 1980's when most recommended insecticides for its control failed to provide satisfactory results (Hardee *et al*., 1992). Pesticides resistance is an evolutionary adaptation conferred by genes encoding modified receptor proteins or enzymes that detoxify insecticides. By this mechanism, cotton aphid has developed high tolerance against several insecticides viz., organophosphates including dicrotophos, oxydemeton-methyl and chlorpyrifos. Cotton aphid has a long history of rapidly developing resistance to multiple insecticides Gong *et al.* (1964); Obrien and Graves (1992); Obrien *et al.* (1992); Rummel *et al*. (1995). Denholm and Devine (2013) reported that, indiscriminate application of organophosphates (dicrotophos, oxydemeton-methyl and chlorpyrifos), pyrethroids (cypermethrin, lambdacyhalothrin, Deltemethrin and fenverelate) and other insecticides, instead of controlling cotton aphid populations, increases their reproductive potential. It was until recently, that the Neonicotinoid class of chemistry provided effective control of this herbivory on cotton in the Southern United States (Muhammad *et al.*, 2014) which could also be applied to other areas.

In a study modeling the development of insecticide resistance in *Helioithis verescence* (F.), Mallet and Luttrell (1991) categorized pests into three groups depending on their reproductive potential and likelihood to develop resistance in relatively short period of time. Insects with high reproductive potential have higher chances of developing resistance to insecticides compared to those of low potential. As it applies to cotton aphid, their high reproductive potential complements their capacity for resurgence after application of especially very effective insecticide. Parajulee *et al.* (2003) buttressed by adding that Parthenogenetic reproduction is observed in many species of aphid females in which adult females give birth to live nymphs. Furthermore, off springs of this type of reproduction are clones of the mother and do not involve gene recombination. This accounts for their highest abundance than all other major insect pests.

African bollworm, *H. armigera* ranked second in abundance which could probably be due to its feeding habit which enables it to grow faster coupled with higher fecundity compared to pink bollworm and spiny bollworms. The reason for high fecundity being a main cause of success of *H. armigera,* however during feeding the larva bore into the cotton bolls with the hind part of the body exposed outside, this exposes the larva to the direct effects of the insecticides than that of the pink bollworm which tunnels into its boll and remain entirely inside (Hill and Weller, 1998; Mathews, 1989). As such the number of *H. armigera* would have been less than other bollworms if not for its high fecundity.

The effect of spraying insecticides was accounted on abilities to suppress pests and allow realization of expected yield. In the current study, the reduction in cotton yield was mostly related to *H. armigera*, *Earias* spp, *A. gossypii*, *Dysdercus* spp and *P. gossipiella* infestation and economic yield would be almost impossible to achieve without the chemical control. Pyrethroids particularly Ninja (Lambdacyhalothrin) and Bamethrin (Deltamethrin) treatments resulted into higher seed cotton yield when compared to Duduall (Chlorpyrifos Cypermethrin).

The good result of synthetic pyrethroids, Ninja in particular conceded the finding of El-Metwally *et al.* (2003) in Egypt who reported that the average reduction of Pink bollworm was (90.3%), (83.6%) and (73.5%) for fenpropathrin, esfenvalerate and lambdcyhalothrin respectively. In addition since lambacyhalothrin has the highest knockdown effects resulted in killing most of yield limiting insects quit fast in so doing the crop was almost free from insect's pest infestation.

Karnel *et al.* (2003) mentioned that cotton yields in insecticidal treated plots were (9%) greater during 13 years of experimentation compared to untreated plots. Studebaker *et al.*, (2003) found that *H. armigera* complex has been reported to cause yield loss in cotton in range of (1.05%) to (3.97%) in the presence of chemical control program. Williams (2003) reported that the bollworm/budworm complex retained the top ranking as the number one cotton pest by reducing yield by (21.31%) in Egypt in the absence of appropriate control measures. Our study revealed that the loss in seed cotton yield in the absence of chemical control program is (> 50%).

Yields from all plots were relatively low. This cannot be attributed to pest control alone but rather in combination of more than one factor such as inadequate rains and the resultant drought spell that affected realization of optimum yield. During crop growth most of the leaves and flowers were abscised coupled with bolls abortion and premature boll opening that contributed to lower yields than the common average. Similar observation has been reported by other workers in cotton. Meetens *et al.* (1992) observed that under inadequate rains, the leaves and flowers were abscission, bolls abortion became common and premature boll opening contributed to lower yields of cotton in Egypt.

Thus, in view of generally poorly growing condition for cotton shading of leaves, dropping of flowers, fruits abortion and premature fruits opening as a results of drought spell, attack by insects pest is seldom severe enough to warrant more than just a few spray for optimal yield (Nyambo, 1989; Meetens *et al.*, 1992).

4.11 A New Insect Pest

During the course of study unidentified species of beetle (Plate 4.1) which has never been reported in WCGA was recorded. This alien was seen to cause significant damages to the cotton squares and bolls. The damages caused were significant to warrant a need for detailed research in order to determine its pest status, its origin and alternative host plants. This beetle was dark brown coloured with white spots all on the elytra; possess two pair of wings with long snout of the mouth parts. The antennae were segmented and capable of flight. The observed characteristics suggest the insect to belongs to the order Coleopteran but detailed studies needs to be undertaken to establish facts about the pest. The pest was found in Misungwi District (at Ukiriguru where the field experiment was conducted) as well as Bariadi and Meatu Districts in the cotton fields at the fruits/bolls setting stage., thus the habitat lately is considered to be the cotton crop however there could other alternative primary and secondary hosts. The beetle was actively feeding on cotton bolls from dawn to dusk.

The damage caused by this alien starts at the bottom of the cotton bolls just after the torus as they feed in aggregation of 2-6 insects/boll. The munched bolls ooze the internal contents in the form of froth which produce odor that attracts flies. Once the boll stars oozing its content the beetle moves to another boll causing the same problem, attacked bolls cease growing and suffers from secondary pathogenic infection. If it succeed to boll opening stage the lint quality is terribly affected and can no longer be harvested for textile uses.

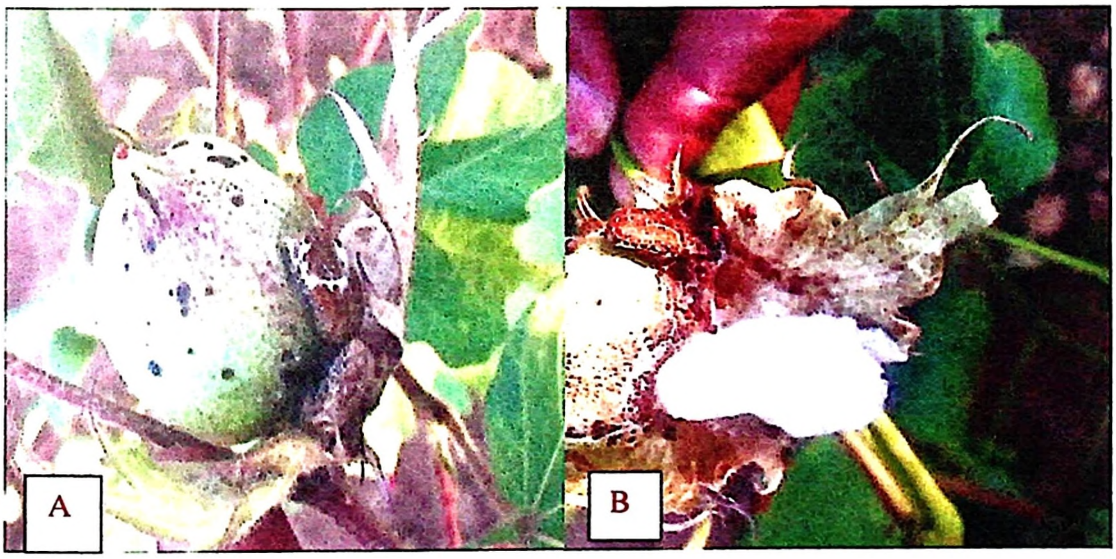

Plate 4.1: Invasive sp of beetle feeding on the cotton boll B: is a picture of munched and perforated oozing boll following attack by the same

4.12 Conclusion

Most cotton insect pests were polyphagous and the tested insecticides showed variation in efficacy. The observed pests complex of bollworms spp, Aphids, unidentified beetle, Dysdercus and the rest in the WCGA require high lipophilic pesticides that would suppress a wide range from eggs through adult stage yet preserve non target natural enemies. In the current study Ninja is one of most effective pyrethroid for the control of bollworm complex followed by Bamethrin that exhibited good efficacy in reducing bollworm infestation and resultant high yield of seed cotton. Zetabestox, Agromethrin and Duduall are good for the control of aphids and other sucking pest but exhibited the lowest potential reduction of bollworms infestation and the seed cotton yield was not significantly different among the three treatments. Reduced efficacy of insecticides particularly on aphids suggests the possibility for resistance but detailed researches would be required to justify this. Given the findings obtained, the need for a combination of high knock down contact and systemic insecticides to take care of the pests' complex cannot be overemphasized. Such combinations could include like lambdacyhalothrin + OPs and Deltamethrin + OPs.

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CHAPTER FIVE

5.0 GENERAL CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The study showed that most farmers do not spray their fields for the required number of three rounds and at best they can manage only one or two sprays in a season. Timing of spray commencement is often compromised. The major reasons unveiled are unavailability of insecticides on time, limited accessibility, lack of pests scouting knowledge that hinders estimation of spray threshold, and bad timing of insecticide application. The poor pest management techniques allow proliferation of pestiferous insects' damage of the squares and consequently premature bolls abortion.

All insecticides conformed to registration standards and proved effective against the pests during the field experiments. Ineffectiveness of the commonly used insecticides such as Ninja on Aphids suggests the need for mixed insecticides that would take care of the escape commonly encountered. The newly recorded beetle suggests continuous dynamism in cotton pests hence there is a need to do more surveys on the pests affecting the crop particularly for the new species.

5.2 Recommendations

Based on the findings from the current study the following measures are recommended:

1. Cotton growers should alternate insecticides such as Organophosphate at the vegetative stage and limit Pyrethroid uses at the fruiting period. This will spare the life of natural enemies and will sufficiently control exocarpic bollworms e.g. *P. gossypiella* and other sucking pests such as *Dysdercus spp*, *Aphis gossypii*, *Nezara*

viridura, *Jacobiasca* sp, *Calidea dregii*, *Tylorilygus vosseleri* and *Oxycarenus hyalinipennis*.

2. Education on the safe use of pesticide, application techniques and associated hazards should be emphasized to farmers.
3. The need to employ skilled personnel with knowledge on handling and dispensing pesticides by shop owners should be a part and parcel of licensing policy.
4. The pesticide procurement process and accessibility should be simplified to allow timely availability of pesticides to farmers.
5. The pesticides procurement process and accessibility should be simplified to allow timely availability of pesticides to farmers
6. All ginneries, buying posts and seeds stores should be kept clean. Any seeds which are no longer required should be burnt.

APPENDICES

Appendix 1: Physical and chemical properties of pesticides collected from vendors

Common name	Insecticide type	Scientific name	Formulation	Chemical name	Mode of action
1. Ninja	Synthetic pyrethroid	Lambdacyhalothrin	5% E. C and 5g/l	(S)-alpha-cyno-3phenoxybenzyl (2) (1R)-cis-3-(2chloro-3,3,3-trifluoropropenyl)-2,2-dimethylcyclo-propanecarboxylate and (R) -alpha-cyno-3-phenoxybenzyl (Z) (1S)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethyl cyclopropane carboxylate	Anticholinesterase AND axon poisoning
2. Karate	Synthetic pyrethroid	Lambdacyhalothrin	5% E. C and 5g/l	(S)-alpha-cyno-3phenoxybenzyl (2) (1R)-cis-3-(2chloro-3,3,3-trifluoropropenyl)-2,2-dimethylcyclo-propanecarboxylate and (R) -alpha-cyno-3-phenoxybenzyl (Z) (1S)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethyl cyclopropane carboxylate	Anticholinesterase AND axon poisoning
3.Bamethrin	Synthetic pyrethroid	Deltamethrin	2.5 E. C	(S)-αCyano-3-phenoxybenzyl (1R,3R) cis-3-(2,2-dibromovinyl)-2,2phenyl)methyl 3-(2,2-dimethyl cyclopropane carboxylate	Anticholinesterase AND axon poisoning
4.Agrithiote	Organophosphate	Dimethoate	40E. Cand 400g/l	O,O-dimethyl S-Methycarbamoylmethy phosphorodithioate	Anticholinesterase
5.Duducper	Synthetic pyrethroid	Cypermethrin	5% E. C and 5g/l	(RS) – α – Cyano – 3 phenoxbenzyl – (1RS) – cis – trans-3- (2,2-dichlorovinyl) -2,2 dimethyl – cyclopropane carboxylate	Anticholinesterase

Common name	Insecticide type	Scientific name	Formulation	Chemical name	Mode of action
6. Banofos	Organophosphate	Profenofos	720E. C and 720g/l	O-4-bromo-2-chloropenyl O-ethyl S-Propyl phosphorothioate	Anticholinesterase
7. Supercron					
8. Sume	Organophosphate	Dimethoate	40E.Cand 400g/l	O,O-dimethyl S-Methycarbamoylmethy phosphorodithioate	Anticholinesterase
9.Select plus	Organophosphate and Synthetic pyrethroid	Profenofos and Lambdacyahalothrin	315E. C	＊O-4-bromo-2-chloropenyl O-ethyl S-Propyl phosphorothioate (S)-alpha-cyno-3phenoxybenzyl (2) (1R)-cis-3-(2chloro-3,3,3-trifluoropropenyl)-2,2-dimethylcyclo-propanecarboxylate and (R) -alpha-cyno-3-phenoxybenzyl (Z) (1S)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethyl cyclopropane carboxylate	
10.Twigathiote	Organophosphate	Dimethoate	40 E. C and 400g/l	O,O-dimethyl S-Methycarbamoylmethy phosphorodithioate	
11.Zetabestox	Synthetic pyrethroid	Zeta-cypermethrin	10%E.C	＊(S)-α-cyano-3- phenoxy cyclopropanecarboxylate	Anticholinesterase and axon poisoning
12.Duduall	Organophosphate and Synthetic pyrethroid	Chlorpyrifos and Cypemethrin	300g/l and 150g/l	＊O,O-diethyl-O-3,5,6-trichloro-2 pyridylphosphorothioate (RS)-α-cyano-3-phenox cyclopropanecarboxylate	Anticholinesterase and axon poisoning
13.Mupacron	Organophosphate	Profenofos	500g/l	＊O-4-bromo-2-chloropenylO-ethylS-Propylphosphorothioate	Anticholinesterase and axon poisoning
14.Akrimactin	Antibiotic	Abamectin	18g/l	avermectinB1[amixture of a avermectin Ala)and≤20%a (1-methylethyl) avermectinAla)]	

Common name	Insecticide type	Scientific name	Formulation	Chemical name	Mode of action
15.Agromethrin	Pyrethroid	Alphacypermethrin	10E.C	(1rcis) S and (1Scis) r enaantiomer isomer pair of alpha-cyno-3-phenoxy benzyl 3-(-2,2- dichlorovinyl) -2,2 dimethyl	Anticholinesterase and axon poisoning
16.Duduthrin	Pyrethroid	Lambdacyhalothrin	5E.C and 5g/l	(S)-alpha-cyno-3phenoxybenzyl (2) (1R)-cis-3-(2chloro-3,3,3-trifluoropropenyl)-2,2-dimethylcyclo-propanecarboxylate and (R) -alpha-cyno-3-phenoxybenzyl (Z) (1S)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethyl cyclopropane carboxylate	Anticholinesterase AND axon poisoning
17.Lambdex Super	Pyrethroid	Lambdacyhalothrin and chlorpyriphos		(S)-alpha-cyno-3phenoxybenzyl (2) (1R)-cis-3-(2chloro-3,3,3-trifluoropropenyl)-2,2-dimethylcyclo-propanecarboxylate and (R) -alpha-cyno-3-phenoxybenzyl (Z) (1S)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethyl cyclopropane carboxylate * O,O-diethyl-O-3,5,6-trichloro-2 pyridylphosphorothioate	

Source: Partly from World Pesticides Manual (Worthing and Hance, 1991) NB: In the table Anticholinesterase means inhibitor of acetylcholinesterase enzyme by phosphorylation of the esteratic site. Axonic poisoning is the interference with sodium channel activation by alteration of sodium and potassium transport along axon membrane

Appendix 2: Questionnaire

Section A: Fill in the empty space

1. Name of interviewer......................Date....................Form No...................
2. Name of respondent......................Institute/Village.....................................
3. Occupation of respondent..
4. Location/zone(s)................................Region...

Section B: Fill in the responses as the need may be

i. Do you cultivate cotton?
Yes/No..

ii. If yes, how many acres? ....
a) On ridges? b) On flat seed bed?

iii. Which cotton variety do you use...
iv. Have you ever had problems with field pests? Yes/No.................................
v. If yes, what are the common pests that affect your cotton? ....,........,........
vi. Of the mentioned insect pests, which ones are the most damaging? ......,..............
vii. What type of damage do they cause? ....,................,................,......................
viii. How do you control the pests? ....,......................, ...
ix. Have you ever used insecticides to control this/these insect pests? Yes/No.......
x. Name the commonly used types of insecticides in the table below:

Type	Dosage (mls of insecticide/acre	Source (where obtained from)	Price	Persistence (days to weeks)

xi. Of the mentioned insecticides (xi) above which one is the most effective and why?

Insecticide	Rank	Why regarded as effective
1		
2		
3		
4		
5		

xi. Do you use this/these insecticides on other crop/crops Yes/No? ....
xii. Mention such crop/crops............., ..., ...

xiii. How the insecticides do works if it is/they are sprayed on that/those crops insect pest? Effectively/ineffective..

xiv. If they ineffective explain what could be the cause ....

xv. Where do you commonly buy your insecticides? ....

xvi. Do you get adequate information from the vendors on the proper use of the insecticides? Yes/No...

xvii. If No explain why...

xv. Do you think the vendor from whom you bought the insecticides knows well enough about the insecticides he/she sells to you? Yes/No...........................

xvi. If Yes in xix above, explain why...

xvii. If No in xix above explain why? ....

xviii. When do you apply (days after planting) insecticides on your cotton field...

xix. Average acreage treated annually ....

xx. How many times do you spray insecticides? ....

xxi. How do you spray insecticides in your field? (Step by step account)

1. ....
2. ....
3. ....
4. ....
5. ....
6. ....
7. ....
8. ....
9. ....
10. ....
11. ....
12. ....

xxii. At what time do you spray insecticides on your cotton field? ....

a) In the morning b) in the afternoon c) at dusk d) before rains e) after rains f) other (please specify)

xxiii. Are you aware that, insecticides are hazardous? Yes/No...

xxiv. If yes what precaution do you take before and after spraying insecticides?

....

xxv. What safety gears do you put on before applying insecticides? ....

xxvi. How long does it take before you re-spray the insecticides...................................

xxvii. Do you re-spray the same insecticide Yes/No? ....

xxviii. If No, why do you change? ....

xxix. How do you dispose off, the emptied insecticide container/ packets? ....

xxx. What other methods do you use to control insect pests on cotton.............................

xxxi. What is your general remark pertaining to cotton insects and the insecticides used to control them?..

xxxii. Any other comments/observations..

Appendix 3: Survey on Insecticides/Pesticides Used in Cotton Industry

Region..Date..

District..Village name ....

GPS ....Farmers name..

Pesticide used	Source	Amount used per acre	Cost/acre pack	Frequency of application	Target pest	Application device used	Effectiveness (farmer opinion)	Sample number

Appendix 4: Insecticides/Pesticides record sheet for all determination

Insecticide Name	Scientific Name	Rec Vol (Ml)/Ha	Actual Vol (Ml)/Ha	Rec A.I (G)/Ha	Act A.I (G)/Ha
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Appendix 5: Commencement of first spray

DEPARTMENT OF CROP SCIENCE AND PRODUCTION INSECTS SAMPLING SHEET

No	ABW eggs	ABW larva	PBW eggs	PBW larva	SBW eggs	SBW larva	Aphids	Cotton Stainers	Remarks
1									
2									
3									
4									
5									
6									
7									
8									
9									
11									
12									
13									
14									
15									
16									
17									
18									
19									

Appendix 4: Insecticides/Pesticides record sheet for all determination

Insecticide Name	Scientific Name	Rec Vol (Ml)/Ha	Actual Vol (Ml)/Ha	Rec A.I (G)/Ha	Act A.I (G)/Ha
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
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14					
15					

Appendix 5: Commencement of first spray

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2									
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6									
7									
8									
9									
11									
12									
13									
14									
15									
16									
17									
18									
19									