

2016-04

The use of pesticidal plants as environmental friendly Practice for field and storage pests' management in Common beans and cowpeas

Mkindi, Angela

<https://doi.org/10.58694/20.500.12479/88>

Provided with love from The Nelson Mandela African Institution of Science and Technology

**THE USE OF PESTICIDAL PLANTS AS ENVIRONMENTAL FRIENDLY
PRACTICE FOR FIELD AND STORAGE PESTS MANAGEMENT IN
COMMON BEANS AND COWPEAS**

Angela Gerald Mkindi

**A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of
Master's in Environmental Science and Engineering of the Nelson Mandela African
Institution of Science and Technology**

Arusha, Tanzania

April, 2016

ABSTRACT

Infestation caused by insect pests on legumes has been witnessed to cause losses in the fields during cultivation as well as during storage. Use of pesticidal plants is seen as an alternative option although it is not used widely. Fresh leaf extracts of *Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara* were evaluated for their efficacy against field insect pests (Aphids (*Aphis fabae*), Bean leaf beetle(*Ootheca bennigseni*), Flower (blister) beetles (*Mylabris sp*), Caterpillars (*Anticarsia gemmatilis*) and Pod suckers) and beneficial insects (Spiders (Araneae), Lady Bird beetles (*Coccinella septempunctata*), Lacewings(Chrysopidae) and Robbe fly (Asilidae)) in common beans (*Phaseolus vulgaris* L) and *Callosobruchus maculatus* on stored cowpeas (*Vigna unguiculata*). Pesticidal plants extracts were prepared in concentrations of (0.1%, 1% and 10% w/v). Weekly spraying of the extracts was done preceded by insects' assessment one day before each spray. Yield of common beans and persistence of compounds from plants solutions was also evaluated. Pesticidal plants powders were tested on stored cowpea against *C.maculatus*. The pesticidal plants showed a significant ($P \leq 0.05$) ability to reduce insect pests as well as favouring presence of predators and natural enemies in the field. Leaf extracts of *T.vogelii* was found the most active in the control of field as well as storage insect pests and again contributing to the growth and yield of common beans. Effectiveness of *T.vogelii* was the highest against *C.maculatus* by exhibiting less infestation by adult insects, less oviposition and low damage. In this study pesticidal plants were observed to be active against common insects' pests when compared with untreated. Their effects against beneficial insects and natural enemies were observed to be lower compared with synthetic pesticide treatment.

DECLARATION

I, **ANGELA GERALD MKINDI** do hereby declare to the Senate of Nelson Mandela African Institute of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Angela Gerald Mkindi

Name and signature of candidate

Date

The above declaration is confirmed

Prof. Patrick A Ndakidemi

Name and signature of supervisor

Date

Prof. Karoli N Njau

Name and signature of supervisor

Date

Dr. Kelvin M Mtei

Name and signature of supervisor

Date

COPYRIGHT

This dissertation is copyright material protected under the Berne Convention, the Copyright Act of 1999 and other international and national enactments, in that behalf, on intellectual property. It must not be reproduced by any means, in full or in part, except for short extracts in fair dealing; for researcher private study, critical scholarly review or discourse with an acknowledgement, without the written permission of the office of Deputy Vice Chancellor for Academics, Research and Innovations, on behalf of both the author and the Nelson Mandela African Institution of Science and Technology.

CERTIFICATION

This is to certify that the accompanying dissertation by ANGELA GERALD MKINDI has been accepted in partial fulfilment of the requirements for the Degree of Environmental science and Engineering of the Nelson Mandela African Institution of Science and Technology Arusha, Tanzania.

Prof. Patrick A Ndakidemi

(Supervisor)

Prof. Karoli N Njau

(Supervisor)

Dr. Kelvin M Mtei

(Supervisor)

ACKNOWLEDGEMENT

I thank my good Lord for giving me all the strength, wisdom and power throughout my master studies. Many thanks to the Nelson Mandela African Institution of Science and Technology for the admission to this degree program and for sponsoring my study. My sincere thanks to McKnight Foundation who funded my research through grant13-338 Safe and effective pesticidal plants for agro-ecological intensification of legumes given to The Nelson Mandela African Institution of Science and Technology.

I would gladly wish to extend my sincere gratitude to my research supervisors; Prof. Patrick A. Ndakidemi, Prof. Karoli N. Njau and Dr. Kelvin M. Mtei for their tireless efforts to advice, guide and support to me towards a successful completion of my research work. Many thanks to all instructors at the NM-AIST who made me this successful academically. I sincerely thank the project partners of the Natural Resource Institute University of Greenwich Prof. Steven Belmain and Prof. Philip Stevenson, for their guidance as external supervision.

I also extend my sincere appreciation to, my parents, Mr. and Mrs. Gerald I Mkindi and relatives, my husband Ferdinand our children Ivan, Joan and Leah for bringing me great happiness and energy to do my very best in this study.

DEDICATION

This dissertation is dedicated to my children, Ivan and Joan. I love you dearly and I pray that God blesses each of you and lead you through, day by day when grow you up and face the world.

TABLE OF CONTENTS

ABSTRACT	i
DECLARATION	ii
COPYRIGHT	iii
CERTIFIATION	iv
ACKNOWLEDGEMENT	v
DEDICATION	vi
TABLE OF CONTENTS	vii
LIST OF FIGURES	x
LIST OF PLATES	xi
LIST OF ABBREVIATIONS AND SYMBOLS	xii
CHAPTER ONE	1
Introduction.....	1
1.1 Background Information	1
1.2 Research problem and justification of study.....	3
1.3 Objectives	3
1.3.1 General objective	3
1.3.2 Specific objectives	3
1.4 Research questions	4
1.5 Significance of the research	4
CHAPTER TWO	5
The Potential of using Indigenous Pesticidal Plants for Insect Pest Control to Small Scale Farmers in Africa	5
Abstract	5
2.1 Introduction	5
2.2 An overview of pesticidal plants use research	7
2.2.1. Importance of enhancing small scale farmer’s knowledge in Africa on the use of pesticidal plants in controlling agricultural pests	7
2.2.2. Environmental and human health impacts of synthetic pesticides	8
2.3. Indigenous Knowledge on the Use of Pesticidal Plants for Field Control of Insect Pests.....	9
2.4. Characterizing Toxicity in Selected Botanical Plants.....	11
2.4.1. <i>Lantana camara</i>	11

2.4.2. <i>Tephrosia vogelii</i>	12
2.4.3. <i>Vernonia amygdalina</i>	14
2.4.4 <i>Tithonia diversifolia</i>	15
2.5. Research needs and Conclusion	17
CHAPTER THREE.....	18
Efficacy Of Pesticidal Plant Extracts In Controlling Common Bean Insect Pests Under Natural Field Conditions.....	18
Summary	18
3.1 Introduction	18
3.2 Materials and Methods.....	19
3.2.1 Study area.	19
3.2.2 Preparation of pesticidal extracts.	20
3.2.3 Field preparation and Experimental design	20
3.2.4 Assessment of insects and plant damage	20
3.2.5 Data analysis	21
3.3. Results.....	21
3.3.1. Insect pests' abundance.	21
3.3.2 Influence of treatments on the levels of damage by insect pests	23
3.4. Discussion	24
3.5. Conclusion.....	25
CHAPTER FOUR.....	27
Contribution of Pesticidal Plants Extracts to Environmentally Sensitive Pest Control Strategy in Northern Tanzania	27
Summary	27
4.1 Introduction	27
4. 2 Materials and Methods.....	28
4.2.1 Study area.	28
4.2.2 Preparation of pesticidal extracts.	29
4.2.3 Field preparation and Experimental design	29
4.3 Data collection	30
4.3.1 Assessment of beneficial insects.	30
4.3.2 Yield assessment	30

4.3.3 Persistence of pesticidal plants on bean plant leaves.....	30
4.3.4 Data analyses.	31
4.4 Results.....	31
4.4.1 Abundance of beneficial insects	31
4.4.2 Growth parameters and yield of common beans.	32
4.4.3 Presence and persistence of active compounds from <i>T.vogelii</i>	33
4.5 Discussion.	34
4.6 Conclusion.....	35
CHAPTER FIVE.....	36
Summary	36
5.1 Introduction	36
5.2 Materials and Methods.....	37
5.2.1 Preparation of <i>Callosobruchus maculatus</i> insect culture	37
5.2.2 Preparation of pesticidal plants.....	38
5.2.3 Experimental setup	38
5.2.4 Data collection	38
5.2.5 Data analysis.	38
5.3 Results.....	39
5.3.1 Infestation by adult <i>C.maculatus</i>	39
5.3.2 The oviposition of <i>C.maculatus</i>	40
5.3.3 Damage by adult <i>C.maculatus</i>	40
5.4 Discussion.	40
5.5 Conclusion.....	42
CHAPTER SIX.....	43
6.1 GENERAL DISCUSSION.....	43
6.2 CONCLUSION.....	45
6.3RECOMENDATIONS	45
REFERENCES.....	47
APPENDICES	59

LIST OF FIGURES

Figure 1A chemical structure of ursolic acid stearylglucoside (UASG).Source: Kazmi <i>et al.</i> , (2013).....	11
Figure 2 Compound structures of chemotype 1 and chemotype 2 of <i>T.vogelii</i> .Source: Stevenson <i>et al.</i> , (2012).....	13
Figure 3 Structures of isolated compounds from <i>Vernonia amygdalina</i> . Source: Farombi and Owoeye, (2011).....	14
Figure 4 1-14 Compounds found in <i>T.diversifolia</i> . Source: Zhao <i>et al.</i> , (2012).	16
Figure 5 Mean abundance of insect pests in response to application of four pesticidal plant extracts, synthetic pesticide and control.	22
Figure 6: Abundance of insect pests in comparison to concentrations of pesticidal plants extracts.	23
Figure 7: Mean percentage damage of common bean plants by key insect pests.	24
Figure 8 Abundance of beneficial insects in response to four plant species, synthetic pesticides and control.....	31
Figure 9: Effects of concentration of treatments on the yield of common beans.	33
Figure 10 Average mean and percentage breakdown of tephrosin from <i>T.vogelii</i>	33

LIST OF PLATES

Plate 1 Botany picture of <i>Lantana camara</i>	12
Plate 2 Botany picture of <i>Tephrosia vogelii</i>	13
Plate 3 Botany picture of <i>Vernonia amygdalina</i>	14
Plate 4 Botany picture of <i>Tithonia diversifolia</i>	16

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation	Meaning.
SARI	Selian Research Institute
ANOVA	Analysis of variance
DDT	Dichlorodiphenyltrichloroethane
UASG	Ursolic acid stearylglucoside
CEC	Cation-exchange capacity
TSP	Triple Super Phosphate
LSD	Least significance difference
USEPA	United States Environmental Protection Agency
TACRI	Tanzania Coffee Research Institute
SE	Standard Error
PD	Percentage damage

LIST OF APPENDICES

Appendix 1 Average abundance of insect pests observed on bean plants in response to treatments at different concentrations.....	59
Appendix 2 Effects of treatments on the percentage damage by insect pests observed on the bean plants.....	60
Appendix 3 The average abundance of beneficial insects observed on bean plants in response to application of treatments.....	61
Appendix 4 Mean yield parameters of common beans collected during harvesting period.....	62
Appendix 5 The mean adult <i>C.maculatus</i> recorded from the cowpea seeds (<i>V.unguiculata</i>) subsample.....	63
Appendix 6 Effects of treatments on the mean number of eggs of <i>C.maculatus</i> on cowpea seeds.....	64
Appendix 7 Mean and percentage damage by adult <i>C.maculatus</i> in response to application of treatments.....	65

CHAPTER ONE

Introduction

1.1 Background Information

Increasing cases of crop damage by insect pests, both in the field and during storage, have a direct impact on food security, especially in developing countries. Synthetic pesticides have been used as a solution against pests and diseases because of their broad spectrum efficacy. Despite the efficacy, the danger caused by persistence of pesticide residues in soil, water and crops themselves have negative impacts to the health of farmers and to the environment (Ngowi *et al.*, 2007). Users of synthetic pesticides are much exposed to danger of their pollution during preparation and application and on consumption of crops that contain pesticide residues. An alternative to synthetics is the use of less harmful pesticides such as pesticidal plants (Sola *et al.*, 2014).

Pesticidal plants have not been widely used in the farming systems even though they are cheaply available and they are easy to prepare and use (Amoabeng *et al.*, 2014). Their active ingredients are safe to the environment and to human beings too because of their easy biodegradability, less toxicity and low harm to beneficial insects (Amoabeng *et al.*, 2010 ; Isman, 2006). Commercially, pesticidal plants are cheap and in this case viable for African growing economy (Amoabeng *et al.*, 2014; Mkenda *et al.*, 2015).

Legumes are crops mentioned for their roles in preventing diseases such as cardiovascular disease, type II diabetes, some cancers, ischemic heart disease (IHD), stroke and diabetes (Fabbri & Crosby, 2015; Malaa *et al.*, 2007). Legumes have been serving as important component in the diets of African societies and an affordable source of protein to poor communities. They are also important sources of income to rural small scale, resource-poor farmers in Africa. Various types of legumes are drought resistant and therefore viable for production even in areas faced by impacts of climate change like unreliable rainfalls and droughts.

Common beans are a leguminous plant growing best in the tropics. It is a good source of protein and starch in Africa and as a staple in the great lakes regions. Tanzania is known as one of the world's largest beans producer although statistics report reduction in production by half in the last 20 years (Hillocks *et al.*, 2006).

Due to this, international programs in collaborations with Tanzania have put efforts on increasing bean varieties in which more than 20 varieties are introduced (Amoabeng *et al.*, 2014). Alternative insect pest control initiatives have also been on the move by using pesticidal plants.

Cowpea represents another group of potential leguminous plants. They contain important minerals such as Zinc and Iron as well as phenolic compounds that are considered important for health (Abizari *et al.*, 2013; Nderituet *et al.*, 2013). It is therefore an important crop in Africa for its nutritional values. However producers in this area face a challenge especially after harvest where fungal infestation and Cowpea weevils (*Callosobruchus maculatus*) have been noted to cause damage to cowpeas during cultivation and storage respectively (Houssou *et al.*, 2009; Sanon *et al.*, 2010).

Both common beans and cowpea are potential to health, nutrition and income in Africa. Challenges facing production and storage of these important crops among others are pests that affect quality and quantities of produce in the farms as well as in the storage facilities. Existence of pests is contributed to by their resistance, weather changes and monoculture which favor their proliferation (Belmain *et al.*, 2013). Various pesticidal plants are naturally available in Africa and have been proven in laboratory as effective against certain insect pests. Of interest in this study are *Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara* commonly found in the Northern Tanzania among many other places. These plants serve as an alternative to the use of synthetic pesticides and therefore increasing the possibility of safe food and environmental friendly farming and storage practices (Sola *et al.*, 2014). Pesticidal plants are also important because of a demand from environmental forums and the need for worldwide safe production of foods that has low health risks, and safe to ecosystems and biodiversity (Sola *et al.*, 2014).

The study intends to assess the efficacy of the four pesticidal plants extracts against insect pests in common beans, its effects on yield and beneficial insects as well as its activity against storage pests. Findings from this study will contribute to efforts of using plant based insect pests control options. In addition, this study will stimulate field research on pesticidal plants that involve small-scale farmers.

1.2 Research problem and justification of study

Economic and nutritional importance of common beans and cowpeas is highly threatened by loss due to attack by insect pests. Synthetic pesticides have been used as a pests control option and with time, have been confirmed to be harmful to environment and humans. Increasing demand for environmental safety in agriculture and safe food has led to focus on the use of pesticidal plant as alternative, pesticidal plants are thought as options since they are environmental friendly. Pesticidal plants have been used by African farmers since long in history in various ways but not as wide as desired. This study intends to evaluate the efficacy of four pesticidal plants in the control of field insect pests in common beans and on stored cowpeas. It also aims at investigating impacts of pesticidal plants against beneficial insects and their contribution to yield of common beans.

1.3 Objectives

1.3.1 General objective

To validate environmental friendly agricultural practices in the control of insect pests affecting common beans and cowpeas.

1.3.2 Specific objectives

1. To determine the abundance of key insect pests and severity of damage by insect pests in response to application of pesticidal plants extracts.
2. To evaluate the effects of four pesticidal plant species on yield of common bean (*Phaseolus vulgaris* L.), abundance of beneficial insects in the field and their persistence in the environment.
3. To assess the toxicity and repellent activity of the pesticidal plants against *Callosobruchus maculatus* in stored cowpea (*Vigna unguiculata*).

1.4 Research questions

- 1 How do pesticidal plants influence the abundance of insect pests and severity of damage by insect pests?
- 2 How does effectiveness of pesticidal plants affect yield and abundance of beneficial insects? And how long does compounds from pesticidal plants persist in the environment?
- 3 What is the toxicity and repellent activity of the botanical pesticides against *Callosobruchus maculatus* in stored cowpea (*Vigna unguiculata*)?

1.5 Significance of the research

Outcomes of this study will enable establishment of environmentally safe agricultural practices and safe food for humans. In addition to that, the study will increase the use and value of available plants in the African ecosystems and lead to lower costs on production that result of using less costful insect pest control strategy.

CHAPTER TWO

The Potential of using Indigenous Pesticidal Plants for Insect Pest Control to Small Scale Farmers in Africa¹

Abstract

Pesticidal plants are scientifically proven for their effectiveness in controlling insect pests. Their activity is enhanced by active compounds contained, which are known for their repellent and antifeedant potentials to the insects. Use of pesticidal plants by local small scale farmers has been a point of concern following information that majority of farmers do not widely use pesticidal plants despite of an indigenous knowledge that exist. Improvement of the technologies used by local farmers in previous times, that are easy and effective need to help farmers abstain from the use of synthetic pesticides that are detrimental to the environment and to their own health. This paper reviews the potentiality using pesticidal plants by small holder farmers. It also gives the status of pesticidal plants use, their possible effectiveness against insect pests, persistence as well as the knowledge that indigenous people possess in their use. Again, the paper suggests the need for more instrumental research on practical improvement of indigenous knowledge on the use of pesticidal plants with scientific evidences.

2.1 Introduction

The awareness and use of pesticidal plants in developing countries is growing over time following the scientific proof of damages caused by synthetic pesticides. In developing countries where massive poisoning due to the use of pesticides is increasing and posing environmental and health risks; use of pesticidal plants is gaining priority (Isman, 2008). Pesticidal plants as an alternative to synthetic pesticides are recognized because of their non-cytotoxicity, easy of biodegradability and simulator nature of host metabolism (Dubey *et al.*, 2008; Sola *et al.*, 2014). Compounds in pesticidal plants break down rapidly, making them more environmental friendly compared with synthetic compounds (Grzywacz *et al.*, 2014). Therefore; they are a good alternative in crop production. Across Africa, there is a massive availability of plants which have been identified for their pesticidal effects (Gakuya *et al.*, 2013; Andel *at al.*, 2015). Their growth, proliferation and cheap availability encourage a history of their use (Gakuya *et al.*, 2013).

¹American Journal of Plant Sciences, 6, <http://dx.doi.org/10.4236/ajps.2015.619308>, 3164-3174

It is understood that the culture of relying on botanical pesticides vanished after the introduction of synthetic DDT in the 1940s (Dunlap, 2014). By the 1960s, their adverse impacts on the environment and human health's were becoming evident (Isman, 2006). Reasons for the use of synthetic pesticides are their immediate impacts against pests, which with time resulted into trading of agricultural products with pesticides residues (Dinham, 2003; Gonzalez, 1999). This scenario is realized to have severe impacts to environment and to people's health (Mazid, 2011). These effects are due to the fact that such pesticides are used improperly and without protective gears. Use of pesticidal plants is hence beneficial for the reasons that firstly, they are relatively cheaper and easily available and secondly their formulations are less persistent to the environment and have less toxic effects (Dubey, 2011). Therefore, innovation in the use of pesticidal plants is a means of reducing production cost and improving existing knowledge on the use of the pesticidal plants in agricultural pest control.

Since long in history, small holder farmers have been knowledgeable on the use of pesticidal plants. In many developing nations, especially parts of Africa, there are several indigenous groups who despite of the available knowledge on the usefulness of botanical pesticides have not fully accepted their use as a more environmentally friendly and cost-effective alternative (Nyirenda and Sileshi, 2011; Belmain and Stevenson, 2001; Paul *et al.*, 2009). In India Mazid, (2011) reported that only 2.89% of the bio pesticides used in India that are registered between 2005 and 2011, there are only 12 types of plant botanical pesticides. Generally, there is a massive research on plant extracts against insect pests that have not been communicated to local farmers, hence this appear to be a major reason for farmers not to use the technology (Stevenson *et al.*, 2012). Conversely, there are other literatures that reported the potential use of crude extracts, simply prepared and to great extent less concentrated to amounts that turn more toxic (Isman, 2008).

The objectives of this review is to argue for more direct investment in research that can support the use of simply prepared plant extracts that have shown positive impacts against insect pests in terms of ease of use, compared with results from laboratory bioassays.

2.2 An overview of pesticidal plants use research

Pesticidal plants compounds can naturally degrade easily in the environment hence rendering them less persistent (Dubey *et al.*, 2008). Compounds from the plants are reported to break down into harmless compounds within hours or days (Dubey, 2011). Literatures indicate effects of climate factors which are daily average temperature and relative humidity in a sense that persistence of the compounds, reduce with their increase (Wang *et al.*, 2011). Being less persistent, these compounds are important in the environment as they pose less harm to non-target organisms. However, plants contain a mixture of chemicals that may have similar or antagonistic activities (Miresmailli and Isman, 2014). There is lack of enough information on the extent of breakdown or rather the persistence of each chemical in a mixture. Breakdown of the compounds in hours or days is not enough to justify persistence of the chemicals and hence more information on time length that these chemicals persist in the environment is required.

Pesticidal plants application rates, persistence of the compounds in the environment and the preparation mechanisms indicate important aspects in the use of pesticidal plants in agriculture. Literatures have reported varied intervals of application of extracts such as three times throughout a growing season (Paul, 2007), twice for the season (Amoabeng *et al.*, 2013) and fifteen days intervals (Mekonnen *et al.*, 2014).

Contrary to synthetic pesticides that can last longer in the environment, pesticidal plants require more frequency if they are to work best. Intervals as stipulated by Paul, (2007); Amoabeng *et al.*, (2013); Mekonnen *et al.*, (2014) vary in different plants in different seasons. This offers a chance to study about the persistence, and favorable time intervals that will be effective for the control of the pests without causing damages to non-target organisms and environment.

2.2.1. Importance of enhancing small scale farmer's knowledge in Africa on the use of pesticidal plants in controlling agricultural pests

Pesticidal plants are proven to be perfect alternative against insect pests. For many years, indigenous Africans have been using the available pesticides at their disposal from plants and other organisms for different purposes including insect pest control (Mugisha-Kamatenesi *et al.*, 2008; Mihale *et al.*, 2009; Grzywacz *et al.*, 2013).

However, findings from the developing countries show that small scale farmers suffer from poor knowledge on the use of introduced synthetic pesticides (Zacharia *et al.*, 2010; Ngowi *et al.*, 2007; Naidoo *et al.*, 2011) and this is associated with detrimental effects to them and the environment. Therefore, research on pesticidal plants is needed to strengthen local knowledge that farmers have been aware of since long time in history.

In Africa, many of the pesticidal plants are found without difficulty. For example, they grow in the wild or even at homesteads and in farm boundaries. In this case, there is almost no cost of growing the plants. Therefore, it is worth promoting their use because synthetics have negative impacts as they are costly to eco-health and the economy (Grzywacz *et al.*, 2014; Miah *et al.*, 2014; Athukorala *et al.*, 2012). A better choice to help growth of African agriculture would be to start from the baseline knowledge on pesticidal plants of the Africans themselves. This can be achieved through the improvement of the available knowledge on the use of pesticidal plants that would even disappear if not used and disseminated widely.

2.2.2. Environmental and human health impacts of synthetic pesticides

Synthetic pesticides are known for their toxicity to the environment and to non-target organisms including wildlife, insects and human beings (Bolognesi and Merlo, 2011; Saxena, 2014). Organochlorines, organophosphate and carbamates are the major groups of chemicals that are used as synthetic pesticides in developing countries despite the ban of others like DDT (Mitra *et al.*, 2011). Their impacts threaten food safety systems (Malhat *et al.*, 2015), human health (Roca *et al.*, 2014; Attfield and Hughes, 2014) and the environment.

Synthetic pesticides have been reported to reduce population among birds (Mitra *et al.*, 2011), and insects (Johnson *et al.*, 2010; Wu *et al.*, 2011). The fact that synthetic pesticides are less selective treatments to insects in agro ecosystem practices gives a caution on the impacts that pesticides may have to non-target and beneficial insects (Jenkins *et al.*, 2013). Human beings are strongly affected during application and handling of the chemicals in the farms. Pesticides are reported to enter into the cells and alter cell's cycles and hence resulting into some cancer (Saxena, 2014).

Reports have revealed several types of cancer that results from improper use of synthetic pesticides such as Leukemia, Lung cancer, Pancreatic cancer, Colon and Rectal cancer, Lymphohematopoietic cancer, on-Hodgkin lymphoma, Bladder cancer, Breast cancer, multi Plemyeloma, Prostate cancer, Kidney cancer and Oral cavity cancer (Weichenthal *et al.*, 2010).

Pesticides are also known for the ability to disrupt endocrine systems in humans and wildlife (Mnif *et al.*, 2011; Watson, 2014). Apart from cancer; skin pill off, hardness in breathing, stomach ache and vomiting as well as farmers collapsing have also affected users (Fuad *et al.*, 2012). These effects then result to high health costs (Wilson and Tisdell, 2001).

Generally, environmental organisms including plants, fish, birds, snakes and the like are affected massively. Farmers in Malaysia reported 80% reduction in number of fish in two cropping seasons during a study conducted to identify impacts of pesticides in paddy farming (Watson, 2014). Studies also show biota uptake of pesticides (Zacharia *et al.*, 2010) which also imply soils contamination. There are therefore more detrimental effects caused by using synthetic pesticides for various agricultural purposes.

2.3. Indigenous Knowledge on the Use of Pesticidal Plants for Field Control of Insect Pests

Indigenous knowledge refers to the informal knowledge, skills and practices that are obtained not in schools, universities and research institutes but rather in local heritable ways normally in rural areas (Lodhi and Mikulecky, 2010). Developing countries are rich in such knowledge (Sukula, 2006). Indigenous knowledge on insect pest control is perceived as important because it was witnessed as useful in food security and survival of the users long before the invention of synthetic pesticides (Lodhi and Mikulecky, 2010). However, maintenance of the indigenous knowledge is found to be difficult because the majority of farmers have turned to modern agriculture that involves use of synthetic pesticides.

Pesticidal plants have been used for more than 150 years ago (El-Wakeil, 2013). Majority of African small holder farmers have been using various botanical pesticides to control insect pests. For example, in the Victoria basin in Uganda, farmers have used *Capsicum frutescens*, *Tagetes spp.*, *Nicotiana tabacum*, *Cypressus spp.*, *Tephrosia vogelii*, *Azadirachta indica*, *Musa spp.*, *Moringa oleifera*, *Tithonia diversifolia*, *Lantana camara*, *Phytollacca dodecandra*, *Vernonia amygdalina*, *Aloe spp.*, *Eucalyptus spp.*, (Mugisha-Kamatenezi *et al.*, 2008).

In addition to the pesticidal plants, farmers in Tanzania have been using other products such as cow's urine, cow dung, and ashes (Mihale *et al.*, 2009).

However, in these areas, there exists little information that this knowledge is used in an effective way in comparison to ancient practices. Research based efforts need to be undertaken to retrieve the knowledge. During farming, indigenous knowledge in insect pest control involves direct spraying, intercropping pesticidal plants with the crops to be protected, and also using the botanicals based on the synthetic formulations (Prakash *et al.*, 2008). Researchers have come up with some application techniques. This includes: the use of the freshly ground leaves, mixed and soaked overnight (Amoabeng *et al.*, 2014; Paul, 2007). Also, boiling plant parts and adding soap for extraction (Belmain and Stevenson, 2001) has been practiced. Paul, (2007) used fresh leaves pounded and mixed with water and 0.1% soap to make 3% w/v of the extract. Mekonnen *et al.*, (2014) used another technique where sun dried plant materials were soaked in acetone and stirred for 30 minutes. Thereafter the mixture was left for 24 hours, filtered and stored under 4° temperature before use.

Application techniques that have been used demonstrated positive results in controlling certain insect pests. These efforts have been done in few parts of developing countries despite presence of pesticidal plants in diverse areas. These calls for diverse research of plants with pesticidal properties coupled with indigenous knowledge from different domains and develop tangible solutions on the use of pesticidal plants to control insect pests.

2.4. Characterizing Toxicity in Selected Botanical Plants

Four plant species, *Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara* will be described. These plants have been tested for their efficacy in the control of insect pests in field and on storage of food crop (Mkenda *et al.*, 2014). They are also massively available in rural environments. Research that builds up from what small scale farmers understand about these plant species is needed in order to improve knowledge with a scientific basis for more reliable use of the technology. Therefore, it is worthy conducting research basing on the preparation techniques documented in the literatures to several other crops and insect pests as well as introducing more favorable techniques that are reliable to small-scale farmers.

2.4.1. *Lantana camara*

Toxicity of *Lantana camara* is reported to have effects to animals and also a noxious plant species that has been cited as invasive in need of control for a long time (Baars and Naser, 1999). Literatures show that Lantana causes less mobility, dehydration and constipation, congested heart and lung, nephrosis, general reproductive performance and teratology to mice (Mello *et al.*, 2005). Lantana is also reported to have a fumigant effects (Zoubiri and Baaliouamer, 2012) and has been revealed for its water purification potential. Compounds that have been revealed in *Lantana camara* are such as ursolic acid stearylglucoside (UASG) (Kazmi *et al.*, 2013) that is associated with toxicity and which includes triterpenoids in the apolar phase.

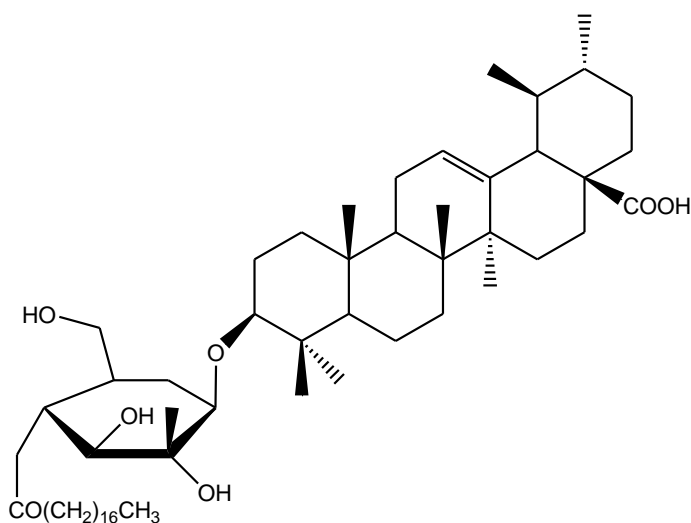


Figure 1A chemical structure of ursolic acid stearylglucoside (UASG).Source: Kazmi *et al.*, (2013).



Plate 1 Botany picture of *Lantana camara*

In agriculture, *Lantana camara* has been used for the control of insect pests in stored grains (Rajashekar *et al.*, 2014; Rajashekar *et al.*, 2013). Lantana has also been tested for its repellent, antifeedant and toxicity against termites (Yuan and Hu, 2012). All these experiments are laboratory based. Hence, there is a need for more practical research on the field to test for the effectiveness of *L. camara* against field insect pests. Furthermore, use, of *Lantana camara* for beneficial effects will help reduce its invasive property to farmlands.

2.4.2. *Tephrosia vogelii*

Tephrosia vogelii is widely used for control of pests and as a source of nutrients to the soil (Stevenson *et al.*, 2012). Leaf extract of *T.vogelii* is reported to exhibit toxicity against *Tilapia nilotica* (Ibrahim and M'batchi ,2000). This is practiced in remote areas of Africa, commonly regarded as illegal fishing (Neuwinger, 2004). It is reported that leaves of *T. vogelii* contain high amounts of rotenone and deguelin (Kalume *et.al.*, 2012) responsible for the toxicity to fish. Compounds and crude materials from *Tephrosia vogelii* has however a great potential in agriculture in the control of insect pests and in soil enrichment through nitrogen fixation (Stevenson *et al.*, 2012). Diverse compounds exist in the plant and according to Belmain *et al.*,(2012) this plant consist of chemotype 1 (C1) and chemotype 2 (C2) (Figure 2) of which C1 is found to be active against insect pests. In additional to insect pest control, mulches of the plant have increased maize biomass while decreasing the weed biomass (Belmain *et al.*, 2012). Therefore, this makes *T. vogelii* to have herbicidal, pesticidal effects and again as a fertilizer (Wang *et al.*, 2011).

More studies support the activity of *T.vogelii* in insects. (Igogo *et al.*, 2011) has confirmed its insecticidal, antifeedant and repellent effects against golden flea beetle that represent a group of insects.

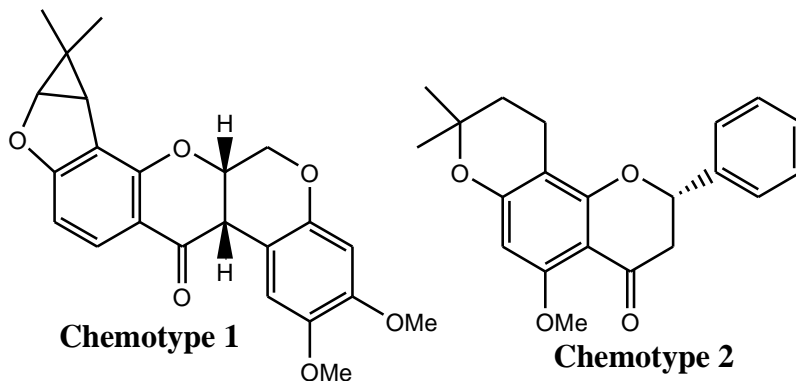


Figure 2 Compound structures of chemotype 1 and chemotype 2 of *T. vogelii*. Source: Stevenson *et al.*, (2012)



Plate 2 Botany picture of *Tephrosia vogelii*

Tephrosia vogelii is a legume, that has higher proliferation rates and this is potential to small scale farmers that will not have more costs in growing and using the plant for agricultural purposes.

2.4.3. *Vernonia amygdalina*

Another pesticidal plant known as *Vernonia amygdalina* is reported to contain useful compounds such as vernolide and vernodalol, epivernodalol (Erasto *et al.*, 2006); Figure 3), kolaviron (Farombi and Owoeye, 2011) as useful phytochemicals.

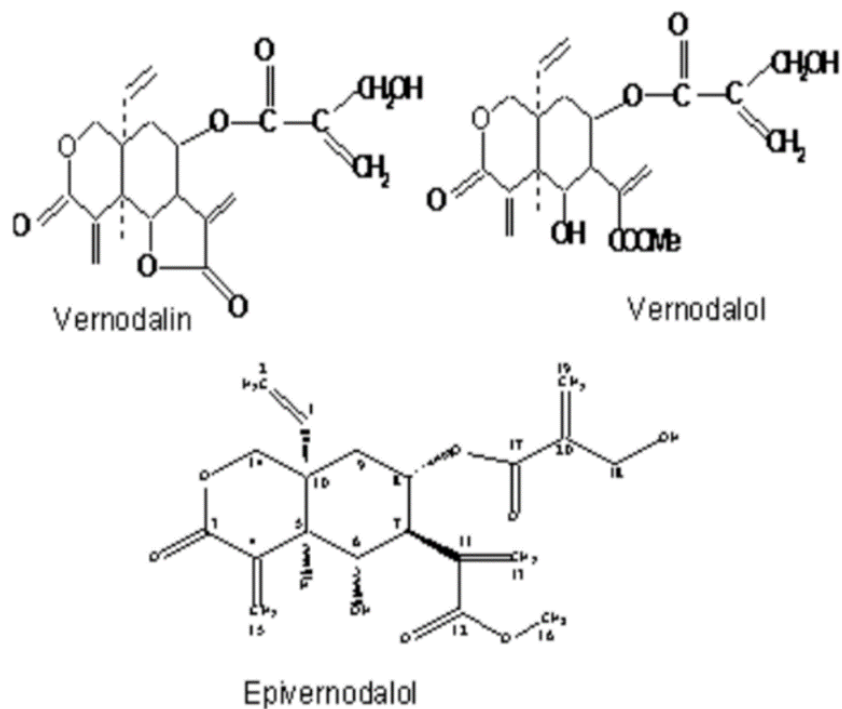


Figure 3 Structures of isolated compounds from *Vernonia amygdalina*. Source: Farombi and Owoeye, (2011).



Plate 3 Botany picture of *Vernonia amygdalina*

Effectiveness of *Vernonia amygdalina* is reported against bacteria, fungi and virus species (Erasto *et al.*, 2006), as an anticancer, anti-malaria and as anti-diabetic antioxidant agent and also used as vegetable (Cameron *et al.*, 2013; Owolabi *et al.*, 2011; Yeap *et al.*, 2010).

Vernonia amygdalina has been reported as a pesticidal plant, in the treatment of been weevils where ethanolic extracts showed activity (Adeniyi *et al.*, 2010). Several other compounds such as saponins and alkaloids, terpenes, steroids, coumarins, flavonoids, phenolic acids, lignans, xanthenes, anthraquinones, edotides and sesquiterpenes have been identified from this plant (Farombi and Owoeye, 2011; Yeap *et al.*, 2010). More studies on identification of useful compounds from *V. amygdalina* and testing their efficacy against field and storage crops is of paramount importance.

2.4.4 *Tithonia diversifolia*

In developing countries, *Tithonia diversifolia* is a well-known traditional plant. It is renowned to have agricultural benefits such as higher phosphorous contents in the above ground biomass (Shokalu, Ojo, E-Adewoyin, and Azeez, 2010), insecticidal effects (Castaño-Quintana, 2013), anti-malarial, and anti-inflammation. It is also used as ruminant fodder (De Toledo *et al.*, 2014; Pérez *et al.*, 2015). *T. diversifolia* contain many compounds. (Zhao *et al.*, 2012) found about 16 compounds while (Chagas-Paula *et al.*, 2012) review about 150 compounds of *Tithonia* and 150 compounds of *Tithonia diversifolia*. Some of them are shown in figure 4.

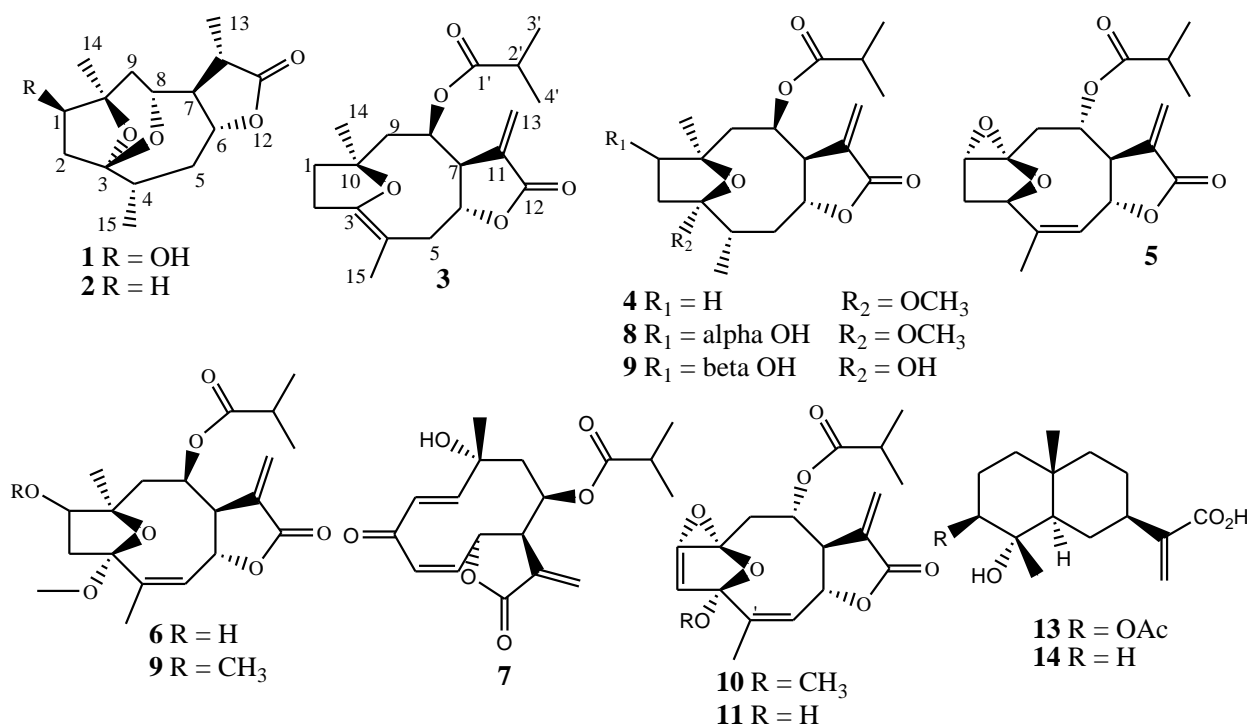


Figure 4 1-14 Compounds found in *T.diversifolia*. Source: Zhao *et al.*, (2012).



Plate 4 Botany picture of *Tithonia diversifolia*

T. diversifolia has been tested for its biochemical and toxicological effects. In China, *T. diversifolia* has been reported to treat, diabetes, hepatitis, and hepatocarcinoma although the mechanism involved is not yet understood (Lin, 2012). In agriculture, chopped pieces of stem and leaves of *T. diversifolia* have showed a significant increase in soil P, Ca, CEC, K and soil organic matter content (Shokalu *et al.*, 2010).

Another study by (Adesodun *et al.*, 2010) showed that *Tithonia diversifolia* has phytoremediation potential with a capacity to accumulate Pb and Zn from the soil to the shoots.

This ability gives room for study on the possible capacity of the plant in the remediation of degraded soils from synthetic pesticides contamination.

2.5. Research needs and Conclusion

The fact that small holder farmers have the knowledge of using pesticidal plants which they hardly use, there is a need of a research based solution on better ways to make the knowledge useful. Practical research based in field situation and that directly involve small scale farmers is important to put into practice experts' understanding. Pesticidal plants contain some degree of toxicity. It is important to understand their persistence to the environment in order to establish clear intervals of application together with the education of safety measures when preparation and use for farmers health's as well as to enhance effectiveness in controlling insect pests.

CHAPTER THREE

Efficacy Of Pesticidal Plant Extracts In Controlling Common Bean Insect Pests Under Natural Field Conditions

Summary

Pesticidal plant extracts are a good alternative to control insect pests attacking common beans during their growth. Four pesticidal plants *Tephrosia vogelii*, *Lantana camara*, *Tithonia diversifolia* and *Vernonia amygdalina* were evaluated under field condition for their effectiveness against common insect pests in the Northern Tanzania. Plant extract preparation involved collection of plant leaves, shade drying and grinding to obtain plant powder for extracts preparation. Three concentrations (0.1%, 1% and 10% w/v) were prepared and sprayed as treatments in the field. Water and a mixture of water and soap were used as control. Application of treatments was done on weekly basis in which record of insects was taken one day before the application of extracts. (Aphids (*Aphis fabae*), Bean leaf beetle (*Ootheca bennigseni*), Flower (blister) beetles (*Mylabris sp*), Caterpillars (*Anticarsia gemmatalis*) and Pod suckers) were observed on the bean plants. Observation made for 10 weeks from the germination of bean plants showed that pesticidal plants possess effects against insect pests when compared with the control. Also, among the plant species, *Tephrosia vogelii* was the most effective plant extract in comparison with *L.camara*, *T.diversifolia*, and *V. amygdalina*. Concentration of 10% was the most effective compared with 0.1% and 1% both in controlling insects' pests of bean plants and in reducing severity of damage by insect pests. The pesticidal plants were not as effective as the synthetic pesticide but were more effective compared with the negative controls.

3.1 Introduction

Common beans (*Phaseolus vulgaris*) is one of major legumes cultivated in the Eastern and Southern Africa and used as a staple food (Aserse and Räsänen, 2012). It is known for its potential to health as it is a source of protein and important minerals that contain low cholesterol (Hernandez, 2012; Njoroge and Kinyanjui, 2015). It also contains important minerals such as zinc and iron (Blair *et al.*, 2011; Blair and Izquierdo, 2012) and digestives like fibers, phenolic, peptides and photo chemicals (Campos-Vega *et al.*, 2013). Cultivation of common bean is faced with challenges that threaten its production process and yield. Prolonged droughts and high insect pests proliferation (Beebe *et al.*, 2011; Beebe *et al.*, 2013) are among the major challenges.

Until 2006, common bean production was reported to reduce by half in 20 years back (Hillocks *et al.*, 2006). Attack by insect pests is one of the major challenges though its contribution is not statistically provided. It is in this regard that efforts are invested to improve beans cultivation to ensure food security and nutritional status amongst African communities.

Synthetic pesticides have been used and with time resulted to negative environmental effects (Schreinemachers *et al.*, 2011) and increased resistance to insect pests against pesticides (Ssekandi *et al.*, 2015). Furthermore, while commercial insecticides are used widely, their purchasing cost is high, their availability is unreliable in remote rural areas and once available, farmers and farm workers use them without following proper directions provided and without protective equipment (Ngowi *et al.*, 2007) leading to health problems and ecosystem destruction. Synthetic pesticides are known also for causing loss of beneficial insects such as those important for pollination and predation which are essential in ecosystem services and crop production.(Ellis, 2010; Johnson *et al.*, 2010;Wu *et al.*, 2011).

Understanding impacts of these challenges to subsistence farming, several researchers have initiated programs to help famers control insect pests through exploring the potential to utilize the pesticidal properties of plants. According to Anyanga et al.,(2013), use of pesticidal plants optimize natural defense in crops and reduce the dependence on commercial synthetic pesticides for farming. This is an added advantage to ensure that solutions for food security do not compromise environmental safety and sustainability. Another advantage includes the fact that plant species are obtained easily from the surroundings at no cost and their preparation mechanism is viable for small scale farmers involving no expensive procedures. Four plants species, *Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara* investigated in this study are among the easily available pesticidal plants in the northern Tanzania.

3.2 Materials and Methods

3.2.1 Study area.

Study was conducted at the Tanzania Coffee Research Institute (TACRI) farms located in Moshi area-Northern Tanzania within latitude 3°13'59.59"S and longitude 37°14'54"E. The area is at an altitude of 1268m above mean sea level with the mean annual rainfall of about 1200mm and a mean temperature of about 18°C. Common crops grown in this region is common beans, banana and coffee.

3.2.2 Preparation of pesticidal extracts.

Fresh leaves of the four plant species (*Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara*) were collected from five different accessible locations in Moshi and Arusha. To ensure uniformity, plant leaves of same species collected from different location were mixed together before drying (Mkenda *et al.*, 2015). Plant leaves were dried under shade for a week and then crushed using an electric grinder after which a powdered form was packed in 1 kg plastic bags and stored in a dark-dry condition. Preparation of a pesticide solution was done by soaking powder at three different concentrations; 10%, 1% and 0.1% (%w/v) using a solution containing 0.1% soap. Soap was used as a medium for extraction of compounds from plants (Belmain *et al.*, 2012). The mixture was left for 24 hours after which extracts were filtered through a clean cloth and used as a spray.

3.2.3 Field preparation and Experimental design

Study was carried out during the long rain season, from March to July 2015 which is the main bean cropping season in the area. Field preparation was done in February by ploughing and then disc harrowing that was done one day before planting. Bean seeds of 'Lyamungo 90' variety were obtained from the Selian Research Institute (SARI) in Arusha and planted on the 31st of March, 2015. Plots of 5m x 5m were prepared with two meters between them and between experimental units and between neighbouring fields. A randomized block design was used in the layout of 15 treatments with four replication each. Planting was done in a space of 20cm within rows and 50cm between rows. Two seeds per hole were planted with Triple Super Phosphate (TSP) fertilizer added during planting at a rate of 20 kg P/Ha. Treatments included four plant species each made in three concentrations (0.1%, 1% and 10%) and synthetic pesticide as a positive control. Water and water + soap were also included as negative control treatments.

3.2.4 Assessment of insects and plant damage

Recording of insects' abundance and severity of damage by insects was done weekly and in each week, one day before the next application of treatments. Five plants inside the 25 meter square block were randomly selected from the center of the plot and sampled for insect pest counting. An entire plant was inspected and insects of interest were counted and recorded. Large insects

were counted individually while smaller and uncountable ones were assessed by categorizing them into scores of 0= none, 1= A few scattered individuals, 2 = A few isolated colonies, 3 = several isolated colonies, 4 = large isolated colonies and 5 = large continuous colonies (Mkenda, 2014). Large insects pests counted were, Bean leaf beetle (*Oothea bennigseni*), Flower (blister) beetles (*Mylabris sp*), Caterpillars (*Anticarsia gemmatalis*) and Pod suckers while uncountable insects were aphids (*Aphis fabae*). Damage by insects was evaluated by whole plant assessment whereby 10 plants were selected randomly inside the 25m² block and inspected for any damage caused by insects. The severity of damage was categorized into; 0% damage, up to 25% damage, up to 50% damage, up to 75% damage and up to 100% damage as explained by Mkenda *et al.*, (2015).

3.2.5 Data analysis

Differences in infestations and damage by the insect pests between treatments were subjected to analysis of variance (ANOVA) and Fisher least significance difference (LSD) used to separate significant treatment means. Statistica software (STATISCTICA 8) was used for the analysis.

3.3. Results.

3.3.1. Insect pests' abundance.

Appendix 1 shows a statistical significance of treatments performance against the abundance of insect pests for Bean leaf beetle (*Oothea bennigseni*) $F = 13.59$, $p \leq 0.001$ Aphids $F=20.58$, $p \leq 0.001$, Flower beetle (*Mylabris sp*) $F=29.20$, $p \leq 0.001$, Caterpillar (*Anticarsia gemmatalis*) $F=4.50$, $p \leq 0.001$ and pod suckers $F=6.03$, $p \leq 0.001$. Comparatively, pesticidal plants extracts at 0.1% 1% and 10% showed a significant effectiveness compared with the negative controls (Water and water +soap) by exhibiting a reduced abundance of insect pests (Appendix 1). Likewise, among the pesticidal plants extracts, higher effectiveness was observed in extracts at higher concentration (10%) compared with concentrations of 1% and 0.1% respectively as shown in Figure 6.

Graphical presentation of plants against insects pests abundance (Figure 5) shows that *T.vogelii* was the most effective of all plant extracts by having a considerable reduction of insects abundance.

Statistically, *T.vogelii* 10% was the most effective in reducing the abundance of aphids, *L. camara* at 10% was the most effective against Bean leaf beetle (*Ootheca bennigseni*), *T.vogelii*, and *L. camara* and *V. amygdalina* at 10% concentration were most effective against caterpillars while *T.vogelii* and *L. camara* at 10% concentration were the most effective against pod suckers. Synthetic pesticide was comparatively most effective by reducing considerable number of all insect pests as shown in Figure 5. However, activity of synthetic pesticide was observed to be closer to that of pesticidal plants at 10% concentration (Appendix 1).

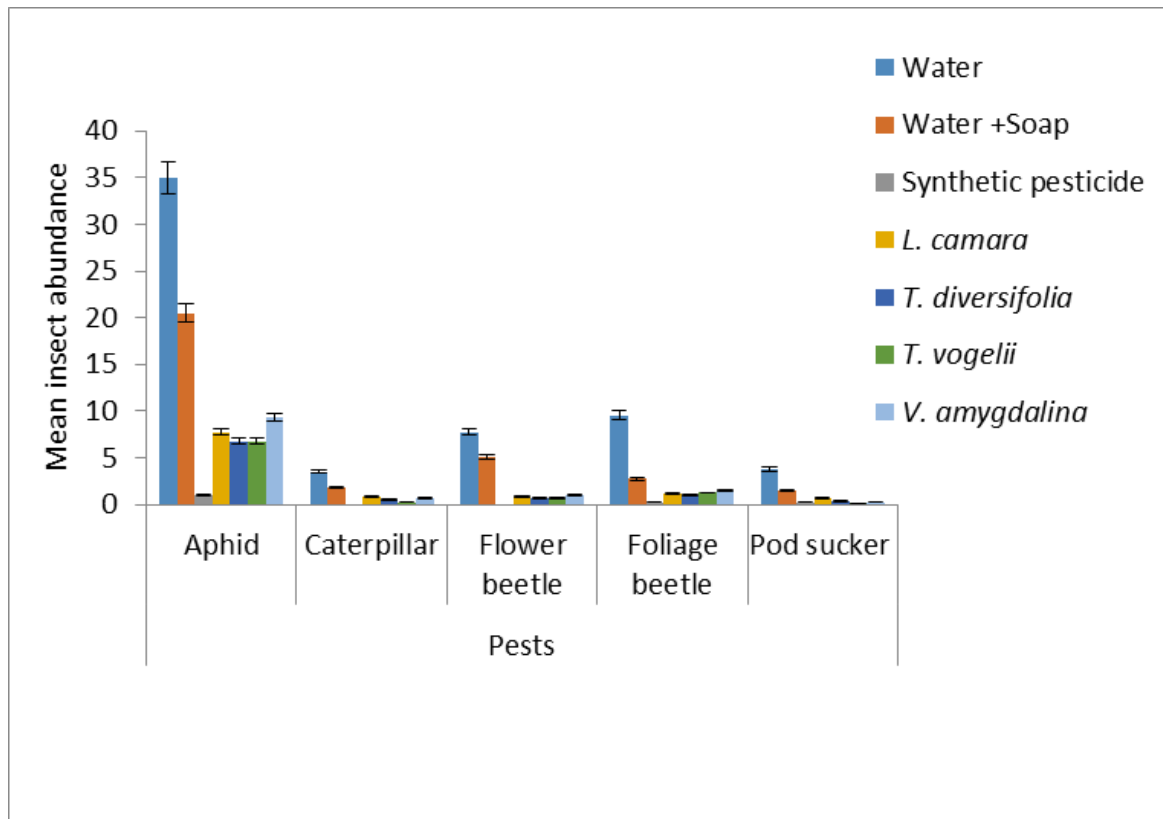


Figure 5 Mean abundance of insect pests in response to application of four pesticidal plant extracts, synthetic pesticide and control.

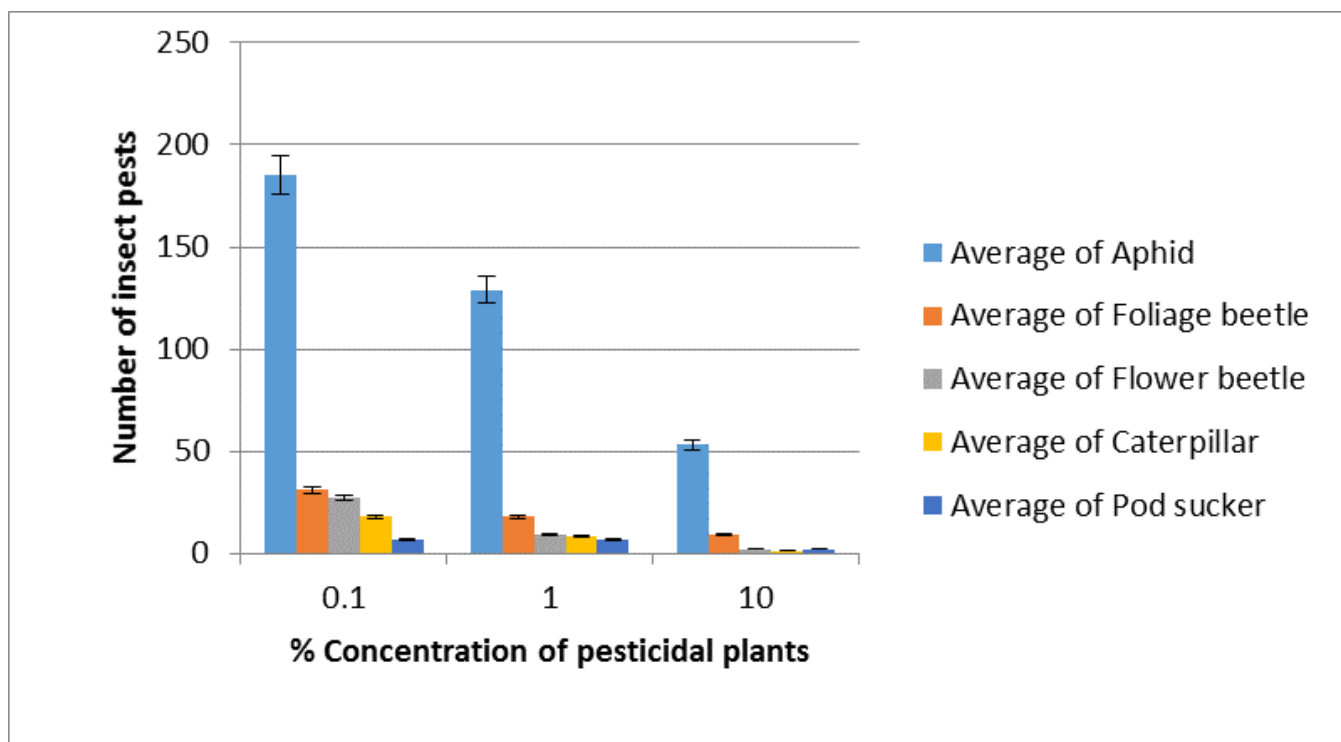


Figure 6: Abundance of insect pests in comparison to concentrations of pesticidal plants extracts.

3.3.2 Influence of treatments on the levels of damage by insect pests

Damage by insect pests was observed in the foliage parts of the bean plant leaves. Bean leaf beetles (*Ootheca*) and caterpillars (*Anticarsia gemmatalis*) were observed to cause foliage damage based on their modes of feeding on the bean leaves. There was a significant difference in the levels of damage from the second to the 6th week where significantly higher damage was observed in the control treatments (water and water +soap) contrary to pesticidal plants extracts at 10%, 1% and 0.1% concentrations (Appendix 2). Among the plant species, *T.vogelii* was observed to prevent damage to higher extent by causing only 2% damage followed by *T. diversifolia*, *L. camara* and *V. amygdalina*. Average percent (< 1%) damage by insect pests was exhibited by synthetic pesticides (Figure 7) as the least damage.

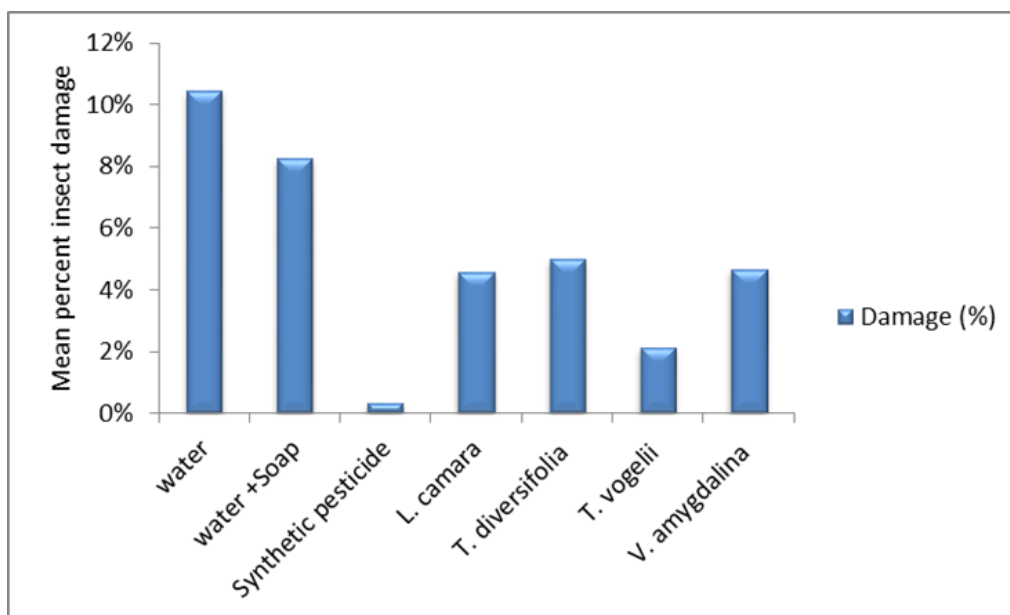


Figure 7: Mean percentage damage of common bean plants by key insect pests.

3.4. Discussion

Pesticidal plants namely *L. camara*, *T. diversifolia*, *T. vogelii*, and *V. Amygdalina* in this study have been proven to contain insecticidal activity against insect pests (Aphids, caterpillars, Bean leaf beetle (*Oothea bennigseni*), flower (blister) beetles and pod suckers) when compared with the controls (water and water + soap). These findings relate to Isman, (2000) who reported that essential oils from majority of plants do not only have insect repellent effects, but also contain contact and fumigant effects against specific insects. Activity of botanical pesticides is associated with compounds that can create desirable effects against insect pests. Ethanol and methanol have been used to extract these compounds under a laboratory conditions and the tests against insects have been recorded (Adeniyi *et al.*, 2010; Kolawole *et al.*, 2011; Atangwho *et al.*, 2012; Belmain *et al.*, 2012; Mamta and Jyoti, 2012; Rajesh *et al.*, 2014). Detergent (liquid soap) has been used for extraction as a cheap mechanism (Belmain *et al.*, 2012). This technique was also adapted in this study.

Higher effect against insect pests and also preventing their damage was observed in *T. vogelii*. Ability of *T.vogelii* to control insect pests was documented by others such as Ogendo and Belmain, (2003),Koono *et al.*, (2007)and Belmain *et al.*, (2012). Extracts from leaves of *T.vogelii* have been proven to contain rotenone that has higher pesticidal effect (Belmain *et al.*,

2012b). Its effects is also been regarded as a fish poison in tropical Africa (Neuwinger, 2004). Its effectiveness has been observed when used as a spray against Bean leaf beetle (*Ootheca bennigseni*), flower beetles (*Mylabris sp*), aphids (*Aphis fabae*) and stem boarers in beans and maize-beans farms (Mkenda *et al.*, 2015; Ogendo and Deng, 2015). Leaf extracts of *Lantana camara*, known by having bio fumigant effect contains coumarins, a compound that has been proven in the laboratory as effective against insects (Rajashekar *et al.*, 2014). Under field conditions, *L. camara* has been reported to treat golden flea beetles in which it was found to have a good repellent effect (Igogo *et al.*, 2011). Findings from this study confirm activity of *Lantana camara* as effective against insect pests. Extracts from *T.diversifolia* has sesquiterpenes lactones which have been tested and proven effective against insect pests (De Toledo *et al.*, 2014). Mkenda *et al.*, (2015) verified its activity against bean foliage beetles (*Ootheca bennigseni*), bean flower beetles (*Mylabris sp*) and aphids (*Aphis fabae*) in common beans (*Phaseolus vulgaris*). Activities of these identified compounds are reflected in the soap extracts of the four plants that were sprayed in beans. Likewise *V. amygdalina* contains phytochemicals such as alkaloids, terpenes, steroids, coumarins, flavonoids phenolic acids, lignansxanthonenes, anthraquinones, edotides and sesquiterpenes whose activity against insects are also noted (Farombi and Owoeye, 2011).

Synthetic pesticide in this study was the most effective in reducing abundance of insect pests and also exhibiting least damage by insect pests. Higher effectiveness of synthetic pesticide is caused by its persistence which can be as far as 14 days and has high mortality potential (Lethal effect) towards insects and its immediate impacts caused by its active ingredients (Biondi *et al.*, 2012). Synthetic pesticides have not been mentioned as being repellent like the case for pesticidal plants as reported by Isman, (2006). This therefore is the evidence for synthetics to contain higher capacity for insects' mortality compared with *T.vogelii*, *V. amygdalina*, *L. camara* and *T. diversifolia*.

3.5. Conclusion

Findings from this study indicate that pesticidal plants extracts from *T. vogelii*, *V. amygdalina*, *L. camara* and *T. diversifolia* have the ability to control insect pests and reduce levels of damage. It also further shows that effectiveness of the plant extracts increase with the increasing concentration in which 10% concentration was more effective compared with 0.1% and 1%

concentrations. In addition, preparation mechanism used in this study is proven appropriate that maintains effectiveness of extracts. Therefore, pesticidal plants can be used as an alternative insect pest control that is environmental friendly and as an option for small scale farmers in sub Saharan Africa due to their easy in preparation, effectiveness and low cost.

CHAPTER FOUR

Contribution of Pesticidal Plants Extracts to Environmentally Sensitive Pest Control Strategy in Northern Tanzania

Summary

Insect pests control mechanisms that involve use of synthetic pesticide have been known to cause threat to agricultural production because of their detrimental impacts to the environment. Efforts are thus underway to use less harmful pesticides from plants in order to enhance a control mechanism that can also maintain generations of pollinators and natural enemies. An experiment conducted in the Northern Tanzania aimed at evaluating effects of four commonly available pesticidal plants namely *Tephrosia vogelii*, *Vernonia amygdalina*, *Lantana camara* and *Tithonia diversifolia* on the abundance of beneficial insects (Spiders (Araneae), Lady Bird beetles (*Coccinella septempunctata*), Lacewings(Chrysopidae) and Robbefly (Asilidae) on bean crop as well as their contribution to yield of common beans (*Phaseolus vulgaris*). Plant materials were extracted using 0.1% soap solution mixed with pesticidal plants powders at concentrations of 0.1%, 1%, and 10% w/v. Application of extracts was conducted at intervals of seven days in which insects were recorded one day before application of treatments. Yield parameters; number of pods per plant, seed per pod, pod weight, 100 seed weight and plot yield were collected close to and during the harvesting period to evaluate yield in response to pesticidal plants extracts. Residues from *T.vogelii* were also analysed to identify length of time its compounds persists in the environment. Plants extracts of *Tephrosia vogelii*, *Vernonia amygdalina* and *Tithonia diversifolia* at 10% concentration significantly contributed to the yield of beans when compared to water and water +soap. Abundance of Ladybird beetles and Spiders was observed to be higher on pesticidal plants and much less to synthetic pesticides. Presence of tephrosin, an important compound for insect pest control from *T.vogelii* was identified and found to be present for seven days.

4.1 Introduction

In agriculture, environmental factors and agricultural practices play a vital role in the growth and yield of crops (Johnston and Sibly, 2015). These factors include natural biological interaction between soils and organisms such as earth worms, insect pollinators and insects that biologically control other pests which attack crops. Protecting the relationships between integrated ecosystem composition of the insects communities and the appropriate agricultural practices is vital for sustainable production and environmental protection (Bommarco *et al.*, 2013). Farmland species play a great role in ecological processes that are beneficial to crops' growth. It is unfortunate that some agricultural practices threaten their processes leading to loss of important species in the environment that are desired for good production through pollination and predation.

Common beans crop is commonly grown in developing countries and is well known for its nutritional importance (Speelpenning *et al.*, 2001). However it is attacked by several insect pests such as Bean foliage beetles (*Oothea bennigseni*), Flower (Blister) beetles and Aphids (Mkenda *et al.*, 2015). Under natural conditions there are also beneficial insects that are a biological control to insect pests by acting as predators and natural enemies. These are such as Spiders (Araneae), Lady Bird beetles (*Coccinella septempunctata*), Lacewings (Chrysopidae) and Robbeffly (Asilidae). Control of insect pests done by using plants extracts proves less harm to beneficial insects. Again, plant extracts are also good contributors of important nutrients necessary for plants' growth thereby leading to increased yield. On the other hand, synthetic pesticide is mentioned to cause impacts to insects communities by reducing immunity regardless of whether they are pests or beneficial to crops (James and Xu, 2012). They are also mention to cause massive deaths of insect colonies (Ellis, 2010). Their active ingredients possess high toxic effects and persist longer in the environment thereby having higher potential to cause effects to broad spectra of insects (Biondi *et al.*, 2012). Under this experiment Spiders (Araneae), Lady Bird beetles (*Coccinella septempunctata*), Lacewings (Chrysopidae) and Robbeffly (Asilidae) were the identified natural enemies and predators in the bean cultivation area. Pesticidal plant extracts and synthetic pesticide were applied and there after abundance of predator insects observed. Likewise, contribution of treatments on the yield of common beans (*Phaseolus vulgaris L*) and persistence of plant compounds to the environment was assessed.

4. 2 Materials and Methods.

4.2.1 Study area.

Study was carried out in the Tanzania Coffee Research Institute (TACRI) farms in Moshi-Northern Tanzania. The area is located within latitude 3°13'59.59"S and longitude 37°14'54"E. It is at an altitude of 1268m above mean sea level with the mean annual rainfall of about 1200mm and mean temperature of about 18°C. This area is mainly an agricultural land, cultivated with coffee, banana, maize and beans.

4.2.2 Preparation of pesticidal extracts.

Fresh leaves of the four species (*Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara*) were collected from five different accessible locations in Moshi and Arusha and each species mixed together before drying (Mkenda *et al.*, 2015). Leaves were dried under shade for a week and then crushed using an electric grinder after which a powdered form was packed in 1 kg plastic bags and stored in a dark dry condition. Preparation of a pesticide solution was done by soaking powder at three different concentrations; 10%, 1% and 0.1% (%w/v) using a solution containing 0.1% soap. Soap is used as a medium for extraction of compounds in the plant extracts (Belmain *et al.*, 2012). The mixture was left for 24 hours after which extracts were filtered through a clean cloth and used as a spray.

4.2.3 Field preparation and Experimental design

Study was carried out during the long rain season, from March to July 2015 which is the main bean cropping season. Field preparation was done in February 2015 by ploughing and then disc harrowing, done one day before planting. Bean seeds of 'Lyamungo 90' variety was obtained from the Selian Research Institute (SARI) in Arusha and planted on the 31st of March 2015. 25m² plots were prepared in two meters between each other and between the experimental units with the neighbouring fields. A randomized block design was used to layout 15 treatments of four replication each. Planting was done in a space of 20cm within rows and 50cm between rows.

Two seeds per hole were planted with Triple Super Phosphate (TSP) fertilizer added during planting following manufacture's recommendation. Treatments included four plant species each made in three concentrations (0.1%, 1% and 10%). Water and water + soap were also included as negative control while synthetic pesticide was used as a positive control.

4.3 Data collection

4.3.1 Assessment of beneficial insects.

Insect assessment was done one day before spraying (one count per week). 5 inner plants inside the 25m² (not on the edge) were randomly selected and sampled each week to assess the abundance of beneficial insects.

An assessment was done to the entire plant to note the presence/absence of beneficial insects. Abundance of Spiders (Araneae), Lady Bird beetles (*Coccinella septempunctata*), Lacewings (Chrysopidae) and Robbeffly (Asilidae) was recorded.

4.3.2 Yield assessment.

Yield parameters (without drying); pods per plant, number of seeds per pod, weight of 100 seeds and total yield in kg/h were collected two weeks before the harvesting period. Five plants were selected randomly from each plot and sampled for number of pods per plant. In each plant, five pods were selected to measure pod weight as well as counting seed per pod. After harvesting, 100 seed weight and plot yield data were recorded.

4.3.3 Persistence of pesticidal plants on bean plant leaves.

Persistence analysis was conducted on the ninth week of the experiment on plots sprayed with 10% concentration of *T.vogelii*. A uniform sized leaf (1cm²) was made using leaf punch apparatus using the dislodgeable foliar residue dissipation methodology by (USEPA-dislodgeable foliar residue dissipation: agricultural guideline 875.2100). A punched leaf was dipped into a vial with 7 ml methanol and left for 10 minutes to dislodge the pesticides residue compounds. Methanol was left to evaporate and vials sealed and stored in a refrigerator for analysis. Analysis was done by using LC–UV–MS methods to analyse MeOH extracts of *T.vogelii* leaves a method by Stevenson *et al.*,(2012).

4.3.4 Data analyses.

Mean number of beneficial insects and yield of beans in four replication plots were subjected to one way analysis of variance using STATISTICA program. The treatment means were separated by Fisher Least Significance Difference at $P=0.05$.

4.4 Results

4.4.1 Abundance of beneficial insects

Abundance of beneficial insects in response to application of treatments evaluated in this study showed a significant difference ($P \leq 0.05$) for lady bird beetles ($F=2.01$, $P \leq 0.05$) and on spiders ($F=4.75$, $P \leq 0.001$) across the treatments. Based on Figure 8 and Appendix 3, abundance of lacewings and robbefly showed no significant difference at $P \leq 0.05$ on the treatments (Appendix 3). Figure 8 depicts higher abundance of ladybird beetles in the controls (water and water +soap) as compared with abundance in *T.diversifolia*, *T.vogelii*, *L. camara* and *V. amygdalina*. Likewise, abundance of spiders was highest in the water treatment. Lacewings and robbefly had less average insects even in the controls. Comparatively, synthetic pesticide was observed to reduce higher number of ladybird beetle and spiders when compared with rest of the treatments as seen in Appendix 3 and Figure 8.

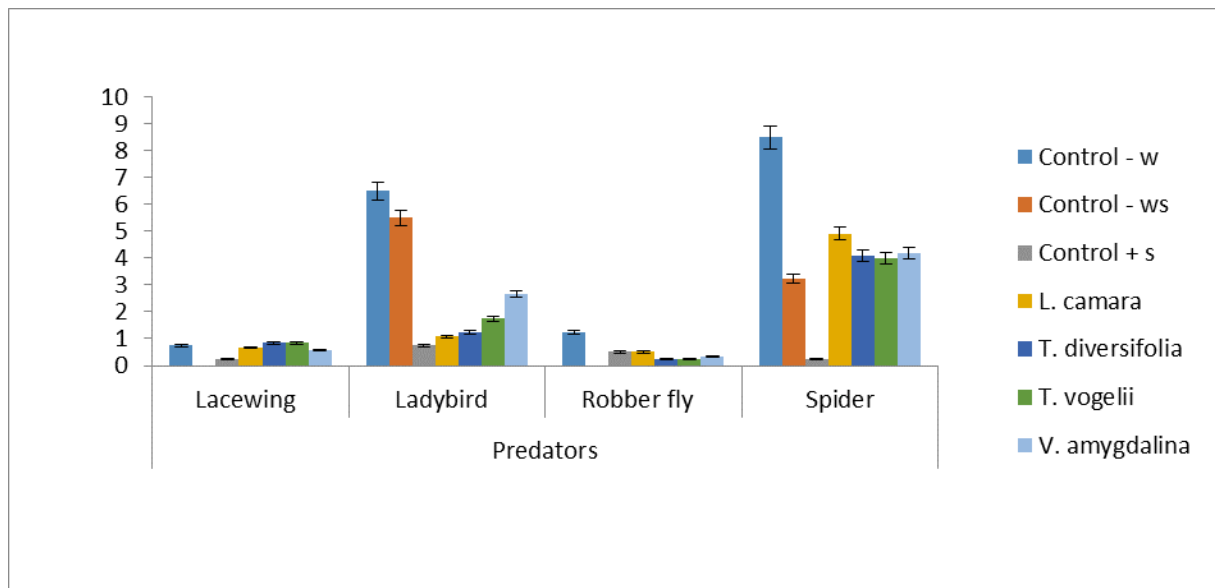


Figure 8 Abundance of beneficial insects in response to four plant species, synthetic pesticides and control.

4.4.2 Growth parameters and yield of common beans.

A significant effect of treatments was observed in yield parameters with 100 seed weight ($F=133.88$, $P \leq 0.001$), Pod weight ($F=3.56$, $P \leq 0.01$), seed per pod ($F=5.17$, $P \leq 0.001$), number of pods per plant ($F=2.22$, $P \leq 0.05$) and plot yield ($F=29.46$, $P \leq 0.001$).

Plots treated with pesticidal plants extracts manifested higher yield compared with the control plots treated with water (Appendix 4). Extracts of *T.vogelii* at 10% showed a significantly higher average 100 seed weight (69.00 ± 0.41), average pod weight (2.95 ± 0.05), average number of seeds per pod (9.05 ± 0.13) average number of pods per plants (10.90 ± 0.81), as well as plot yield (961.10 ± 81.86). Comparatively, lower average yield parameters were observed in the plots treated with water (Appendix 4).

Among the four pesticidal plants, extracts of higher concentration (10%) of *T.vogelii*, *T.diversifolia* and *V. amygdalina* at 10% concentration showed higher yield compared with plant extracts of lower concentrations (0.1% and 1%). Exceptionally, *Lantana camara* at 10% concentration exhibited lower yield. (Figure 9). Synthetic pesticide treatment was observed to have comparably higher yield as the pesticidal plants treatments (Figure 9). Statistically, there was no significance difference of the 100 seed weight between synthetic pesticide and *T.diversifolia* at 10% concentration, similarly no significant difference of the average pod weight was observed between synthetic pesticides, *Lantana camara* (10%) and *V. amygdalina* (10%) showing that pesticidal plants extracts were as effective as the synthetic pesticide.

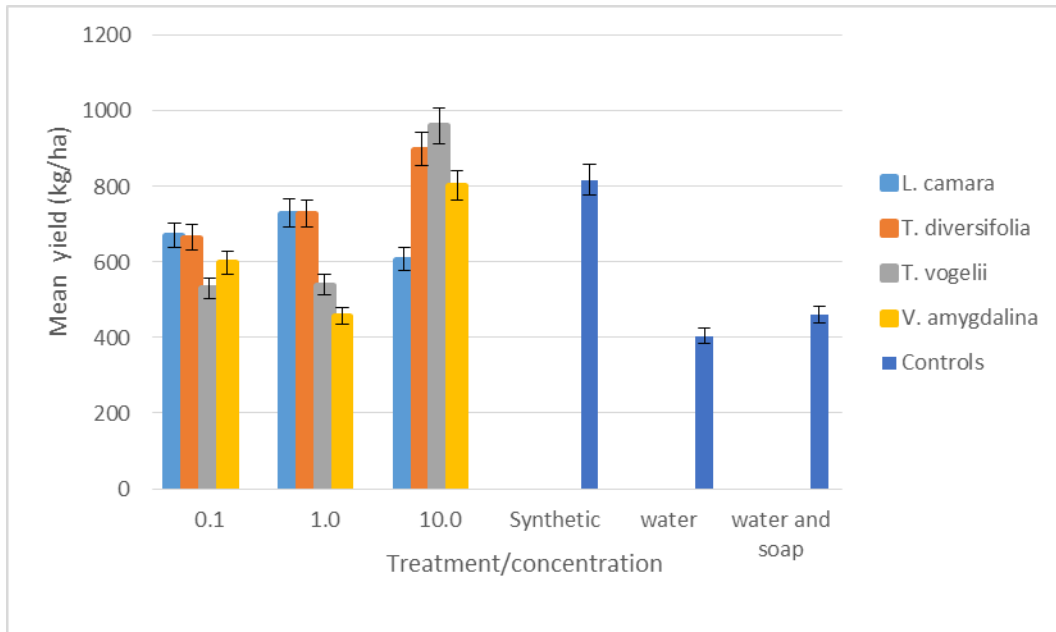


Figure 9: Effects of concentration of treatments on the yield of common beans.

4.4.3 Presence and persistence of active compounds from *T.vogelii*.

Figure 10 Shows average and percentage tephrosin that was recovered from the *T.vogelii* (10%) treated plots. Fast reduction was observed on the second day in which 13.83% of tephrosin was reduced. A slight shift was observed on the third day in which 0.24% was observed to increase. 70.56% of tephrosin was however observed on the seventh day after the spraying of *T.vogelii* extract.

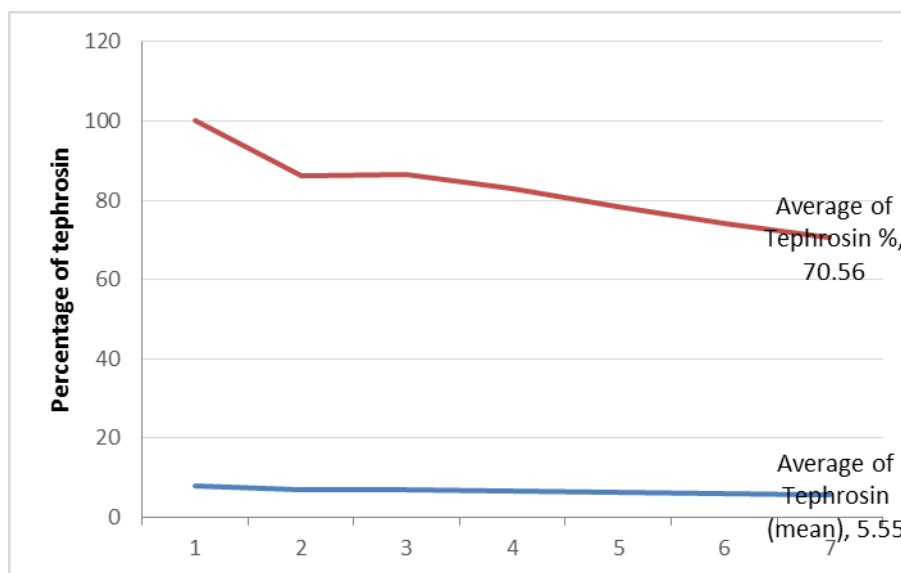


Figure 10 Average mean and percentage breakdown of tephrosin from *T.vogelii*.

4.5 Discussion.

Findings from this study show that pesticidal plants have less detrimental effects on beneficial insects. Mkenda *et al.*, (2015) reported less effect on spiders and ladybird beetles, findings that relate to the results of this study. However, this study also revealed a smaller number of lacewings and robber fly. Lacewings are believed to live in an extensive range of habitats in which case they are rarely concentrated in one area (Henry and Brooks, 2012) and their survival is supported by flowers that have open nectaries to enable laying eggs (Rijn, 2012). Absence of habitats of this nature in the vicinity of the experimental area may have led to their less abundance. Likewise, robber flies are known to be restricted to habitat requirement and are vulnerable to habitat destruction (McCravy and Baxa, 2011). As a result, less number of lacewings and robberfly has been observed.

Yield of common beans in this study is found to be influenced by pesticidal plants and by synthetic pesticide treatments. Higher yield in synthetic pesticide treatment as observed in the results appear to be an indication of low infestation and less damage by insect pests. Synthetic pesticide has been proven to have the most effective in controlling insects when compared with other insect control mechanisms (El-Wakeil, 2013; Igogo *et al.*, 2011; Mkenda *et al.*, 2015). On the other hand, pesticidal plants, *Tephrosia vogelii* (10%), *Tithonia diversifolia* (10%) and *Vernonia amygdalina* (10%) were observed to have higher plot yield similar to the synthetic pesticide. In addition to ability of repelling insect pests hence leading to reduced infestation and damage, these plants have ability to increase nutrients to crops leading to increased yield. This observation is supported by the findings from Stevenson *et al.*, (2012) who found that *T.vogelii* has a capacity of nitrogen fixation leading to better plant performance and hence higher yield. Extracts of *T.diversifolia* have also been tested and has shown its contribution of minerals important in the soil for growth of crops (Shokalu *et al.*, 2010; Olabode and Ogunyemi, 2007) by improving soil pH, N, P, K, Mg and Zn. It is also reported by Mkenda *et al.*, (2015) that plants extracts that contribute to yield had ability to prevent insect pests and have less effects on beneficial ones.

The length of time that pesticidal compounds persist in the environment was also investigated. In this study, rotenone from *T.vogelii* a compound proven by Belmain and Amoah, (2012) for its insecticidal effect was evaluated where rate of degradation and persistence in the environment under a field condition was assessed. Results from 10% concentration of *Tephrosia vogelii*

support the fact that compounds from plant have capability of persisting in the environment for an ample time to cause appreciable impacts such as insects repellence and nutrients availability for plants growth (Isman, 2006).

Pesticidal plants compounds like rotenone are generally known to persist in the environment for a time ranging from hours to a number of days (Dubey, 2011) depending on natural climatic variations such as humidity, sunshine and rains. Slow degradation of tephrosin is linked with the high humidity and low temperature that persisted during sampling process.

4.6 Conclusion.

Pesticidal plants have been observed to support presence of Spiders and Lady Bird beetles, which are beneficial insects to beans (*Phaseolus vulgaris*). This study has also shown that application of *T.vogelii*, *T.diversifolia* and *V. amygdalina* lead to increased yield of common beans. On the other hand, synthetic pesticide reduced the abundance of beneficial insects much more compared with the pesticidal plants and the negative control. Pesticidal plants are therefore good alternatives to synthetic pesticides because of their less harm to beneficial insects and contribution to yield of crops.

CHAPTER FIVE

Efficacy of Pesticidal Plants Powders in Controlling *Callosobruchus maculatus* on Stored Cowpeas (*Vigna unguiculata*).

Summary

Cowpea is an important legume in developing countries because of its nutritional and economic values to small scale farmers. It is however faced by destruction caused by storage insect pests that lead to significant post-harvest losses. Plant based insecticides have been proven effective in the insect control and are known to be environmental friendly. Efficacy of four pesticidal plants, *Tephrosia vogelii*, *Lantana camara*, *Tithonia diversifolia* and *Vernonia amygdalina* was tested against *Callosobruchus maculatus* infestation on stored cowpeas grains (*Vigna unguiculata*). Cowpea seeds free from infestation were admixed with powders of the plant leave at concentrations of (25g/2500 and 250/2500g w/w) and a synthetic pesticide (Actelic dust) was included in the experiment as a positive control. Adult (*C.maculatus*) infestation, oviposition and cowpea damage were assessed. Results show that synthetic pesticide had highest efficacy in preventing infestation while *T.vogelii* was the most active pesticidal plant at all concentrations followed by *Lantana camara*. With time of exposure, *T.diversifolia* and *V. amygdalina* showed the least efficacy. This study concludes that *T.vogelii* is a reliable alternative to synthetic pesticides use in the control of *C.maculatus* in stored cowpeas.

5.1 Introduction

Cowpeas represent a group of leguminous plants grown in developing countries, in Africa, Latin America and Asia (Zulu, 2011). It is an important legume that has a supply of protein from its grains, green pods and fresh leaves (Pule-Meulenberg, 2010), is drought resistant and has important role in fixing nitrogen in the soil and so contributing to soil fertility. (Baributsa and Lowenberg-DeBoer, 2010). Cowpeas has also high contents of vitamin C (Wawire *et al.*, 2011). Cowpeas are grown mainly by small scale farmers across Africa as a source of income for small scale farmers. It has been sold locally, but also has been exported outside producing countries, thereby providing income to farmers (Baributsa and Lowenberg-DeBoer, 2010).

Small scale farmers in Sub-Saharan Africa face a challenge in the cultivation and storage of cowpeas (*V. unguiculata*). During growth, aphids have been found to be an important pest in the tropics that has led to the destruction of the cowpea plants (Obopile and Ositile, 2010). Weed management is another constraint facing farmers, especially those having smaller areas of cultivation that result in less yield (Mashingaidze and Madakadze, 2012).

Nevertheless, studies by Ilboudo *et al.*, (2010) and Murdock *et al.*, (2012) have highlighted a major cause of cowpeas loss to be insect pests during storage in which *Callosobruchus maculatus* is an insect species that has been mentioned to cause serious losses during storage of cowpeas in many regions of Africa.

Control of *C. maculatus* has been done in various technologies to avoid losses. These include storing grains in airtight containers (Murdock *et al.*, 2012), use of synthetic pesticides such as pirimiphos-methyl (Actelic dust) and use of bio pesticides. Synthetic pesticides are known for their effects to the environment and to humans (Jenkins *et al.*, 2013). In this case massive studies support the use of pesticidal plants for the reason that they are less toxic to the environment and to people's health. Plant species are also cheaply available on the roadsides, farm margin and on uncultivated areas. They are therefore a cheap alternative to small scale farmers. However, majority of studies have been conducted and their results are promisingly effective but have been done under a laboratory scale that reflects less of what small scale farmers experience in the fields. This study assessed the efficacy of leave powders made from four plants namely *Tithonia diversifolia*, *Lantana camara*, *Tephrosia vogelii* and *Vernonia amygdalina* against infestation by cowpea weevils (*Callosobruchus maculatus*) under farmers' actual storage condition.

5.2 Materials and Methods

The experiment was conducted in the Nelson Mandela African Institution of Science and Technology premises. A storage house was designed to resemble a normal farm store that small scale farmers use for storage. It included ventilated windows covered with net to ensure containment of the insects.

5.2.1 Preparation of *Callosobruchus maculatus* insect culture

Callosobruchus maculatus were obtained through a stock of cowpeas slightly infested with eggs purchased from Kikatiti local market in Arusha region. Infested cowpeas were kept under a room temperature and ambient air for 21 days in the jars with perforated tight lids at the Nelson Mandela African Institution of Science and Technology laboratory. After the emergence of the insects, infested cowpeas were transferred into 5 buckets each containing whole cowpea seeds to provide for growth of adult insects.

Cowpeas of Raha 1” variety which were organically produced and free from infestation were obtained from Ilonga Agricultural Research institute in July 2015 were used for growing insects and for the whole experiment.

5.2.2 Preparation of pesticidal plants

Leaves of pesticidal plants namely *Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara* were collected from five different locations and each species mixed together. Collected leaves were dried under a shade in a closed aerated room to prevent breakdown of active compounds. as reported by Dubey *et al.*,(2008). Dried leaves were ground using an electronic grinder and kept into the plastic bags in a dark condition.

5.2.3 Experimental setup

Cowpeas used for the experiment were frozen at -20⁰C and oven dried at 70⁰C to kill possible existing insects’ larvae and eggs. Thereafter, 2500g of cowpeas were weighed and admixed with concentrations of 25g and 250g (w/w) of *Tephrosia vogelii*, *Vernonia amygdalina*, *Tithonia diversifolia* and *Lantana camara*. Weighed and admixed cowpea and plant powders were packed into 2500g capacity sisal bags. Actelic super dust at a concentration provided by the manufacturer was also used in the experiment as a positive control. Each treatment was replicated five times. Treated cowpeas were transferred into a closed, isolated storage room and exposed to natural infestation by *Callosobruchus maculatus* wick were stored in the 5 (five) open lid buckets. Insects from the buckets were left to fly into the cowpeas arranged in the storage room. The cowpeas were exposed to a continuous supply of insects throughout the experiment time.

5.2.4 Data collection

Packed cowpea bags were opened and inspected for assessment of infestation, oviposition and damage. An assessment was conducted after every two weeks from the on-start of the experiment. Bags were opened and cowpea seeds stirred after which 125g sample of the cowpea was weighed and used to assess the extent of infestation by *Callosobruchus maculatus*. Hand

lens was used to visualize and count number of any adults' eggs and holes on the seeds. After the assessment, cowpeas were returned back to the respective bags, closed and stored again.

5.2.5 Data analysis.

The number of adults, number of eggs and number of holes on the seeds and percent damage were subjected to one-way analysis of variance (ANOVA) using the STATISTICA program. Statistical differences between the means were separated using the least significant difference (LSD) test at the level of $P \leq 0.05$.

5.3 Results

5.3.1 Infestation by adult *C.maculatus*.

Appendix 5 indicates a significant difference ($P \leq 0.05$) in the mean number of adult *C.maculatus* observed from a 125g subsample. Under a continuous possibility of infestation, there was no significant difference in the number of adults in the second week of exposure of cowpeas to *C.maculatus* infestation. Comparatively, number of insects increased with increase in time of exposure. There was a significant difference ($P \leq 0.05$) in the mean number of adult insects between the (Pirimiphos-methyl) and the pesticidal plant powders in which least number of adult insect was observed in the Actelic dust (Appendix 5). Powder of *Tephrosia vogelii* at 25 and 250g/2500 g of cowpea showed a minimum infestation on the 10th week of observation (4.60 ± 1.50) compared with the rest of pesticidal plant species. Followed by *T.vogelii* was *L.camara* having a slight higher infestation than *T.vogelii* but less than *V.amygdalina* and *T.diversifolia* that exhibited much higher infestation.

Statistically, a significance difference ($P \leq 0.05$) was observed between untreated control and *T.vogelii*. Conversely, no significant difference was observed between *T.vogelii* and the Actelic dust thus showing higher effectiveness of *T.vogelii* (Appendix 5). There was also no significant difference at $P \leq 0.05$ between the untreated controls with *L. camara*. Hence only *T.vogelii* of the four species was observed to have effectiveness against adult *C.maculatus* infestation.

5.3.2 The oviposition of *C.maculatus*.

Oviposition started on the fourth week after the exposure of the treated cowpeas to adult *C.maculatus* (Appendix 6). An increasing trend of oviposition was observed to other treatments except for Actelic dust and *T. vogelii* (250/2500g) where oviposition decreased from the 8th to the 10th week. There was no significant difference in the mean oviposition between the Actelic dust with *T.vogelii* and *L. camara* until the 10th week of observation. On the other hand, a significant difference was observed between Actelic dust with *V. amygdalina* and *T. diversifolia*. Among the plant species, *T.vogelii* was observed to have highest efficacy by having less oviposition ($2.20 \pm 1.36d$) as with the commercial actelic dust ($3.80 \pm 1.62d$). Lowest efficacy was exhibited by *V. amygdalina* and *T.diversifolia* (Appendix 6).

5.3.3 Damage by adult *C.maculatus*.

Extent of damage of the cowpea seeds was done by observing number of holes made on the cowpea grains. Appendix 7 shows significance ($P \leq 0.05$) of treatments on the damage by *C.maculatus*. Among the botanical plant powders, *T. vogelii* (250/2500g) exhibited lowest percent damage ($1.09 \pm 0.17\%$) followed by *T.vogelii* (25/2500g). Least effect was shown by *T.diversifolia* (250/2500) by exhibiting highest percentage damage ($65.67 \pm 17.24\%$). There was a significant percentage damage difference between the untreated control and the plant powders treatments. No significance difference was statistically observed between the actelic dust and *T.vogelii*, thereby indicating *T.vogelii* as the most active plant powder against damage to the cowpeas for the test period in this study.

5.4 Discussion.

In this study, leaf powder from *Tephrosia vogelii* showed highest control of infestation by fewer adults, oviposition and damage by *Callosobruchus maculatus* compared with *Lantana camara*,

Tithonia diversifolia, and *Vernonia amygdalina*. Effectiveness of *T. Vogelii* is proven to be higher against *C.maculatus* in stored *V. unguiculata* (Mkenda *et al.*,2015). Extracts of *T vogelii* consists of compound of chemotype 1 (Presence of rotenoids) that is proven to have an effective insecticidal activity against pests as opposed to chemotype 2 that has an absence of rotenoids as reported by Belmain *et al.*, (2012). Apart from stored cowpeas pests, Hexane extracts of *T.vogelii* have also been proven to work against *Sitophilus zeamais* Motschulsky a common maize pest in Africa (Koono and Koono, 2007).

Ogendo and Belmain ,(2003)observed that *L. Camara* follows *T.vogelii* in its activity against damage and on oviposition caused by *Sitophilus zeamais* Motschulsky on maize. Effectiveness of *L. camara* and *T.vogelii* is reflected in this study where *L.camara* exhibited lower adult infestation compared with *T.diversifolia* and *V. amygdalina* although its activity was less than that of *T.vogelii*. Again, *L. camara* has also been proven to contain fumigant and contact toxicity molecules against insect pests including *Callosobruchus chinensis* (Rajashekar, 2014). Coumarins is a compound that has been found in *Lantana camara* as potential bio fumigant and which is observed to be environmentally friendly and therefore thought of as a good grain storage pest control option(Rajashekar *et al.*, 2013).

Effectiveness of *Vernonia amygdalina* was found less against all observed parameters at concentrations of 25 and 250g/2500g of *C.maculatus*. The same result was discussed by Mkenda *et al.*, (2015) and recommended it not worthy of promotion for storage pests control. These results however are different from Adeniyi *et al.*,(2010) who observed that *V. amygdalina* possess mortality effect against storage pests (*A. obtectus*). Musa *et al.*,(2009) confirmed the mortality, small egg count and suppressed adults' emergence when a mixture of *V. Amygdalina* with *Ocimum gratissimum* was used against *Callosobruchus maculatus*. The same observation was noted in *Tithonia diversifolia* in which Kolawole *et al.*,(2011) investigated ethanol extracts on *T.diversifolia* and highlighted its efficacy by their enzyme inhibition properties against *C. maculatus*.

However, a difference between results that reported activity on *V. amygdalina* and *T.diversifolia* and the observed less activity of the same plant species in this study appear to be caused by experimental setups and preparation mechanisms of plant extracts.

This study was a large scale involving natural environmental conditions and natural infestation by *Callosobrochus maculatus* as well as naturally prepared treatments without any additional controlled extraction mechanisms. Studies done by Adeniyi *et al.*, (2010) and Musa,(2009) on the other hand were small scale and restricted to the laboratories conditions. In these cases, results between laboratories based experiment and field based experiment appear to contribute to the differences.

5.5 Conclusion.

In this study, *T.vogelii* showed higher effectiveness more than the rest of pesticidal plants powders. Cowpeas treated with *T.vogelii* exhibited less counts of adult *C.maculatus*, less oviposition and also less number of holes (damage).For *T.vogelii*, 250g concentration showed higher effectiveness compared with lower concentration (25g). On the other hand, effectiveness of *V. amygdalina*, *T.diversifolia* and *L. camara* were lower and therefore not recommended as an insect control mechanism. Therefore *T.vogelii* is recommended as a control measure in stored cowpeas.

CHAPTER SIX

6.1 GENERAL DISCUSSION

Environmental friendly options for controlling insect pests to small-scale farmers were evaluated in this study. Great diversity of pesticidal plants in Africa have been proven by various researchers as being effective against insect pests (Mkenda *et al.*, 2015a; Mkenda *et al.*, 2015b; Amoabeng *et al.*, 2013; Brisibe *et al.*, 2013; Stevenson *et al.*, 2014). Compounds from pesticidal plants are a proven solution against insect pests that do not affect ecological settings and that are cost effective. In this study, four pesticidal plants (*T.vogelii*, *L. camara*, *V. amygdalina* and *T.diversifolia*) were evaluated and found to have activity against insect pests on common beans in the field as well as on storage cowpeas.

Effectiveness of synthetic pesticides as a positive control in this study appeared to exceed that of botanical pesticides. Synthetic pesticides have been predestined as being less selective and highly toxic to organisms (Johnson *et al.*, 2010; Wuet *et al.*, 2011). Again synthetic pesticides have residue effects and stay longer on the environment in which case are regarded as destructive to a broad spectrum of organisms and to health of users and consumers (Biondiet *et al.*, 2012).

Pesticidal plants appear to have repellent effects that only keep insects away for a while without damaging them. Isman *et al.*, (2011) demonstrated repellent effects of oils from plants and suggested a repellent potential that they can pose to insects. Likewise, Khater, (2012) suggested that pesticidal plants induces acute toxicity, deterrent and repellent effects towards insects and hence worthy being incorporated into integrated pest management for pre- and post-harvest to ensure residues free foods as well as safe environment to live. In this study, related results were observed when in each experiments; synthetic pesticide appeared the most effective by reducing a considerable number of insects compared with the pesticidal plants and the negative control.

Under field condition, observation showed effectiveness of pesticidal plants against common insect pests of beans (Bean leaf beetles (*Oothea*), Flower beetles, Pod suckers, Aphids and caterpillars) by reducing their abundance and reducing damage by insect pests. Extracts from *T. vogelii* was recorded as the most effective compared with *L. camara*, *V. amygdalina* and *T.diversifolia*. Belmain *et al.*, (2012) reported *T.vogelii* to contain rotenoids, which contain a strong insecticidal activity.

Being effective imply that Northern Tanzanian species of *T.vogelii* contain Chemotype 1 which according to Belmain *et al.*, (2012) are effective against insect pests. This is similar to its effectiveness against *C.maculatus* in stored cowpeas. Leaf powder of *T.vogelii* was the most effective compared with the rest of plant species tested by manifesting less adult infestation, inhibition of oviposition and controlled damage of the grains by the *C.maculatus*. After mixing plant powders with the grains, results showed that adult insects could not fly into the bags treated with *T.vogelii* and especially at its highest concentration (250g/2500g). It is evident that *T.vogelii* contains a strong repellent effect at various states; in solution form as well as a grounded powder. This observation is supported by findings from Igogo and Ogendo, (2011), Isman, (2006), Ogendo and Belmain, (2003).

Extracts of *Tithonia diversifolia* is observed to contain pesticidal effects against insect pests whose activity follows second after *T.vogelii* in treating the field insect pests. Dry leaves as the case in this study appear to have more efficacy as also reported by Castaño-Quintana *et al.*,(2013) and Mkenda *et al.*,(2015).On the other hand, efficacy of leaf powder of *T.diversifolia* against *C.maculatus* during storage of cowpeas grains was lower in this study. In other words it appears that *T.diversifolia* has poor fumigant effect as was similarly reported by Mkenda *et al.*,(2015a). Again *V. amygdalina* and *L. camara* were observed to have less effectiveness on their efficacy in the control of insect pests under field condition. Contrary to the field, *L. camara* was recorded to have improved activity against *C.maculatus* infestation in stored cowpeas when compared with *V. amygdalina*. The findings on *V. amygdalina* relate to those of Mkenda *et al.*,(2015a) supporting less activity of *V. amygdalina*. Contrary to the effectiveness of *V. amygdalina* and *T.diversifolia*, *Lantana camara* was found by Ogendo *et al.*,(2003) to have an activity on a bioassay experiment against *Sitophilus zeamais* and also ranked second after *T.vogelii* in its activity against *C.maculatus*.

Pesticidal plants investigated in this study are associated with growth and yield of the bean plants under field conditions. Contribution of pesticidal plants on the growth and yield of bean plants can be discussed on three aspects. Firstly, the ability of plant extracts to repel insect pests and thereby leading to less damage and infestation, Secondly, its ability to maintain a diversity of beneficial insects that are useful in predation and pollination (James and Xu, 2012; Laubertie *et al.*, 2012; Lenget *et al.*, 2011) and thirdly because of the contribution of nutrient supply to growing plants (Olabode and Ogunyemi, 2007; Wang *et al.*, 2011). Extracts from *Tithonia diversifolia*

and *Tephrosia vogelii* were observed to influence high yield. Specifically, Shokaluet *et al.*, (2010) documented importance of *Tithonia diversifolia* in soils for its contribution to soil pH, N, P, K, Mg and Zn all of which are important for plants growth and yield. Likewise, *Tephrosia vogelii* contribution to Nitrogen fixation is reported in several literatures (Munthali *et al.*, 2014; Stevenson *et al.*, 2012; Wang *et al.*, 2011) as contributing to the proper growth of plants and enhanced yield.

Less persistence to the environment is one of the credits that pesticidal plants possess. It is an important aspect to ecological balance and residue free food. In this study, *T.vogelii* was evaluated for the persistence of rotenone, a compound responsible for pesticidal effect. Slow degradation was observed and was considered as an effect of low temperature and high humidity that persisted over the time of sampling. This observation is confirmed by findings from Dubey, (2011) who highlighted that compounds of the pesticidal plants can persist for hours or days.

6.2 CONCLUSION

Pesticidal plants evaluated in this study have shown their contribution to the control of insect pests under field and also in storage conditions. Under field condition all the four pesticidal plants (*T.vogelii*, *T.diversifolia*, *V. amygdalina* and *L. camara*) were observed to have effectiveness against insect pests. Higher concentration (10%) was found to be more effective compared with lower concentrations (0.1% and 1%). Also these plants were observed to favor abundance of beneficial insects that were identified as well as contribute increased yield of common beans. However, effectiveness of the positive control manifested the highest efficacy of all treatments indication that its ability to control insect pests was higher. Effectiveness of *T.vogelii* appears to be contributed to by its ability to persist longer in the environment as observed in this study. Different from the field experiment, only *T.vogelii* was found effective against *C. Maculatus*. Adult infestation, oviposition and damage by *C maculatus* was less in the cowpea grains treated with *T. Vogelii* and a positive control (Actelic super dust).

6.3 RECOMENDATIONS

Use of pesticidal plants has been practiced since long in history by indigenous Africans before the advent of use of synthetic pesticides. Effects of synthetic pesticides also lead to scientific researches on alternative pests control options.

It is evident that a limited research has been done to uptake the knowledge possessed by local small scale farmers who are the typical users and instead have been focusing on small scale laboratory bioassays. It is therefore recommended to strengthen practical research, which focuses on uptake of this knowledge to small scale farmers. In this study, *T.vogelii* is found to have the highest effectiveness compared with the rest of pesticidal plants tested both in the field and storage conditions and its persistence was determined to be longer in the environment indicating better ability to control insect pests. This gives room for more research on *T.vogelii* on several aspects such as a possibility to use it on a commercial scale, increase its shelf life, and improve proper storage condition that keeps its active ingredient and possible conditions and standards of use by small-scale farmers. In addition, the study suggests further research on proper methods of recovering and determining compounds from pesticidal plants sprayed in the field in order to understand persistence and therefore suggest possible intervals of application for better results.

REFERENCES

- Abizari, A.-R., Pilime, N., Armar-Klimesu, M., and Brouwer, I. D. (2013). Cowpeas in Northern Ghana and the factors that predict caregivers' intention to give them to schoolchildren. *PloS One*, **8**(8): e72087.
- Adeniyi, S. A., Orjiekwe, C. L., Ehiagbonare, J. E., and Arimah, B. D. (2010). Preliminary phytochemical analysis and insecticidal activity of ethanolic extracts of four tropical plants weevil (*Acanthscelides obtectus*). *International Journal of the Physical Sciences* **5** (6):753–762.
- Amoabeng, B. W., Gurr, G. M., Gitau, C. W., and Stevenson, P. C. (2014). Cost : benefit analysis of botanical insecticide use in cabbage : Implications for smallholder farmers in developing countries. *Crop Protection*, **57**: 71–76.
- Amoabeng, B., Gurr, G., and Gitau, C. (2013). Tri-trophic insecticidal effects of African plants against cabbage pests. *PloS One*. **8**(10):1-10.
- Anyanga, M., and Muyinza, H. (2013). Resistance to the weevils *Cylas puncticollis* and *Cylas brunneus* conferred by sweetpotato root surface compounds. *Journal of Agricultural and Food Chemistry*.**81**:8141-8147.
- Aserse, A., Räsänen, L., Assefe F., Hailemariam, A and Lindstrom, K. (2012). Phylogeny and genetic diversity of native rhizobia nodulating common bean (*Phaseolus vulgaris* L.) in Ethiopia. *Systematic and Applied Microbiology*.**35** (2012):120-131.
- Atangwho, I. J., Edet, E. E., Uti, D. E., Obi, A. U., Asmawi, M. Z., and Ahmad, M. (2012). Biochemical and histological impact of *Vernonia amygdalina* supplemented diet in obese rats. *Saudi Journal of Biological Sciences*.**19** (3): 385–392.
- Attfield, K., and Hughes, M. (2014). Within-and between-child variation in repeated urinary pesticide metabolite measurements over a 1-year period. *Environmental Health Perspect*.**122** (2): 201–206.

- Baributsa, D., and Lowenberg-DeBoer, J., Murdock, L. and Moussa, B. (2010). Profitable chemical-free cowpea storage technology for smallholder farmers in Africa: opportunities and challenges. Proceedings of the 10th International Working Conference on Stored-Product Protection, 27 June - 2 July, 2010, Estoril, Portugal. *Julius-Kuhn-Archiv*, **425**: 1046-1053.
- Beebe, S. E., Rao, I. M., Blair, M. W., and Acosta-Gallegos, J. A. (2013). Phenotyping common beans for adaptation to drought. *Frontiers in Physiology*, **4**:1-20
- Beebe, S., Ramirez, J., Jarvis, A., Rao, I. M., Mosquera, G., Bueno, J. M., and Blair, M. W. (2011). Genetic Improvement of Common Beans and the Challenges of Climate Change. *In Crop Adaptation to Climate Change* (pp. 356–369). Wiley-Blackwell.
- Belmain, S. R., Amoah, B. A., Nyirenda, S. P., Kamanula, J. F., and Stevenson, P. C. (2012). Highly variable insect control efficacy of *Tephrosia vogelii* chemotypes. *Journal of Agricultural and Food Chemistry*, **60** (40):10055–10063.
- Belmain, S., Haggart, J., Holt, J., and Stevenson, P. (2013). Managing legume pests in sub-Saharan Africa: Challenges and prospects for improving food security and nutrition through agro-ecological intensification. Chatham maritime (United Kingdom): Natural resource Institute, University of Greenwich. 34p
- Biondi, A., Desneux, N., Siscaro, G., and Zappalà, L. (2012). Using organic-certified rather than synthetic pesticides may not be safer for biological control agents: Selectivity and side effects of 14 pesticides on the predator *Orius laevigatus*. *Chemosphere*, **87** (7), 803–812.
- Blair, M. W., and Izquierdo, P. (2012). Use of the advanced backcross-QTL method to transfer seed mineral accumulation nutrition traits from wild to Andean cultivated common beans. TAG. Theoretical and Applied Genetics. *Theoretische Und Angewandte Genetik*, **125** (5): 1015–31.
- Blair, M. W., Astudillo, C., Rengifo, J., Beebe, S. E., and Graham, R. (2011). QTL analyses for seed iron and zinc concentrations in an intra-genepool population of Andean common beans (*Phaseolus vulgaris* L.). TAG. *Theoretical and Applied Genetics. Theoretische Und Angewandte Genetik*. **122**(3): 511–21.

- Bolognesi, C., and Merlo, F. D. (2011). Pesticides: Human Health Effects. In J. O. Nriagu (Ed.). *Encyclopedia of Environmental Health* (pp. 438–453).
- Brisibe, E., Aduabo, S., Ekanem, U., Brisibe, F. and Figueira, G.M. (2011). Controlling bruchid pests of stored cowpea seeds with dried leaves of *Artemisia annua* and two other common botanicals. *African Journal of Biotechnology*. **10** (47): 9586-9592.
- Cameron, K., Howard, C., and Izevbigie, E. (2013). Sensitivity and mechanisms of taxol-resistant prostate adenocarcinoma cells to *Vernonia amygdalina* extract. *Experimental and Toxicologic Pathology*. **65** (6): 759–765
- Campos-Vega, R., Oomah, B., Loarca-Piña, G., and Vergara-Castañeda, H. (2013). Common Beans and Their Non-Digestible Fraction: Cancer Inhibitory Activity—An Overview. *Foods*. **2**(3): 374–392.
- Castaño-Quintana, K., Montonya-Lerma, J. and Giraldo-Echeverri, B. (2013). Toxicity of foliage extracts of *Tithonia diversifolia* (Asteraceae) on *Atta cephalotes* (Hymenoptera: Myrmicinae) workers. *Industrial Crops and Products*. **44**: 391–395.
- Chagas-Paula, D. A., Oliveira, R. B., Rocha, B. A., and Da Costa, F. B. (2012). Ethno botany, chemistry, and biological activities of the genus *Tithonia* (Asteraceae). *Chemistry and Biodiversity*. **9** (2): 210-235.
- De Toledo, J. S., Ambrósio, S. R., Borges, C. H. G., Manfrim, V., Cerri, D. G., Cruz, A. K. and Costa, F. B. (2014). In Vitro leishmanicidal activities of sesquiterpenes lactones from *Tithonia diversifolia* against *Leishmania braziliensis* promastigotes and amastigotes. *Molecules*. **19**: 6070–6079.
- Dubey, N., K., Srivastava, B., and Kumar, A. (2008). Current Status of Plant Products as Botanical Pesticides in storage pest management. *Journal of Biopesticides* **1**: 182–186.
- Ellis, M.D., 2010. Pesticides Applied to Crops and Honey Bee Toxicity. *American Bee Journal*. **150**(5):485–486.

- El-Wakeil, N. E. (2013). Botanical Pesticides and Their Mode of Action. *Gesunde Pflanzen*. **65**(4): 125–149.
- Erasto, P., Grierson, D., and Afolayan, A. (2006). Bioactive sesquiterpene lactones from the leaves of *Vernonia amygdalina*. *Journal of Ethnopharmacology*. **106**(1): 117–120.
- Fabbri, A. D. T., and Crosby, G. A. (2015). A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes. *International Journal of Gastronomy and Food Science*.
- Farombi, E. O., and Owoeye, O. (2011). Antioxidative and Chemopreventive Properties of *Vernonia amygdalina* and *Garcinia biflavonoid*. *International Journal of Environmental Research and Public Health*. **8**: 2533–2555.
- Fuad, M. J. M., Junaidi, A. B., Habibah, A., Hamzah, J., Toriman, M. E., Lyndon, N., Azima, A. M. (2012). The Impact of Pesticides on Paddy Farmers and Ecosystem. *Advances in Natural and Applied Sciences*. **6** (1): 65–70.
- Hernandez, G., Iniguez, L., O'Rourke, J., McClean, P., Shoemaker, R., Jackson, S. and Vance, C. (2012, January). Transcriptome of common bean (*Phaseolus vulgaris*) through RNA-seq: nodulation, symbiotic nitrogen fixation, transcription factors [abstract]. Plant and Animal Genome XX Conference, January 14-18, 2012, San Diego, California. In *Plant and Animal Genome Conference*.
- Hillocks, R. J., Madata, C. S., Chirwa, R., Minja, E. M., and Msolla, S. (2006). Phaseolus bean improvement in Tanzania 1959 – 2005. *Euphytica*. **150**:215-231.
- Houssou, P. A., Ahohuendo, B. C., Fandohan, P., Kpodo, K., Hounhouigan, D. J., and Jakobsen, M. (2009). Natural infection of cowpea (*Vigna unguiculata* (L.) Walp.) by toxigenic fungi and mycotoxin contamination in Benin, West Africa. *Journal of Stored Products Research*. **45** (1): 40–44.
- Ibrahim, B. and M'batchi, B. (2000). Effect of *Tephrosia vogelii* and *Justicia extensa* on *Tilapia nilotica* in vivo. [Journal of Ethnopharmacology](#). **69**(2): 99–104.

- Igogo, J. M., Ogendo, J. O., Kariuki, S. T. and Otaye, D. O. (2011). Insecticidal, antifeedant and repellent effects of *Tephrosia vogelii* Hook, and *Lantana camara* L. Aqueous crude extracts against golden flea beetle, *Aphthona whitfieldi* bryant in *Jatropha*, *Jatropha curcas* L. *Biopesticides International*.**7**(2): 93–103.
- Ilboudoa Z., Dabiréb L.C.B., Nébiéc R.C.H., Dickod I.O., Dugravote S., Corteseroe A.M., and Sanona A. (2010). Biological activity and persistence of four essential oils towards the main pest of stored cowpeas, *Callosobruchus maculatus* (F.)(Coleoptera: Bruchidae). *Journal of Stored Products Research*.**46** (2): 124–128.
- Isman, M. (2000). Plant essential oils for pest and disease management. *Crop Protection*.**19** (2000):603-608
- Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review of Entomology*.**51**: 45–66.
- Isman, M., Miresmailli, S. and Machial, C. (2011). Commercial opportunities for pesticides based on plant essential oils in agriculture, industry and consumer products. *Phytochemistry Reviews*. **10**:197-204.
- Jenkins, S., Hoffmann, A. a, Mccoll, S., Tsitsilas, A., and Umina, P. a. (2013). Synthetic pesticides in agro-ecosystems: are they as detrimental to nontarget invertebrate fauna as we suspect.*Journal of Economic Entomology*.**106** (2): 756–75.
- Johnson, R. M., Ellis, M. D., Mullin, C. a. and Frazier, M. (2010). Review article Pesticides and honey bee toxicity – USA. *Apidologie*.**41**: 312–331.
- Kalumea M.K., Lossonb B., Angenotc L., Titsc M., Wautersc J.N., Frédéricic M. and Saegermand C., (2012). Rotenoid content and in vitro acaricidal activity of *Tephrosia vogelii* leaf extract on the tick *Rhipicephalus appendiculatus*. *Veterinary Parasitology*.**190** (1-2): 204–209
- Kazmi, I., Afzal, M., Ali, B., Damanhour, Z. A., Ahmaol, A. and Anwar, F. (2013). Anxiolytic potential of ursolic acid derivative-a stearyl glucoside isolated from *Lantana camara* L. (verbanaceae). *Asian Pacific Journal of Tropical Medicine*.**6** (6): 433–437.

- Khater, H. (2012). Prospects of botanical biopesticides in insect pest management. *Pharmacologia*.**3** (12):641-656.
- Kolawole, A., Okonji, R. and Ajele, J. (2011). *Tithonia diversifolia*, *Cyperus rotundus* and *Hyptis suaveolens* ethanol extracts combinatorially and competitively inhibit affinity purified cowpea storage bruchid. *Arthropod-Plant Interactions*.**5**:175-184
- Koona, P., Malaa, D. and Koono, O. (2007). Hexane extracts from *Tephrosia vogelii* Hook. f. protect stored maize against the weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). *Entomological Science*. **10**(2): 107–111.
- Koona,P.,Tatchago, V. and Malaa,D (2007). Impregnated bags for safer storage of legume grains in West and Central Africa.*Journal of Stored Products Research*.**43**: 248-251.
- Laubertie, E., Wratten, S., and Hemptinne, J. (2012). The contribution of potential beneficial insectary plant species to adult hoverfly (Diptera: Syrphidae) fitness. *Biological Control*.**61** (2012):1-6.
- Leng, P., Zhang, Z., Pan, G. and Zhao, M. (2011). Applications and development trends in biopesticides. *African Journal of Biotechnology*.**10** (86): 19864–19873.
- Lodhi, S. and Mikulecky, P. (2010). Management of Indigenous Knowledge for Developing Countries. *Communication and Management in Technological Innovation and Academic Globalization*. 94–98.
- Malhat, F., Haggag, M.and Loutfy, N. (2015). Residues of Organochlorines and synthetic pyrethroid pesticides in honey, an indicator of ambient environment, a pilot study. *Chemosphere*.**120**: 457–461.
- Mamta, S. and Jyoti, S. (2012). Phytochemical screening of *Acorus calamus* and *Lantana camara*. *International Research Journal of Pharmacy*. **3**: 324–326.
- Mashingaidze, N., Madakadze, C., Twomlow, S.,Nyamangara,J. and Hove, L. (2012). Crop yield and weed growth under conservation agriculture in semi-arid Zimbabwe. *Soil and Tillage research*.**124** (2012):102-110.

- Mihale, M. J., Deng, A. L., Selemani, H. O., Mugisha-Kamatenesi, M., Kidukuli, A. W. and Ogendo, J. O. (2009). Use of indigenous knowledge in the management of field and storage pests around Lake Victoria basin in Tanzania. *African Journal of Environmental Science and Technology*.**3** (9): 251–259.
- Mitra, A., Chatterjee, C. and Mandal, F. B. (2011). Synthetic Chemical Pesticides and Their Effects on Birds. *Research Journal of Environmental Toxicology*.**5** (2):81-96
- Mkenda,P.A., Stevenson,P.C., Ndakidemi,P., Farman,D.I., and Belmain,S.R.(2015a). Contact and fumigant toxicity of five pesticidal plants against *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) in stored cowpea (*Vigna unguiculata*). *International Journal of Tropical Insect Science*.**35** (4): 172-184.
- Mkenda, P., Mwanauta, R., Stevenson, P.C., Ndakidemi, P., Mtei, K. and Belmain, S.R. (2015b). Extracts from field margin weeds provide economically viable and environmentally benign pest control compared to synthetic pesticides. *PloS One*.**10** (11): e0143530.
- Mnif, W., Hassine, A. I. H., Bouaziz, A., Bartegi, A., Thomas, O., and Roig, B. (2011). Effect of endocrine disruptor pesticides: A review. *International Journal of Environmental Research and Public Health*. **8** (6): 2265-2303
- Mugisha-Kamatenesi, M., Deng, A. L., Ogendo, J. O., Omolo, E. O., Mihale, M. J., Otim, M. and Bett, P. K. (2008). Indigenous knowledge of field insect pests and their management around Lake Victoria basin in Uganda. *African Journal of Environmental Science and Technology*.**2** (8): 342–348.
- Munthali, M. G., Gachene, C. K. K., Sileshi, G. W. and Karanja, N. K. (2014). Amendment of Tephrosia Improved Fallows with Inorganic Fertilizers Improves Soil Chemical Properties, N Uptake, and Maize Yield in Malawi. *International journal of Agronomy*. **2014**:9pages
- Murdock, L., Margam, V., Baoua, I. and Shade, R.E.(2012). Death by desiccation: effects of hermetic storage on cowpea bruchids. *Journal of Stored Products Research*.**49**: 166–170.

- Musa, A., Oyerinde, A. and Owolabi, F. (2009). Evaluation of the efficacy of mixed leaf powders of *Vernonia amygdalina* L. and *Ocimum gratissimum* Del. against *Callosobruchus maculatus* (F.)(Coleoptera: *Academic Journal of Entomology*. **2**(2):85-87
- Nderitu, A. M., Dykes, L., Awika, J. M., Minnaar, A. and Duodu, K. G. (2013). Phenolic composition and inhibitory effect against oxidative DNA damage of cooked cowpeas as affected by simulated in vitro gastrointestinal digestion. *Food Chemistry*.**141** (3): 1763–1771.
- Neuwinger, H. (2004). Plants used for poison fishing in tropical Africa. *Toxicon*. **44**(4): 417–430.
- Ngowi, A. V. F., Mbise, T. J., Ijani, A. S. M., London, L., and Ajayi, O. C. (2007). Pesticides use by smallholder farmers in vegetable production in Northern Tanzania. *Crop Protection (Guildford, Surrey)*.**26**(11): 1617–1624.
- Njoroge, D., Kinyanjui, P.,Christiaens,S.,Shpigelman,A.,Makokha,O.A.,Sila,D.N. and Hendrickx,M.E. (2015). Effect of storage conditions on pectic polysaccharides in common beans (*Phaseolus vulgaris*) in relation to the hard-to-cook defect. *Food Research International*.**76** (1): 105–113.
- Obopile, M., and Ositile, B. (2010). Life table and population parameters of cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae) on five cowpea *Vigna unguiculata* (L. Walp.) varieties. *Journal of Pest Science*. **83**:9-14.
- Ogendo, J.,Belmain, S.,Deng A.L. and Walker D.J. (2003). Comparison of toxic and repellent effects of *Lantana camara* L. with *Tephrosia vogelii* Hook and a synthetic pesticide against *Sitophilus zeamais* Motschulsky. *International Journal of tropical insect science*. **23**(2):127-135.
- Ogendo, J.,Belmain, S.,Deng A.L. and Walker D.J. (2003b). Efficacy of *Lantana camara* l. and *Tephrosia vogelii* hook against *Sitophilus zeamais* (Coleoptera: Curculionidae) in stored maize grains. Congress on Medicinal and Aromatic Plants - Volume 5: Quality, Efficacy, Safety, Processing and Trade in Medicinal and Aromatic Plants.

- Ogendo, J. O., Deng, A. L., Omollo, E. O., Matasyoh, J. C., Tuey, R. K., and Khan, Z. R. (2015). Management of stem borers using selected botanical pesticides in a maize-bean cropping system. *Egerton Journal of Science and Technology*, **13**.
- Owolabi, M., Jaja, S., Olatunji, O., Oyekanmi, O., and Adepoju, S. (2011). Attenuation of Oxidative Damage in Alloxan Induced Diabetic Rabbits Following Administration of the Extract of the Leaves of *Vernonia amygdalina*. *Free Radicals and Antioxidants*, **1**(3):94-101.
- Pérez, A., Montejo, I., Iglesias, J. M., López, O., Martín, G. J., García, D. E. and Hernández, A. (2009). *Tithonia diversifolia* (Hemsl.) A. Gray. *Pastos y Forrajes*. **32** (1): 1-1.
- Pule-Meulenberg, F., Belane, A. K., Krasova-Wade, T., and Dakora, F. D. (2010). Symbiotic functioning and bradyrhizobial biodiversity of cowpea (*Vigna unguiculata* L. Walp.) in Africa. *BMC microbiology*. **10**(1): 89.
- Rajashekar, Y., Ravindra, K. V., and Bakthavatsalam, N. (2014). Leaves of *Lantana camara* Linn. (Verbenaceae) as a potential insecticide for the management of three species of stored grain insect pests. *Journal of Food Science and Technology*. **51**(11): 3494-3499.
- Rajashekar, Y., Raghavendra, A., and Bakthavatsalam, N. (2014). Acetylcholinesterase Inhibition by Biofumigant (Coumaran) from Leaves of *Lantana camara* in Stored Grain and Household Insect Pests. *BiomedicalResearch International*, 2014.
- Rajashekar, Y., Vijay, H., Ravindra, K. V, and Bakthavatsalam, N. (2013). Isolation and characterization of biofumigant from leaves of *Lantana camara* for control of stored grain insect pests. *Industrial Crops and Products*. **51**: 224–228.
- Rajesh, R., Jaivel, N., and Marimuthu, P. (2014). Muntingia calabura botanical formulation for enhanced disease resistance in tomato plants against *Alternaria solani*. *African Journal of Microbiology Research*. **8**(20): 2059–2068.
- Roca, M., Miralles-Marco, A., Ferré, J., Pérez, R., and Yusà, V. (2014). Biomonitoring exposure assessment to contemporary pesticides in a school children population of Spain. *Environmental research*. **131**:77-85.

- Sanon, A., Ba, N. M., Binso-Dabire, C. L., and Pittendrigh, B. R. (2010). Effectiveness of spinosad (naturalytes) in controlling the cowpea storage pest, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Journal of Economic Entomology*.**103** (1): 203–210.
- Saxena, P. (2014). Comparative Prediction of binding site of Organophosphorus, Carbamate and Synthetic pyrethroid Pesticides on Human Cyclin-dependent Protein kinases Cdk2 and Cdk4.*Journal of Entomology and Zoology Studies*, **2** (2): 106-110
- Schreinemachers, P., Sringarm, S., and Sirijinda, A. (2011). The role of synthetic pesticides in the intensification of highland agriculture in Thailand. *Crop protection*.**30** (11): 1430-1437.
- Shokalu, A. O., Ojo, A. O., E-Adewoyin, D. T., and Azeez, J. A. (2010). Evaluation of *Tithonia diversifolia* for soil improvement in celosia (*Celosia argentea*) production. *Electronic Journal of Environmental, Agricultural and Food Chemistry*. **9**(5): 951–957.
- Sola, P., Mvumi, B. M., Ogendo, J. O., Mponda, O., Kamanula, J. F., Nyirenda, S. P., and Stevenson, P. C. (2014). Botanical pesticide production, trade and regulatory mechanisms in sub-Saharan Africa: making a case for plant-based pesticidal products. *Food Security*. **6**(3): 369-384.
- Ssekandi, W., Mulumba, J. W., Colangelo, P., Nankya, R., Fadda, C., Karungi, J. and Jarvis, D. I. The use of common bean (*Phaseolus vulgaris*) traditional varieties and their mixtures with commercial varieties to manage bean fly (*Ophiomyia* spp.) infestations in Uganda. *Journal of Pest Science*.1-13.
- Stevenson, P. C., Kite, G. C., Lewis, G. P., Forest, F., Nyirenda, S. P., Belmain, S. R., and Veitch, N. C. (2012). Distinct chemotypes of *Tephrosia vogelii* and implications for their use in pest control and soil enrichment. *Phytochemistry*.**78**: 135–146.
- Stevenson, P. C., Arnold, S. E., and Belmain, S. R. (2014). Pesticidal plants for stored product pests on small-holder farms in Africa. In *Advances in Plant Biopesticides*. (pp. 149-172). Springer India.

- Stevenson, P. C., Kite, G. C., Lewis, G. P., Forest, F., Nyirenda, S. P., Belmain, S. R., and Veitch, N. C. (2012). Distinct chemotypes of *Tephrosia vogelii* and implications for their use in pest control and soil enrichment. *Phytochemistry*.**78**:135-146.
- Kanaujia Sukula, S. (2006). Developing indigenous knowledge databases in India. *The Electronic Library*. **24**(1): 83-93.
- Wang, R., Yang, X., Song, Y., Zhang, M., Linhu, Su, Y. and Zeng, R. (2011). Allelopathic potential of *Tephrosia vogelii* Hook. f.: Laboratory and field evaluation. *Allelopathy Journal*. **28** (1): 53–62.
- Watson, S. L. (2014). Assessing the Impacts of Unrestricted Pesticide Use in Small-Scale Agriculture on Water Quality and Associated Human Health and Ecological Implications in an Indigenous Village in Rural Panam [aacute].*University Of South Carolina*. Pg 1-94
- Wawire, M., Oey, I., Mathooko, F., Njoroge, C., Shitanda, D., and Hendrickx, M. (2011). Thermal stability of ascorbic acid and ascorbic acid oxidase in African cowpea leaves (*Vigna unguiculata*) of different maturities. *Journal of agricultural and food chemistry*, **59**(5): 1774-1783.
- Weichenthal, S., Moase, C., and Chan, P. (2010). A review of pesticide exposure and cancer incidence in the Agricultural Health Study cohort. *Environmental health perspectives*.1117-1125.
- Wilson, C.and Tisdell, C. (2001). Why farmers continue to use pesticides despite environmental, health and sustainability costs. *Ecological Economics*.**39** (3): 449–462.
- Wu, J. Y., Anelli, C. M., and Sheppard, W. S. (2011). Sub-lethal effects of pesticide residues in brood comb on worker honey bee (*Apis mellifera*) development and longevity. *PloS one*. **6**(2): e14720.
- Yeap, S. K., Ho, W. Y., Beh, B. K., Liang, W. S., Ky, H., Yousr, A. H. N., and Alitheen, N. B. (2010). *Vernonia amygdalina*, an ethnoveterinary and ethnomedical used green kvegetable with multiple bioactivities. *Journal of Medicinal Plants Research*, **4**(25):2787-2812.

- Zacharia, J. T., Kishimba, M. A., and Masahiko, H. (2010). Biota uptake of pesticides by selected plant species; the case study of Kilombero sugarcane plantations in Morogoro Region, Tanzania. *Pesticide Biochemistry and Physiology*.**97** (1): 71–75.
- Zhao, G., Li, X., Chen, W., Xi, Z. and Sun, L. (2012). Fitoterapia Three new sesquiterpenes from *Tithonia diversifolia* and their anti-hyperglycemic activity. *Fitoterapia*. **83**(8):1590–1597.

APPENDICES

Appendix 1 Average abundance of insect pests observed on bean plants in response to treatments at different concentrations.

Treatments	Concentration	Ootheca	Aphids	Flower beetles	Caterpillars	Pod sucker
Water	0	9.50±0.50a	35.00±2.68a	7.75±0.25a	3.50±1.04a	3.75±0.85a
Water and soap	0.10%	2.75±0.95b	20.50±2.60b	5.00±0.71b	1.75±0.48bc	1.50±0.87b
Synthetic pesticide	0.6ml/l	0.25±0.25de	1.00±0.71g	0.00±0.00f	0.00±0.00e	0.25±0.25d
<i>L. camara</i>	0.10%	2.00±0.91bcd	12.00±0.41cd	2.00±0.71cd	2.00±0.82b	0.75±0.48bcd
	1%	1.50±0.29bcde	5.75±2.22efg	0.50±0.29ef	0.50±0.29cde	1.25±0.25bc
	10%	0.00±0.00e	5.50±1.66efg	0.00±0.00f	0.00±0.00e	0.00±0.00d
<i>V. amygdalina</i>	0.10%	2.50±0.96bc	15.25±3.09bc	2.50±0.29c	1.50±0.50bcd	0.25±0.25cd
	1%	1.00±0.71bcde	9.50±2.50de	0.50±0.50ef	0.50±0.50cde	0.25±0.25cd
	10%	0.75±0.25cde	3.25±1.60g	0.00±0.00f	0.00±0.00e	0.25±0.25cd
<i>T. diversifolia</i>	0.10%	1.50±0.65bcde	10.00±1.47cde	1.25±0.25de	0.75±0.48bcde	0.75±0.48bcd
	1%	0.75±0.25cde	7.00±1.58def	0.75±0.48def	0.50±0.29cde	0.00±0.00d
	10%	0.75±0.25cde	3.25±1.25fg	0.00±0.00f	0.25±0.25de	0.25±0.25cd
<i>T. vogelii</i>	0.10%	1.75±1.03bcde	9.00±1.78de	1.00±0.58e	0.25±0.25de	0.00±0.00d
	1%	1.25±0.58bcde	10.00±2.12cde	0.50±0.29ef	0.50±0.50cde	0.25±0.25cd
	10%	0.75±0.48cde	1.25±0.95g	0.50±0.50ef	0.00±0.00e	0.00±0.00d
F statistics		13.59***	20.58***	29.20***	4.50***	6.03***

Each value is a mean ± standard error of four replicates, *** are significant at P≤0.001. Means within the same column followed by the same letter(s) are not significantly different at (P=0.05) from each other using Fishers Least significant Difference (LSD)

Appendix 2 Effects of treatments on the percentage damage by insect pests observed on the bean plants

		Percentage damage								
Treatment	Concentration	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9
Water	0	0.03±0.01a	0.04±0.01a	0.12±0.03a	0.09±0.02ab	0.11±0.02abc	0.05±0.03a	0.10±0.04a	0.13±0.03a	0.03±0.03b
Water and soap	0.10%	0.03±0.00ab	0.02±0.01bcd	0.05±0.02bcde	0.04±0.03cdef	0.13±0.02a	0.10±0.05ab	0.03±0.03bc	0.12±0.05ab	0.09±0.03a
Synthetic pesticide	0.6ml/l	0.02±0.01b	0.01±0.01d	0.00±0.00e	0.00±0.00f	0.00±0.00d	0.00±0.00d	0.00±0.00c	0.00±0.00c	0.01±0.01b
<i>L.camara</i>	0.10%	0.03±0.00ab	0.03±0.01abcd	0.09±0.03abcd	0.06±0.02abcd	0.04±0.02bcd	0.10±0.05ab	0.04±0.02abc	0.11±0.04ab	0.02±0.02b
	1%	0.03±0.00ab	0.01±0.01cd	0.06±0.02abc	0.08±0.02abc	0.08±0.04abcd	0.02±0.01abc	0.01±0.01c	0.12±0.03ab	0.06±0.03ab
	10%	0.03±0.00ab	0.04±0.02	0.06±0.02abcd	0.10±0.01a	0.04±0.04cd	0.05±0.02bcd	0.03±0.02bc	0.03±0.02bc	0.04±0.02ab
<i>V.amygdalina</i>	0.1%	0.02±0.01b	0.02±0.01bcd	0.06±0.02bcde	0.07±0.02abc	0.11±0.05abc	0.09±0.04bcd	0.03±0.02bc	0.09±0.01abc	0.03±0.02ab
	1%	0.03±0.00ab	0.01±0.01d	0.07±0.02abcd	0.02±0.01def	0.12±0.04ab	0.07±0.04bcd	0.05±0.03abc	0.09±0.02ab	0.05±0.03ab
	10%	0.03±0.00ab	0.03±0.00abcd	0.10±0.02ab	0.04±0.02cdef	0.05±0.03bcd	0.02±0.01bcd	0.01±0.01c	0.04±0.01abc	0.06±0.02ab
<i>T.diversifolia</i>	0.1%	0.03±0.00ab	0.02±0.01bcd	0.10±0.01ab	0.10±0.02a	0.11±0.01abc	0.07±0.03ab	0.08±0.03ab	0.12±0.03ab	0.03±0.01b
	1%	0.03±0.00ab	0.02±0.01bcd	0.12±0.03ab	0.07±0.01abc	0.06±0.02abcd	0.08±0.04bcd	0.01±0.01c	0.10±0.04ab	0.04±0.02ab
	10%	0.03±0.00ab	0.02±0.01bcd	0.08±0.02abcd	0.04±0.02cdef	0.04±0.02bcd	0.04±0.02cd	0.02±0.01bc	0.09±0.01abc	0.03±0.02b
<i>T.vogelii</i>	0.1%	0.03±0.00ab	0.03±0.01abc	0.03±0.01de	0.07±0.01abc	0.08±0.02abcd	0.05±0.03bcd	0.04±0.03abc	0.11±0.05ab	0.03±0.02b
	1%	0.03±0.00ab	0.04±0.01ab	0.06±0.03abcd	0.05±0.02bcde	0.03±0.02d	0.10±0.05abc	0.04±0.02abc	0.09±0.03abc	0.03±0.01b
	10%	0.03±0.00ab	0.01±0.01d	0.04±0.01cde	0.01±0.01ef	0.02±0.02d	0.04±0.02cd	0.06±0.03abc	0.07±0.04abc	0.03±0.02b
F statistics	statistics	1.05ns	1.93*	0.06*	3.41**	0.09*	2.15*	1.53ns	1.35ns	0.93ns

Each value is a mean ± standard error of four replicates, *, and ** are significant at $P \leq 0.05$ and $P \leq 0.01$ respectively, and ns means not significant. Means within the same column followed by the same letter(s) are not significantly different at ($P=0.05$) from each other using Fishers Least significant Difference (LSD) test

Appendix 3 The average abundance of beneficial insects observed on bean plants in response to application of treatments

Treatment	Concentration	Lace wing	Ladybird beetle	Robber fly	Spider
Water	0	0.75±0.48ab	6.50±0.85a	1.25±0.25a	8.50±2.63a
Water + Soap	0.1%	0.00±0.00	5.50±3.10ab	0.00±0.00b	3.25±0.75cdef
Synthetic pesticide	0.6ml/l	0.25±0.25b	0.75±0.75c	0.50±0.50ab	0.25±0.25f
<i>L. Camara</i>	0.1%	1.75±0.85a	1.00±0.58c	0.25±0.25b	8.25±1.11ab
	1%	0.25±0.25b	2.25±0.48bc	1.25±0.63a	2.75±1.49def
	10%	0.00±0.00b	0.00±0.00c	0.00±0.00b	3.75±1.31cdef
<i>T. diversifolia</i>	0.1%	1.00±0.58ab	3.00±1.73abc	0.50±0.29ab	5.00±0.71abcd
	1%	1.00±0.71ab	0.50±0.29c	0.25±0.25b	7.00±1.78abc
	10%	0.50±0.29ab	0.25±0.25c	0.00±0.00b	0.25±0.25f
<i>V. amygdalina</i>	0.1%	1.00±0.41ab	2.00±0.41bc	0.25±0.25b	7.00±1.29abc
	1%	0.25±0.25b	2.50±0.65bc	0.75±0.75ab	4.50±1.71bcde
	10%	0.50±0.50ab	3.50±1.55abc	0.00±0.00b	1.00±0.71ef
<i>T. Vogelii</i>	0.1%	1.00±0.00ab	1.50±0.87c	0.50±0.25ab	6.50±2.06abcd
	1%	1.00±0.71ab	1.75±1.75c	0.25±0.25b	5.00±0.41abcd
	10%	0.50±0.29ab	2.00±2.00bc	0.00±0.00b	0.50±0.29f
F statistics		1.13ns	2.01*	1.58ns	4.75***

Each value is a mean ± standard error of four replicates, *, and *** are significant at P≤0.05 and P≤0.001 respectively, and ns means not significant. Means within the same column followed by the same letter(s) are not significantly different at (P=0.05) from each other using Fishers Least Significant Difference (LSD) test

Appendix 4 Mean yield parameters of common beans collected during harvesting period

Treatment	Concentration	100seed weight (g)	Pod weight (g)	Seed per pod	No. of pods per plant	Yield (kg/h)
Water	0	56.00±0.41k	1.90±0.17cde	5.60±0.38d	6.95±0.61de	403.70±11.19l
Water + Soap	0.1%	60.00±0.41i	1.75±0.10de	5.95±0.38cd	6.40±0.48e	461.20±9.43hi
Synthetic pesticide	0.6ml/l	66.50±0.29b	2.35±0.13bc	6.60±0.29bc	10.30±1.31abc	817.80±16.63bc
<i>L. Camara</i>	0.1%	62.75±0.25h	2.15±0.17bcd	6.35±0.50bcd	8.00±1.60bcde	671.20±18.49ef
	1%	63.75±0.25efg	1.65±0.15e	6.05±0.36bcd	7.75±1.17cde	729.80±7.90de
	10%	65.75±0.25bc	2.30±0.17bc	6.40±0.22bcd	8.70±0.79abcde	607.00±60.75fg
<i>T. diversifolia</i>	0.1%	64.50±0.29cd	1.95±0.05cde	6.00±0.18cd	7.05±0.90de	665.00±28.24ef
	1%	65.25±0.25cd	2.20±0.24bcd	6.20±0.12bcd	7.20±0.96de	728.60±16.53de
	10%	66.25±0.25b	2.45±0.19b	7.00±0.57b	10.70±0.37ab	899.30±25.06ab
<i>V. amygdalina</i>	0.1%	63.25±0.25gh	2.15±0.13bcd	6.45±0.48bcd	8.10±1.11bcde	598.50±8.16fg
	1%	63.500±0.29fgh	2.05±0.05bcde	6.25±0.15bcd	7.15±1.01de	456.70±14.73hi
	10%	65.75±0.25bc	2.35±0.22bc	6.50±0.51bcd	9.20±0.70abcd	802.70±10.88cd
<i>T. Vogelii</i>	0.1%	57.50±0.29j	2.10±0.13bcde	6.25±0.13bcd	8.85±1.10abcde	530.80±25.73gh
	1%	64.25±0.25ef	2.20±0.29bcd	6.15±0.29bcd	8.90±0.37abcde	540.10±4.81gh
	10%	69.00±0.41a	2.95±0.05a	9.05±0.13a	10.90±0.81a	961.10±81.86a
F statistics		133.88***	3.56**	5.17***	2.22*	29.46***

Each value is a mean ± standard error of four replicates, *, **and *** are significant at P≤0.05, P≤ 0.01 and P≤0.001 respectively, and ns means not significant. Means within the same column followed by the same letter(s) are not significantly different at (P=0.05) from each other using Fishers Least Significant Difference (LSD) test

Appendix 5 The mean adult *C.maculatus* recorded from the cowpea seeds (*V. unguiculata*) subsample

Treatments	Concentration (g/2500g cowpea seeds)	Mean \pm SE of adult <i>C.maculatus</i>				
		week 2	week4	week 6	week 8	week 10
Control	0	0.40 \pm 0.24ab	7.20 \pm 2.01a	16.20 \pm 2.24a	20.80 \pm 1.93a	15.80 \pm 1.46ac
Actelic dust	0.2	0.00 \pm 0.00b	0.00 \pm 0.00b	1.40 \pm 0.40c	1.00 \pm 0.45c	0.80 \pm 0.58b
<i>T. vogelii</i>	25	0.00 \pm 0.00b	0.00 \pm 0.00b	3.40 \pm 0.68bc	4.60 \pm 1.50ce	4.20 \pm 0.58b
	250	0.00 \pm 0.00b	0.00 \pm 0.00b	1.40 \pm 0.51c	4.60 \pm 0.40ce	4.20 \pm 0.49b
<i>L. camara</i>	25	0.40 \pm 0.24ab	1.80 \pm 1.20b	2.40 \pm 1.12c	10.60 \pm 2.09bde	10.60 \pm 1.60ab
	250	0.20 \pm 0.20ab	0.20 \pm 0.20b	1.00 \pm 1.00c	13.40 \pm 2.58bd	18.80 \pm 4.66ac
<i>T. diversifolia</i>	25	1.00 \pm 0.77a	1.00 \pm 0.77b	4.00 \pm 1.22bc	15.00 \pm 5.14ad	14.80 \pm 5.44ac
	250	0.20 \pm 0.20ab	0.20 \pm 0.20b	3.40 \pm 1.40bc	7.00 \pm 1.05bce	24.60 \pm 4.46c
<i>V. amygdalina</i>	25	0.20 \pm 0.20ab	0.20 \pm 0.20b	7.20 \pm 2.73b	11.60 \pm 2.11ad	22.20 \pm 5.29c
	250	0.40 \pm 0.24ab	0.40 \pm 0.24b	4.40 \pm 2.34bc	16.60 \pm 3.60ad	21.60 \pm 4.74c
One way ANOVA F-statistics		1.01ns	7.86***	8.27***	6.18***	5.61***

Each value is a mean \pm standard error of four replicates, *** are significant at $P \leq 0.001$, and ns means not significant. Means within the same column followed by the same letter(s) are not significantly different at ($P=0.05$) from each other using Fishers Least significant Difference (LSD) test.

Appendix 6 Effects of treatments on the mean number of eggs of *C.maculatus* on cowpea seeds

Mean \pm SE of eggs counted on cowpea seed samples					
Treatments	(Concentration)	Week 4	Week 6	Week 8	Week 10
	seeds g/2500g cowpea				
Control	0	7.00 \pm 1.00c	23.40 \pm 5.57b	150.40 \pm 16.52b	634.00 \pm 71.81bc
Actelic dust	0.2	0.00 \pm 0.00d	0.00 \pm 0.00b	4.60 \pm 2.79c	3.80 \pm 1.62d
<i>T. vogelii</i>	25	0.00 \pm 0.00d	3.00 \pm 1.64b	7.20 \pm 1.02c	10.20 \pm 3.51d
	250	0.00 \pm 0.00d	1.00 \pm 0.63b	4.20 \pm 1.32c	2.20 \pm 1.36d
<i>L. camara</i>	25	3.80 \pm 1.62bcd	35.20 \pm 14.14b	16.40 \pm 3.08c	122.00 \pm 19.75d
	250	5.80 \pm 1.46c	7.80 \pm 2.78b	52.60 \pm 16.34c	198.60 \pm 45.44d
<i>T. diversifolia</i>	25	0.80 \pm 0.49bd	37.60 \pm 14.21b	198.80 \pm 60.71ab	514.20 \pm 167.72c
	250	0.00 \pm 0.00d	48.00 \pm 28.90b	243.20 \pm 52.34a	454.80 \pm 145.94ac
<i>V. amygdalina</i>	25	4.80 \pm 3.01bc	355.80 \pm 182.84a	139.80 \pm 20.41b	802.80 \pm 154.69b
	250	16.00 \pm 3.55a	32.20 \pm 6.03b	139.00 \pm 22.45b	739.20 \pm 139.31bc
One way ANOVA F-statistics		9.27***	3.31**	10.10***	10.03***

Each value is a mean \pm standard error of four replicates, **, *** are significant at $P \leq 0.01$, $P \leq 0.001$ and ns means not significant. Means within the same column followed by the same letter(s) are not significantly different at ($P=0.05$) from each other using Fishers Least Significant Difference (LSD) test.

Appendix 7 Mean and percentage damage by adult *C.maculatus* in response to application of treatments.

Treatments	(Concentration)	Mean number of damaged	Mean % damage
	g/2500g cowpea seeds		
Control	0	827.60±84.92b	75.24±7.72b
Actelic dust	0.2	2.60±1.54d	0.24±0.14d
<i>T. vogelii</i>	25	12.00±1.92d	1.09±0.17d
	250	4.40±1.47d	0.40±0.13d
<i>L. camara</i>	25	130.60±28.02ad	11.87±2.55ad
	250	123.20±37.02ad	11.20±3.37ad
<i>T. diversifolia</i>	25	507.80±232.94bc	46.16±21.18bc
	250	722.40±189.66bc	65.67±17.24bc
<i>V. amygdalina</i>	25	601.20±90.17bc	54.65±8.20bc
	250	452.80±159.54ac	41.16±14.50ac
One way ANOVA F-statistics		7.66***	7.66***

Each value is a mean ± standard error of four replicates, *** are significant at $P \leq 0.001$. Means within the same column followed by the same letter(s) are not significantly different at ($P=0.05$) from each other using Fishers Least significant Difference (LSD) test.

