DISTRIBUTION AND USE OF VARIETAL RESISTANCE AND PESTICIDE IN THE CONTROL OF RED SPIDER MITE *Tetranychus evansi* (BAKER AND PRITCHARD) IN TOMATO *Lycopersicon esculentum* (MILL) PRODUCTION IN NAKURU COUNTY, KENYA

EGERTON UNIVERSITY LIBRARY

EGERTON UNIVERSITY LIBRARY
19 SEP 2013
P.O. BOX 536,
EGERTON
ACQUISITION SECTION

MUSAH SAMUEL MATIKA

A thesis Submitted to the Graduate School in fulfilment of requirement for the Degree of Master of Science in Agronomy (Crop Protection) of Egerton University.

2013/96670

EGERTON UNIVERSITY

APRIL 2013

EULIB
041 040

DECLARATION AND RECOMMENDATION

DECLARATION

I declare that this is my original work and has not been submitted for the award of a degree examination in any other university.

Signature:  Date: 18/04/2013

Musah Samuel Matika

Reg. Number KM12/1346/04

RECOMMENDATION

This thesis has been submitted with our approval as University supervisors.

Signature:  Date: 18/04/2013

Prof. Alice. W. Kamau

Department of Crops, Horticulture and Soil Sciences

Egerton University, Kenya.

Signature:  Date: 18/04/2013

Dr. Macharia Munene

Kenya Agricultural Research Institute

Njoro, Kenya.

DEDICATION

This thesis is dedicated to my wife, Sarah.

COPY RIGHT

Copy right © 2013 by Musah Samuel Matika

All rights reserved. No part of this Msc thesis may be reproduced, stored in a retrieval system or transmitted in any form by any means without the prior written permission of author or Egerton University.

ACKNOWLEDGEMENT

I am very appreciative to my supervisors Dr. A. W. Kamau and Dr. M. Macharia for the guidance and support throughout the study period, proposal development, research implementation and thesis preparation. I thank Egerton University Research and Extension Department that gave the funds for the research work. I thank Mr. Kamundia for his assistance on data analysis and guidance on how to use SAS computer programme. Many thanks go to fellow graduate students Mr. Godwin Macharia and M/s Wanja for their continued encouragement.

Lastly but not least, I want to appreciate my dear wife, Sarah Wanjiru and Son, Noah Musah for their moral support. In addition, I thank, Presbyter Clement Kambo and Pastor Lucy Kambo for their prayers and spiritual support.

ABSTRACT

Red spider mite *Tetranychus evansi* (Baker & Pritchard) is relatively new pest of tomato (*Lycopersicon esculentum*) in Africa, accidentally introduced into Southern Africa around 1980. Since then the species has spread and was recorded for the first time in Kenya in 2001. It is a very important pest limiting tomato production in Kenya. The objective of this study was to determine the effect of *T. evansi* on tomato varieties, its distribution and damage in Subukia and Rongai divisions and effect of pesticides on its population and damage on tomatoes. To determine the effect of *T. evansi* on tomato varieties, an experiment was conducted in greenhouse using Randomized Complete Block Design (RCBD) replicated four times at Kenya Agricultural Research Institute (KARI) –Njoro. The tomato varieties assessed for host plant resistance were: Cal J, Onyx, Roma VFN, Riogrande, Money Maker, Eden F1, Anna F1, and wild type. The lowest and highest total average number of Red spider mite (*T. evansi*) population was recorded on Wild type (2.6/leaf disc-10mm diameter) and Variety Money Maker (12.2/leaf disc-10mm diameter) respectively. The highest leaf damage was recorded on tomato variety Money Maker (4.0) while the lowest was recorded on the Wild variety (1.8). There was no significance difference ($P>0.05$) in leaf damage between Anna F1, Riogrande, Roma VFN and Onyx. Studies on the effect of tomato varieties on development time from egg to adult, fecundity and longevity of *T. evansi* was conducted in a conviron incubator maintained at 25 ± 2 ^{o}C , 50-70 % relative humidity and photoperiod 12:12 L:D. Petri dishes containing leaf discs were placed in the incubator in a Complete Randomized Design (CRD) arrangement. The results showed that, mortality rate for protonymph, deutonymph and adult stages was highest in Wild type (95%) and lowest in variety Money Maker (50%). In addition, the average number of eggs per female mite was significantly higher ($P<0.05$) on variety Money Maker (52.4) and Riogrande (48.6), while the least number of eggs was recorded on Wild type (9.1). The number of mites recorded on Vapcothion treated plants was significantly ($P< 0.05$) lower than all other treatments. Significantly ($P<0.05$), low tomato fruit yield was recorded on control plants while highest yields was recorded on Vapcothion (Dicofol 8%, Tetradifon 25%) treated plants. However, total average mean number of mites per leaf disc recorded on chilli extract treated tomato plants was significantly ($P<0.05$) lower than the control plant. The survey showed that most farmers (96.7%) perceived or recorded Red spider mite as the most important pest of tomatoes. The farmers indicated that they experience a crop loss of more than 50% in both short rain and dry seasons if proper control measures were not applied.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION.....ii
DEDICATION.....iii
COPY RIGHT.....iv
ACKNOWLEDGEMENT.....v
ABSTRACT.....vi
TABLE OF CONTENTS.....vii
LIST OF TABLES.....x
LIST OF FIGURES.....xi
LIST OF PLATES.....xii
LIST OF APPENDICES.....xiii
CHAPTER ONE.....1
INTRODUCTION.....1
1.1 Background information.....1
1.2 Problem statement.....3
1.3 Justification.....3
1.4 Objectives.....3
1.5 Hypotheses (H_o).....4
CHAPTER TWO.....5
LITERATURE REVIEW.....5
2.1 Importance of Red spider mite (*Tetranychus evansi*) in Tomato production.....5
2.2 Mites dispersal and infestation.....5
2.3 Biology of Red Spider mite (*Tetranychus evansi*).....6
2.4 Symptoms of damage.....6
2.5 Common methods of control.....7
2.5.1 Chemical control.....7
2.5.2 Cultural practice.....7
2.5.3 Biological control.....7
2.5.4 Integrated pest management.....8
2.6 Tomato host plant resistance.....8

EGERTON UNIVERSITY LIBRARY

CHAPTER THREE 10
MATERIALS AND METHOD 10
3.1 Effect of Red spider mite (*T. evansi*) on tomato varieties under green house conditions.... 10
3.1.1 Mite culture 10
3.1.2 Experimental design and layout 10
3.1.3 Non variables 10
3.1.4 Infestation 12
3.1.5 Variables measured 12
3.1.6 Data analysis 14
3.2. Effect of tomato varieties on development time, fecundity and longevity of *T. evansi* 17
3.2.1 Development time from egg to adult 17
3.2.2 Fecundity and longevity 17
3.2.3 Data analysis 18
3.3. Effect of pesticides on *Tetranychus evansi* population and damage on tomatoes..... 19
3.3.1 Experimental design and layout 19
3.3.2 Non variables 19
3.3.3 Infestation 20
3.3.4 Variables measured 20
3.3.5 Data analysis 23
3.4. Survey on distribution and damage on tomatoes by Red spider mite in Subukia and Rongai divisions, Kenya 24
3.4.1 Introduction 24
3.4.2 Materials and methods 24
3.4.3 Data analysis 25
CHAPTER FOUR 26
RESULTS AND DISCUSSION 26
4.1 Experiment 1: Effect of Red spider mite (*T. evansi*) on tomato varieties under green house conditions 26
4.1.1 Mite population 26
4.1.2 Leaf damage 27
4.1.3 Webbing 29

4.1.4 Dead flower buds and flowers....31
4.1.5 Yield....33
4.2. Experiment 2 : Effect of tomato variety on development time, fecundity and longevity of *T. evansi*....37
4.2.1 Development time from egg to adult of *T. evansi*....37
4.2.2 Fecundity and longevity *T. evansi*....38
4.3 Experiment 3 : Evaluation of pesticides against Red spider mite (*T. evansi*)....42
4.3.1 Effect of acaricide on *T. evansi* population....42
4.3.2 Effect of acaricide treatment against *T. evansi* on leaf damage....43
4.3.3 Effect of acaricide against *T. evansi* on average percent webbing....43
3.3.4 Effect of acaricide against *T. evansi* on damage of flowers and flower buds....46
3.3.5 Effect of acaricide against *T. evansi* on the yield of tomatoes....47
4.4. Survey on distribution and damage on tomatoes by Red spider mite in Subukia and Rongai divisions, Kenya....51
4.4.1 Tomato varieties grown....51
4.4.2 Important pests of tomato as listed by farmers....51
4.4.3 Effect of tomato growing season on Red spider mite infestation and crop loss....54
4.4.4 Pesticide used by farmers in Rongai and Subukia divisions for the control of Red spider mite....54
CHAPTER FIVE....57
CONCLUSION AND RECOMMENDATION....57
REFERENCES....59
APPENDICES....66

LIST OF TABLES

Table 4.1: Average number of Red spider mite (*T. evansi*) mites /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions.....28

Table 4.2: Effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions.....30

Table 4.3: Effect of Red spider mite (*T. evansi*) *on* average percent webbing on tomato varieties grown under green house conditions.....32

Table 4.4: Effect of Red spider mites (*T. evansi)* infestation on flower buds and flowers of tomato varieties grown under green house conditions.....35

Table 4.5: Effect of Red spider mite (*T. evansi*) infestation on yield of tomato varieties grown under green house conditions.....36

Table 4.6.1: Effect of tomato varieties on duration (days) of incubation, larvae and protonymph stages of Red spider mite (*T. evansi)*.....39

Table 4.6.2: Effect of tomato varieties on duration (days) of deutonymph stage, a dult stage, sex and mortality of Red spider mite (*T. evansi)*.....40

Table 4.7: Effect of tomato varieties on fecundity and longevity of Red spider mite (*T. evansi*).....41

Table 4.8: Effect of acaricides on *T. evansi* population under green house conditions 44

Table 4.9: Effect of acaricide treatment against *T. evansi* on leaf damage of tomatoes rated on scale 1-5.....45

Table 4.10: Effect of acaricide treatment against *T. evansi* on average percent webbing.....48

Table 4.11: Effect of acaricide treatment against *T. evansi* on damage of flowers buds and flowers /plant.....49

Table 4.12: Effect of acaricide treatment against Red spider mite (*T. evansi*) on the yield of tomatoes.....50

Table 4.13: Effect of tomato growing season on Red spider mite (*T. evansi*) infestation and crop loss.....55

Table 4.14: Pesticide used by farmers in Subukia and Rongai division for the control of Red spider mite (*Tetranychus evansi*) on the yield of tomatoes.....56

LIST OF FIGURES

Figure 3.1: Experiment layout- Effect of Red spider mite *Tetranychus evansi* on tomato varieties under green house conditions.....11

Figure 3.2: Experiment layout- Effect of pesticides on *Tetranychus evansi* population and damage on tomatoes.....21

Figure 4.1: Tomato varieties grown by open field tomato farmers in Subukia and Rongai divisions, Kenya.....52

Figure 4.2: Important insect pests and other arthropods as percieved by tomato farmers in Subukia and Ronga divisions, Kenya.....53

LIST OF PLATES

Plate 3.1: Clean or healthy plant.....15

Plate 3.2: Slight damage; a few leaves showing slight yellowing and whitening due to mite feeding, (< 25% of the plant leaves damaged due to Red spider mite (*T. evansi*) attack.....15

Plate 3.3: Moderate damage; many leaves showing yellowing and whitening due to mite feeding, (26-50%% of the plant leaves damaged due to Red spider mite (*T. evansi*) attack 16

Plate 3.4: Severe damage; 51-75% of the plant leaves showing yellowing, whitening, desiccation, defoliation and webbing due to Red spider mite (*T. evansi*) feeding 16

LIST OF APPENDICES

Appendix 1: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 4.....66

Appendix 2: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 4.....66

Appendix 3: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 5.....67

Appendix 4: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 5.....67

Appendix 5: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week6.....68

Appendix 6: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 6.....68

Appendix 7: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 7.....69

Appendix 8: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf.....69

Appendix 9: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 8.....70

Appendix 10: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 8.....70

Appendix 11: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions (Average from week 4 to week 8).....71
Appendix 12: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions (Average from week 4 to week 8).....71
Appendix 13: Analysis of variance for average number of dead flowers and flower buds of protected tomato varieties grown under green house conditions..72
Appendix 14: Analysis of variance for average number of dead flowers and flower buds of infested tomato varieties grown under green house conditions.....72
Appendix 15: Analysis of variance for yield of infested tomato varieties grown under green house conditions.....73
Appendix 16: Analysis of variance for yield of protected tomato varieties grown under green house conditions.....73
Appendix 17: Analysis of variance for average percent webbing on tomato varieties grown under green house conditions in week 5.....74
Appendix 18: Analysis of variance for average percent webbing on tomato varieties grown under green house conditions in week 6.....75
Appendix 19: Analysis of variance for average percent webbing on tomato varieties grown under green house conditions in week 7.....76
Appendix 20: Analysis of variance for effect of tomato varieties on incubation period of *T. evansi*.....77
Appendix 21: Analysis of variance for effect of tomato varieties on larvae period of *T. evansi*.....77
Appendix 22: Analysis of variance for effect of tomato varieties on deutonymph period of *T. evansi*.....78
Appendix 23: Analysis of variance for effect of tomato varieties on protonymph period of *T. evansi*.....78
Appendix 24: Analysis of variance for effect of tomato varieties on fecundity of *T. evansi*.....79
Appendix 25: Analysis of variance for effect of tomato varieties on longevity of *T. evansi*.....79

Appendix 26: Analysis of variance for effect of acaricide treatment against Red spider mite (*T. evansi*) on yield of tomatoes.....80
Appendix 27: Analysis of variance for effect of acaricide treatment on average *T. evansi* population (Pre-treatment).....81
Appendix 28: Analysis of variance for effect of acaricide treatment against Red spider mite (*T, evansi*) on leaf damage of tomatoes.....81
Appendix 29: Analysis of variance for effect of acaricide treatment on average *T. evansi* population in week 1.....82
Appendix 30: Analysis of variance for effect of acaricide treatment on average *T. evansi* population week 2.....82
Appendix 31: Analysis of variance for effect of acaricide treatment on average *T. evansi* population week 3.....83
Appendix 32: Analysis of variance for effect of acaricide treatment on average *T. evansi* population week 4.....83
Appendix 33: Analysis of variance for effect of acaricide treatment on average *T. evansi* population in week 5.....84
Appendix 34: Analysis of variance for effect of acaricide treatment on average *T. evansi* population in week 6.....84
Appendix 35: Analysis of variance for effect of acaricide treatment against Red spider mite (*T, evansi*) on leaf damage of tomatoes (Eight weeks after first spray application).....85
Appendix 36: A survey on Red spider mite (*Tetranychus evansi*) and farmers control measures on tomato in Subukia and Rongai Divisions.....86

CHAPTER ONE

INTRODUCTION

1.1 Background information

Tomato *Lycopersicon esculentum* (Mill) is the world's most popular vegetable, with an annual world production of 80 million metric tons (FAO, 2001). Kenya produces an estimated 318,639 metric tons and earning cash value of Ksh 5.1 billion (KARI, 1996). Tomato is third to kales and cabbages in terms of hecterage and production, but first overall in terms of cash value in horticultural vegetable crops (KARI, 1996).

Tomato is a fruit vegetable that is consumed fresh (raw) or cooked, and is used to process various products (Di Mascio *et al.,* 1989). Ripe tomato is used in the manufacture of puree, sauces, paste, juice, powder and ketchup or may be canned as whole fruits. The unripe green fruits are used for pickles and preserves and are consumed after cooking.

In Kenya, tomatoes are grown for fresh domestic market and processing, for export (Kamau, 1985) and consequently its production can improve the total earning of Kenyan farmers. This is supported by a total of 5 billion Kenya shillings realized from tomato sales in the whole country (KARI, 1996). Calkings (1978) considered tomato in the tropics as the most popular vegetable with great potential for improving three fundamental components of living namely: income, employment and nutrition. The increased popularity in tomato production may be attributed to both its high yield potential, high prices and a continuous source of income (Kamau, 1985), and perhaps more than any other vegetable, it has a higher monetary return per unit area. Tomato growing is thus an important undertaking by low to moderate class earners and goes along way in supporting the fight against poverty and nutritional improvement in Kenya.

Commercial varieties grown in Kenya include "Beauty", "Marglobe", "Money Maker", "Cal J" and "Roma (Ministry of Agriculture, Kenya and JICA, 2000). The cultivars exhibit wide variation in fruit shape, size, colour, plant type, and pest resistance, ripening time and processing characteristics.

Kamau (1985) reported that there is high demand for tomatoes in Kenya experienced every year in the months of December to June when supply is low. The diseases and pests are among major problems experienced in growing tomatoes in Kenya, with Red spider mites being most important pests of tomatoes. This is in agreement with Kamau (1985), who reported that the major constraint to obtaining high yields of tomatoes is damage caused by the Tomato russet

mite *Aculops lycopersici* (Massee) and the Red spider mites (*Tetranychus spp.).* These are serious pests of a tomato crop grown in areas where the crop experience periods of hot and warm dry weather (Kamau, 1985). *Tetranychus spp.* causes serious damage to the tomatoes by reducing their yields and affecting quality, not to mention the cost of pesticides used by the farmers (Knapp *et al.*, 2003). Compounding their effects is the fact that in many instances, farmers have listed Red spider mites as a disease (Yang *et al., 2004)* because they are unable to recognize their minute sizes on crop surfaces.

Tetranychus evansi (Baker and Pritchard), is the most damaging and difficult to control arthropod pest of tomato (Mariatou and Kwaramba, 1999). *Tetranychus evansi* was first reported in Brazil (Silva, 1954). This indicates South America as its possible centre of origin (Gutierrez and Etiene, 1986). It was introduced accidentally in Africa in 1980's (Varela *et al.*, 2003). Presently it occurs in many countries of the African continent e.g. Zimbabwe (Smith Meyer, 1987), Morocco (E-Jaovani 1988), and Senegal (Duverney *et al.*, 2005). In Kenya it was first discovered in 2001 (Knapp *et al*; 2003). According to regional priotization of tomato diseases and pests problems in Eastern and Southern Africa, Red spider mite was given the highest priority (Varela *et al.*, 2003)

1.2 Problem statement

Tomato production during the hot and dry weather seasons has remained elusive due to outbreaks of spider mites. When grown under irrigation, during the hot and dry seasons, tomatoes fetch the best prices in the market. However, spider mites infestation is also very high resulting in to low and poor quality yields.

Resistant varieties to Red spider mites have been reported in some countries. In USA, Kalohi lines recorded high tolerance to mite injury (Varela *et al.*, 2003).

In Brazil, some promising tomato genotypes tolerant to *T. evansi* have been identified (Varela *et al.*, 2003). There are many tomato varieties commercially available to growers in Kenya. These varieties have not been screened to compare their resistance levels to Red spider mites. Successful production of tomatoes has been impossible without the use of chemicals in some countries (Avidov and Harpaz, 1969). There is a wide range of pesticides including some fungicides which have been screened and found effective against Red spider mites (Avidov and Harpaz, 1969).

1.3 Justification

In Kenya tomato yields in smallholder cropping systems are generally far below the potential of the crop. Average yields as low as 13.9 t/ha have been reported (MOARD, 2000). This is below the potential as compared to Zimbabwe where production of 100 t/ha has been reported (Verela *et al.*, 2003). There are several causes of low yields in Kenya. However, one of the main causes for low yields in Kenya is pest and diseases (MOARD, 2000). According to regional priotization of tomato pest and disease report of 1995, Red spider mite was considered as the most dangerous pest (Varela *et al.*, 2003). It is reported that there are difficulties in controlling outbreaks of spider mites when they occur because they are mostly found on the lower leaf surface where they are protected by the webbing which hinders spray penetration resulting in mites receiving insufficient doses required to kill them (Varela *et al.*, 2003). Many of the chemicals used are also not environmentally safe, are hazardous to user and have negative effects on natural enemies (Varela *et al.*, 2003). There is also need for a systematic evaluation to clearly show that there is variation in the tomato cultivars grown in Kenya against red spider mite.

In Kenya, studies have not been conducted to ascertain the efficacy of specific types of pesticides that are commonly used by farmers to control Red spider mite. Therefore studies were initiated to evaluate the effectiveness of commonly used pesticides against Red spider mites and identification of resistant varieties to Red spider mite as an integral part of an integrated pest management program. The use of resistant cultivars will reduce the need for repeated insecticide application by farmers to control red spider mites.

Tetranychus evansi was first discovered in Kenya in 2001 (Knapp *et al.*, 2003). However, a survey to determine the distribution and damage on tomatoes in Rongai and Subukia districts has not been done. Therefore, a survey was found necessary to determine the distribution and damage on tomatoes by red spider mite and farmers' management practices against the pest.

1.4 Objectives

1.4.1 Broad objective

Increase tomato yields by identifying resistant varieties and effective pesticide against Red spider mite (*T. evansi*)

1.4.2 Specific objective

1. Determine the effect of tomato varieties on development time from egg to adult, fecundity and longevity of *T. evansi*.
2. Determine the effect of tomato varieties on population density, damage of *T. evansi* and yield of tomatoes.
3. Determine the effect of acaricide application on *T. evansi* population density, damage and yield of tomatoes.
4. Determine the effect of farmers' management practices on damage of tomatoes by *T. evansi* in Rongai and Subukia divisions.

1.5 Hypotheses (H_o)

1. The effect of tomato varieties on development times from egg to adult, fecundity and longevity of *T. evansi* is the same.
2. The effect of tomato varieties on population density, damage of *T. evansi* and yield of tomatoes is the same.
3. The effect of acaricide application on *T. evansi* population density, damage and yield of tomatoes is the same.
4. The effect of farmers' management practices on damage of tomatoes by *T. evansi* in Rongai and Subukia divisions is the same.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of red spider mites (*Tetranychus evansi)* in tomato production.

The spider mite (Tetranychidae) represents an economically important group of the order Acarina that in matters of control are generally considered together with insects (Ennis 1979). A number of spider mites species have been associated with tomato damage in Kenya, and this includes *T. cinabarinus,* and *T. urticae (*Varela, *et al.,* 2003*). T. evansi* was first reported in Kenya in 2001 by scientists from ICIPE (Knapp *et al.*, 2003). *Tetranychus evansi* has been reported to cause yield loss of up to 90% on tomato in smallholder production systems in Zimbabwe (Knapp *et al 2003).* In a survey conducted in Kenya in the high tomato growing areas from 1998 to 2000 (ICIPE, 2003) only *T. urticae* was found.

2.2 Mites dispersal and infestation

In an experiment conducted by Suski and Naegele (1996) they concluded that the initiation of the dispersal of *T. urticae* was a response to food shortages and desiccation, interacting with some unknown factors. Horizontal dispersal is faster than vertical dispersal in tomato plants and Krainacker and Carey (1990) suggest the behavioural response of mites to environmental conditions probably played an important role in determining the initial dispersal direction. Spider mites are also reported to avoid unfavourable conditions on over exploited leaves (Kielkiewies, 1996). Nihoul *et al.*, (1991) reported that populations of *T. urticae* showed a greater tendency to increase on the upper ten leaves and the most marked increase in population was found in the middle leaves of the plants. Lack of correlation between mite density and leaf damage can be attributed to spider mites moving upwards to colonize youngest leaves (Kielkiewies, 1996).

Spider mites tend to disperse by wind or by walking up a plant as the mite population increase and plant grow (Sabelis and Dicke, 1985). Sabelis (1985) reviewed and reported that the vertical and horizontal course of mite movement may vary widely for different species of host plant and spider mite species. Factors such as leaf surface, food availability and quality, leaf exploitation, predation, mite density, temperature, light, gravity and humidity can modify interplant mite dispersal (Kielkiewies, 1996).

Experiments have shown that infestation often starts on the outside (border rows) of a plot (Sabelis, 1985). Therefore other adjacent (tomato) crops, wild plants and weeds can serve as a

source of infestation. The mites can also be spread by irrigation water, dust storms, clothing and implements (Keizer and Zuubier, 2001).

2.3 Biology of Red spider mites, (*Tetranychus evansi*)

Preferred oviposition site is on the lower leaf surface at the junction of veins. Oviposition begins a day after adult emergence. Female reach their maximum egg laying capacity on the 4th day and oviposition rate decreases, as the mite grows old. All active stages of the mites feed together on the lower sides of the leaves and they move to the upper side, stems and fruits at high densities. The development stages include egg, larvae, protonymph, deutonymph and adult (Meyer, 1996). Eggs are spherical, 0.15mm in diameter, translucent when first laid and hatch after 4-7 days. A larva has 6 legs and larval stage lasts 3-5 days. Following the larvae is a rest stage then a protonymph with a pink tinge, another rest stage before the reddish deutonymph. Both nymph instars have eight legs. Adults emerge after another resting stage. Total nymph period lasts 6-10 days. Fertilized female longevity is 13-32 days while unfertilized females live 27-39 days. Spider mites are active within 16-37 ^{0}C and flourish at relative humidity of between 50 -70 % (Keizer and Zuubier, 2001). Reproduction continues through out the year, resulting in 24-30 generations per year.

2.4 Symptoms of damage

Spider mites typically produce leaf scarification and bronzing as their main symptom of damage, sometimes accompanied by extensive foliage webbing with silk (Hill, 1987). The epidermal cells are emptied of sap and the air that enter inside gives the leaf surface a silvery appearance, and when the epidermal damage is extensive, the leaf suffers from dehydration followed by desiccation and bronzing. Severely bronzed leaves fall prematurely. Spider mites prefer the lower surface of leaves but in severe infestation, mites may also be found on the upper surface as well as on the stems and fruits (Meyer, 1996).

As the population increases the mites may completely cover the plant with webbing (Craemer *et al.*, 1998) resulting in reduced leaf tissue chlorophyll content and reduced photosynthesis, CO_2 assimilation and transpiration. This causes disturbances of metabolic process which leads to reduced growth, flowering and yields (Mathews and Tunstall, 1994). Crop yields are diminished as essential plant processes are affected. Nihoul *et al.*, (1991) found out that in a tomato plant, the mean leaf damage index (MLDI) increase exponentially with respect to the total number of mites. According to Mckinlay (1992), tomatoes, yields may be reduced by mite induced

physiological shock, reduced size and fruit numbers and sun-scalded fruits arising from loss of leaves. Smaller and lighter fruits with lower contents of soluble solids and ascorbic acid may also be produced (Valera *et al.*, 2001).

2.5 Common methods of control

2.5.1 Chemical control

Different types of acaricides have been used for mites control in the tomato production but poor use of pesticides results in pests developing resistance (Carriere *et al.*, 1994), resulting in the need for alternative control measures that are safe and environmentally friendly. Yang *et al.*, (2004) reported that small-scale farmers are usually resource poor. The limited resources therefore must be correctly used to avoid wastage and the risk of pollution. The use of pesticides without ecological knowledge causes the dilemma of resistance, resurgence of pests and residue of pesticides in many crops through out the world (Yang *et al.*, 2004). Farmers should use chemicals correctly as a last result, and even then, only if the costs and risks involved do not outweigh the benefits (Keizer and Zuubier, 2001).

2.5.2 Cultural practices

The separation of infected crops from newly planted crops or nursery areas and the burning or removal of infected crop residues and weeds helps minimize mite problem (Keizer and Zuubier, 2001). Removal and burning of infected plants can be successful during the early stages of infestation when the mites concentrate on a few plants. Pruning and trellising improves chemical contact therefore better mite control is achieved (Saunyama and Knapp, 2003). Mites favor dry and hot conditions thus applying mulch and incorporating organic matter into the soil can improve the water holding capacity and reduce evaporation, thus avoid water stress (Keizer and Zuubier, 2001).

2.5.3 Biological control

Use of predatory mites has been practiced in the tropics in the field crops but usually only limited control is achieved (Hill, 1987). Predatory phytoseeid mite (*Phytoseiulus persimilis* (Athias-Henriot)) has been a success in greenhouse control of mixed and pure populations of *T. urticae and T. cinabarinus* on various crops; however suppression on *T. cinabarinus* populations was delayed in open fields (Bitton and Nakash, 1986). *T. evansi* has few predators in Africa since they were introduced accidentally to the continent recently and the predators are not adapted to them, thus no suitable biological control agent is available yet.

2.5.4 Integrated pest management

Pimentel *et al.*, (1992) reported that because of the problems with resistance to acaricides, it is vital to use integrated management programs whenever possible to maximize the regulating effects of natural enemies. Varietal resistance is a major element in the integrated control of spider mites; it is the least expensive and the easiest technique for crop protection (Impe and Van Hance, 1993).

2.6 Tomato host-plant resistance

Resistant plants are any plants that are attacked less or damaged less by a pest than other host plants grown under same environment in the field (Ennis, 1979). It does not necessarily imply total absence of a pest or attack, although in certain circumstances this may be achieved. Any cultivar that sustains a small amount of damage than another in the same situation would thus be considered resistant. Varietal resistance is a major element in the integrated control of spider mites. Resistance may be based upon biochemical or structural differences, growth characteristics and timings of development (Ennis, 1979). However, in many instances the actual basis of the resistance is not known, even though its existence is recognized and may be used in agriculture. Resistance traits are pre-adaptive characteristics of a plant and so plants with genes for these pre-adaptive characters withstand the selective pressure of herbivore populations, thus increasing chances for their survival and reproduction (Ennis, 1979).

Tolerance is also a resistance mechanism where a genetic trait of a plant protects it against an insect population which would damage a susceptible host variety, so that there is no reduction in yield or lowering quality of the marketable plant product (Panda and Khush, 1995). In their long association with pests and pathogens, plants have evolved an impressive array of defence tools.

Natural resistance has obvious advantages over the use of chemical pesticides or other methods for pest control and these include nominal genetic permanency and negligible cost once cultivars are developed and quite high efficacy (Patricia and James, 1999).

Tomato production is considered a high-risk crop, requiring intense use of pesticides especially in tropical countries (Maluf *et al.*, 2001). The authors reported that varietal resistance could become an important component of an IPM program aimed at reducing the chemical sprays and allowing for a smaller environmental impact. Resistance to spider mites has been found in many crops, as is apparent from a review of the literature on the resistance to the two spotted spider mites by De Ponti (1977). Resistance to many arthropod pests have been recorded in the wild

tomato species *Lycopersicon hirstum var hirstum;, L. hirstum var glabratum;, L. peruvian and L. pennellii (*Maluf *et al.*, 2001) but these species do not have immediate commercial value. A lot of work has been done on insect and mite resistance in vegetable crops (Kalloo, 1988) and prospects for developments of more resistant cultivars are bright. Differences in leaf wax in onions and crucifers, low level of chlorogenic in carrots, glandular trichomes on the leaf surface and associated methyl ketones, sugar esters, sesquiterpenes, phenolics and polyphenal oxidizes in tomatoes, potatoes and egg plants have been identified as plant characteristics that facilitate insect resistance among these crops (Stoner, 1992).

Unfortunately breeding programmes aimed at introgression of arthropod resistance from wild *Lycopersicon* species into the cultivated tomato often face methodological difficulties of keeping uniform conditions for infestation necessary for resistance selection, making direct selection expensive and slow (Maluf *et al.*, 2001). Selection for either high Zingiberene content or for high type IV trichome densities should be a suitable indirect selection criterion not only for spider mites resistance, but also for resistance to other tomato pests (Good and Snyder, 1988). Trichome densities vary with seasons thus trends of within plant variation among leaflets surface features are generated by seasonal variations.

In developing countries, resistance is important because virtually no skill in pest control or cash investments is required of the grower (Jennings and Maxwell, 1980) and resistance developed in plants for one pest species may provide resistance to several others. Studies of the use of pest resistance suggest that it has not been exploited to the extent possible and further research is vitally needed to utilize rationally resistance in an optimum way (Ennis, 1979). Same author reported that in using resistance, farmers' save and saving to farmers is passed on to consumers in lower food prices.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment 1: Effect of Red spider mite *Tetranychus evansi* on tomato varieties under green house conditions

3.1.1 Mite culture

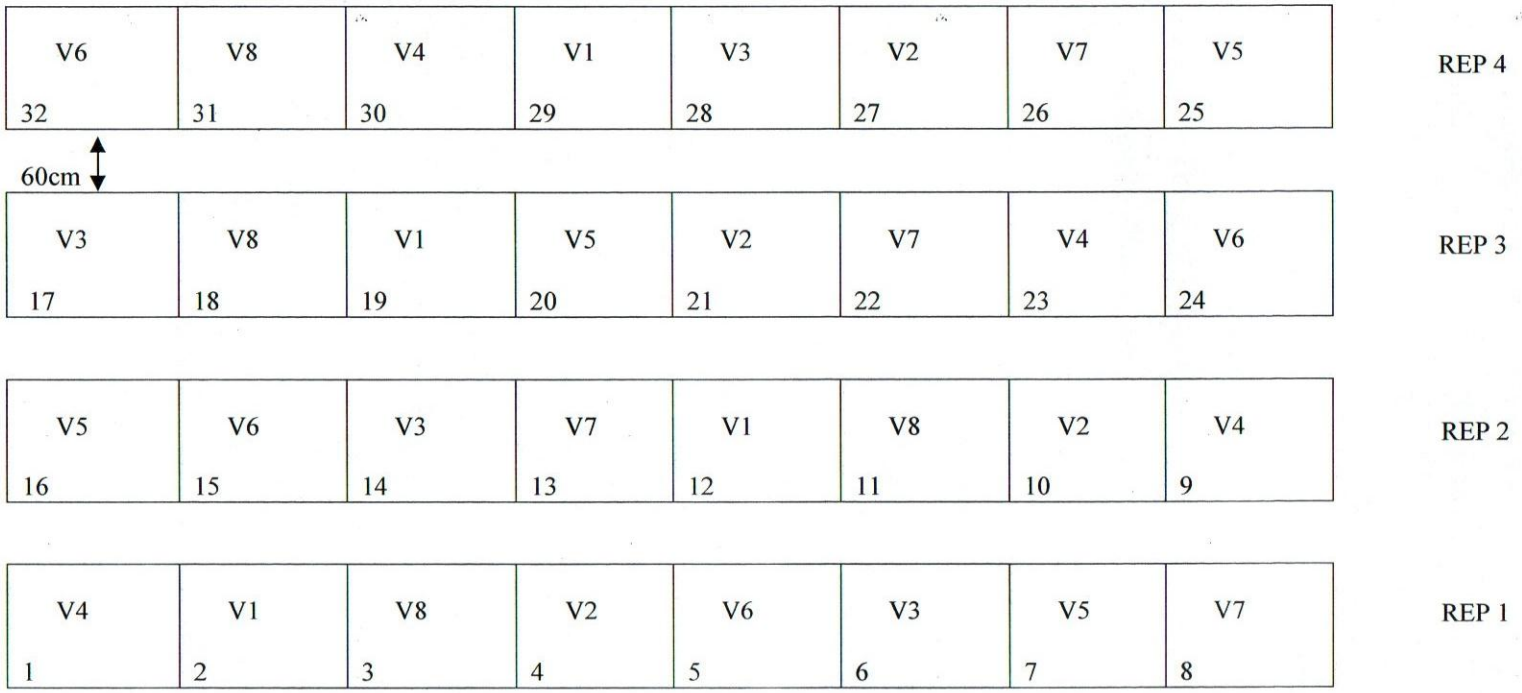
A stock culture of Red spider mite *T. evansi* was established in green house at KARI- Njoro (0^0 20'S 35^0 56'E, 2164 m above sea level). The initial culture was collected from Horticulture Department (Field 3), Egerton University-Njoro, Kenya and reared on potato plants. The reared red spider mites were later used in both green house and laboratory experiments carried out at KARI- Njoro. Red spider mite, *T. evansi* was identified in consultation with International Centre of Insect Physiology and Ecology (ICIPE) - Nairobi, and with the help of research supervisors.

3.1.2 Experimental design and layout

The experiment was conducted using Randomized Complete Block Design replicated four times (Figure 3.1). The tomato varieties assessed for host plant resistance were: Cal J, Onyx, Roma VFN, Riogrande, Money Maker, Eden F1, Anna F1, and Wild type. All the varieties a part from the Wild type were obtained from seed companies in Kenya. The seeds of the Wild variety used in the evaluation were extracted from wild tomato plants collected from farmer's field in Njoro. A separate set of experiment (control) of same varieties protected from red spider mite infestation was placed 2m a way from the infested plants in another adjacent green house for comparison. This experiment was done twice.

3.1.3 Non variables

Loam and sand soil were sterilized by steam heating to 180F (82.2°C) and mixed with well decomposed manure at the ratio of 2:1:1. The soil mixture was then put in polythene bags of 30 cm diameter and 40 cm depth. Diammonium Phosphate (18-46-0) at the rate of one teaspoonful per pot (200 kg/ha) was added in the polythene bags and mixed with the soil. Four seeds of each tomato variety were sown in the pot and were later thinned at 21 days from the date of planting leaving only one healthy plant. Plants were top dressed with Calcium Ammonium Nitrate (26%N) at the rate of a half teaspoonful per plant (100 kg/ha) at 45 days after planting. The plants were watered once per day in the evening.



KEY

V1	Cal J	V5	Money Maker
V2	Onyx	V6	Eden F1
V3	Roma VFN	V7	Anna F1
V4	Riogrande	V8	Wild type

Figure 3.1: Experiment layout- Effect of Red spider mite *Tetranychus evansi* on tomato varieties under green house conditions

Early blight *Alternaria solani* (Ellis and Martin) and late blight *Phytophthora infestans* (Mont) DeBary diseases were controlled by spraying using Ridomil 68 WG (Metalaxyl 40gkg^{-1} and Mancozeb 640 gkg^{-1}) at the rate of 2 kgha^{-1} at 21 days interval. Sucking pests (aphids and white flies) were controlled by spraying the seedling with Actara 25 WG (Thiamethoxam 25%) at the rate of 0.5 kgha^{-1}. The control plants were sprayed once every two weeks with Mitigan 18.5EC (Dicofol 185 gl^{-1}) at the rate of 1lha^{-1} to ensure that they were free from mite damage.

3.1.4 Infestation

Leaflets infested with mites were collected from the mite culture and examined under light microscope. The mites were removed using camel hair brushes leaving only 20 mites per leaflet. The leaflet was then attached on the second leaf of tomato plant using a pin. This was done to all the tomato plants when the plants were 30 days old.

3.1.5 Variables measured

Mite population density

Sampling for mite began on the 4th week from the date of artificial infestation. This was done on a weekly basis up to the 8th week. Three leaves from each test plant were picked at random; one from top, middle and bottom. One leaf disc (10 mm in diameter) was punched from each leaf using a cork borer. All motile stages and eggs were counted with a tally counter on both sides of each leaf disc in the laboratory using a dissecting microscope.

Leaf damage

Leaf damage was scored on a visual rating of a 1 to 5 scale (Kamau, 1985) where:

1= Clean or healthy plant – **Plate 3.1**

2= Slight damage; a few leaves showing slight yellowing and whitening due to mite feeding (punctures), (<25% of the leaves damaged) –**Plate 3.2**

3=Moderate damage; many leaves showing yellowing and whitening due to mite feeding (punctures), (26-50% of the leaves damaged) – **Plate 3.3**

4=Severe damage; Plant leaves showing yellowing, whitening, desiccation, defoliation and webbing due to mite feeding (punctures).

(51-75 % of the leaves damaged) – **Plate 3.4**

5=Very severe damage; webbing, severe defoliation dying of leaves and the entire plant (76-100% of the leaves damaged)

The third and fourth leaves of every test plant were rated first and two successive leaves were included during every successive sampling period. A total number of ten leaves per plant were rated during the sampling period. Damage assessment was done once a week starting on the fourth week from the date of artificial infestation to the eighth week.

Webbing

The percentage of webbing on the plants was based on the whole plant. The plant was divided into four equal parts (quarters). To determine the percentage of webbing, the level of web formation was first determined on the lower quarter before moving to the upper quarters. Formation of webbing by the *T. evansi* on the plants was assessed once every week starting from the fourth week from the date of artificial infestation up to the eighth week. This was done on the same day the mites were counted and leaf damage assessed.

Dead flower and flower buds

The dead flowers and flower buds of the first four clusters of each plant were counted once every week starting from one week from the onset of flowering.

Fruit formation

The formed fruits were counted on the first four clusters once every week starting fifteen days after the onset of flowering.

Yield

The tomatoes were harvested as they matured and were counted and weighed using electronic balance (Mettler Toledo PB602). The damaged fruits by *T. evansi* were also sorted, counted and weighed using the same electronic balance. However they were discarded because they were regarded as having no market value.

3.1.6. Data analysis

Data collected was organized and Analysis of variance (ANOVA) was done using the General linear model (GLM) procedure of SAS 2001 version 8.02. Means were separated using Tukey's Studentized Range Test. Data was analysed using the following complete randomized Design (RCBD) model and ANOVA.

Model:

$$Y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij}$$

$$i = 1.....8$$

$$j = 1.....4$$

Where: Y_{ij} = the expected observation

μ = Overall mean which is constant with all expected observations

τ_i = the effect of tomato varieties on the expected observations

β_j = the effect of blocking on the expected observation

ϵ_{ij} = random error component, distributed normally N $(0,\sigma^2)$

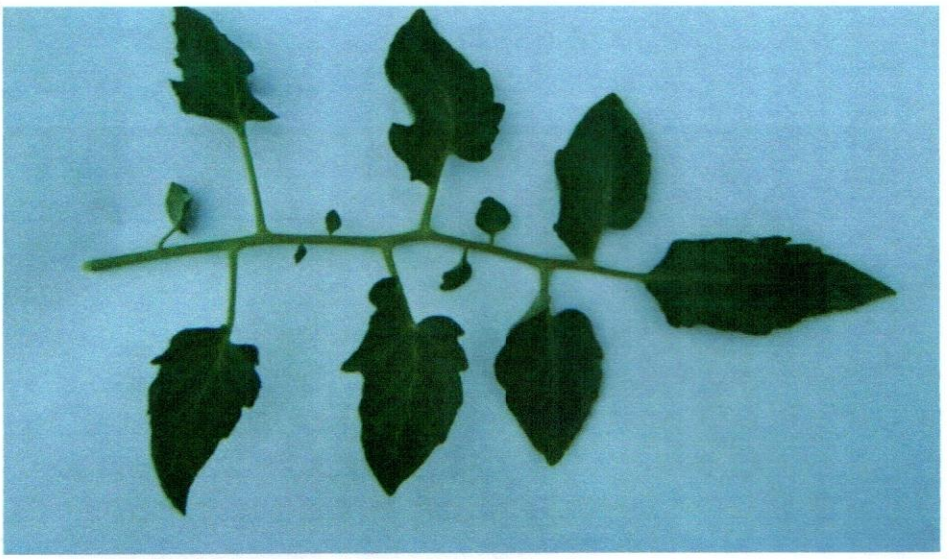


Plate 3.1: Clean or healthy plant.



Plate 3.2: Slight damage: a few leaves showing slight yellowing and whitening due to mite feeding, < 25% of the plant leaves damaged due to Red spider mite (*T. evansi*) attack.



Plate 3.3: Moderate damage; many leaves showing yellowing and whitening due to mite feeding, 26-50% of the plant leaves damaged due to Red spider mite (*T. evansi*) attack.



Plate 3.4: Severe damage: 51-75 % of the plant leaves showing yellowing, whitening, desiccation, defoliation and webbing due to Red spider mite (*T. evansi*) feeding.

3.2. Experiment 2: Effect of tomato varieties on development time, fecundity and Longevity of *T. evansi*

3.2.1. Development time from egg to adult

Studies on the effect of tomato varieties on the development time from egg to adult of *T. evansi* were done in a conviron incubator maintained at 25 ± 2 °C, 50-70 % relative humidity and photoperiod 12:12 L:D (Helle and Sabelis, 1985). Small Petri dishes (100 mm diameter) were loaded half with cotton wool and kept wet by adding 5ml of clean water in the morning and evening. Ten leaf discs from each tomato variety with a diameter of 20 mm each were punched from the tomato varieties using a cork borer. The leaf discs were placed in individual Petri dishes, the underside facing up. Thin layer of vaseline was placed on the edges of the leaf disc to prevent the mite from walking a way from the leaf disc and drowning. Ten female mites were taken from the colony, put on each leaf disc for each tomato variety separately and left for six hours to allow egg laying. Afterwards, eggs were removed (killed) using fine camel hair brush leaving only two eggs per leaf disc. Petri dishes containing leaf discs were then placed in an incubator in a complete randomized design (CRD) arrangement replicated four times. The leaf discs were checked after every 12 hours with the aid of a dissecting microscope and development time from egg to larva, protonymph, deutonymph and adult, as well as adult survival and sex were noted and recorded. Leaf discs were changed after every three days to provide fresh leaves for mites to feed on.

3.2.2. Fecundity and longevity

Studies on the effect of tomato varieties on fecundity and longevity of *T. evansi* were done in a conviron incubator maintained at 25 ± 2 °C, 50-70 % relative humidity and photoperiod 12:12 L:D (Helle and Sabelis, 1985). Small Petri dishes (100mm diameter) were loaded half with cotton wool and kept wet by adding 5 ml of clean water in the morning and evening. Ten leaf discs with a diameter of 20 mm from each tomato variety were punched using a cork borer. The leaf discs were placed in individual petri dishes, the underside facing up. Thin layer of vaseline was placed on the edges of the leaf disc to prevent the mite from walking a way from the leaf disc and drowning. One female deutonymph was placed on each leaf disc for each of the ten leaf disc per tomato variety. Petri dishes containing leaf discs were then placed in an incubator in a complete

randomized design (CRD) arrangement replicated four times. The numbers of eggs were counted and recorded using dissecting microscope after every 48 hours and killed until the mite died. The fecundity and adult longevity on each leaf disc was recorded. Leaf discs were changed after every three days to provide fresh leaves for mites to feed on.

3.2.3 Data analysis

Data collected was organized and Analysis of variance (ANOVA) was done using the General linear model (GLM) procedure of SAS 2001 version 8.02. Means were separated using Tukey's Studentized Range Test. Data was analysed using the following complete randomized Design (CRD) model and ANOVA

Model:

$$Y_{ij} = \mu + \tau_i + \epsilon_{ij}$$

$i = 1.....8$

$j = 1.....4$

Where:

Y_{ij} = the expected observation

μ = Overall mean which is constant with all expected observations

τ_i = the effect of tomato varieties on the expected observations

ϵ_{ij} = random error component, distributed normally N $(0,\sigma^2)$

3.3. Experiment 3: Effect of pesticides on *Tetranychus evansi* population and damage on tomatoes

3.3.1. Experimental design and layout

The experiment was conducted using Randomized Complete Block Design replicated four times (Figure 3.2). The following pesticides were evaluated: Mitigan (Dicofol 185 gl^{-1}) at the rate of 1.0 l ha^{-1}, Dictator plus (Tetradifon 21.2%, Propergite 7.5%) at the rate of 0.5 l ha^{-1}, Neembicide (Azadirachtin 0.03%) at the rate of 1.0 l ha^{-1}, Ortus (Fenpyroximate 50 g/l) at the rate of 0.5 l ha^{-1}, Vapcothion (Dicofol 8%,Tetradifon 25%) at the rate of 1.0 l ha^{-1}, and Chili (*Capsicum frutescens*) extract 4 kg ha^{-1}. The control treatment was sprayed with water.

3.3.2. Non variables

Loam and sand soil were sterilized by steam heating to 180F (82.2°C) and mixed with well decomposed manure at the ratio of 2:1:1. The soil mixture was then put in polythene bags of 30 cm diameter and 40 cm depth. Diammonium Phosphate (18-46-0) at the rate of one teaspoonful per pot (200 kg/ha) was added in the polythene bags and mixed with the soil. Four seeds of tomato variety Roma VFN were sown in each pot. Plants were thinned at 21 days from the date of planting leaving only one healthy plant. Plants were top dressed with 100 kg ha^{-1} of Calcium Ammonium Nitrate (26% N) at the rate of a half teaspoonful per plant (100 kg/ha) at 45 days after planting. The plants were watered once per day in the evening

Early blight *A. solani* (Ellis and Martin) and late blight *P. infestans* (Mont De Bary) diseases were controlled by spraying Ridomil 68 WG (Metalaxyl 40g kg^{-1} and Mancozeb 640g kg^{-1}) at the rate of 2 kg ha^{-1} at 21 days interval. Sucking pests (aphids and white flies) were controlled by spraying the seedling with Actara 25 WG (Thiamethoxam 25%) at the rate of 0.5kg ha^{-1}. Fully ripe, dry hot pepper pods were ground into fine powder using a morter and pestle and sieved to pass through No.18 (1mm) mesh screen. Hot pepper extract were prepared by shaking 20 g dried fruit powder with 100 ml of distilled water.

Pesticides were sprayed using 1.5 liters hand sprayer outside green house to avoid contamination of neighboring plants (method adopted from Wekesa *et al.*, 2005). The plants were tied on the support sticks using sisal twines.

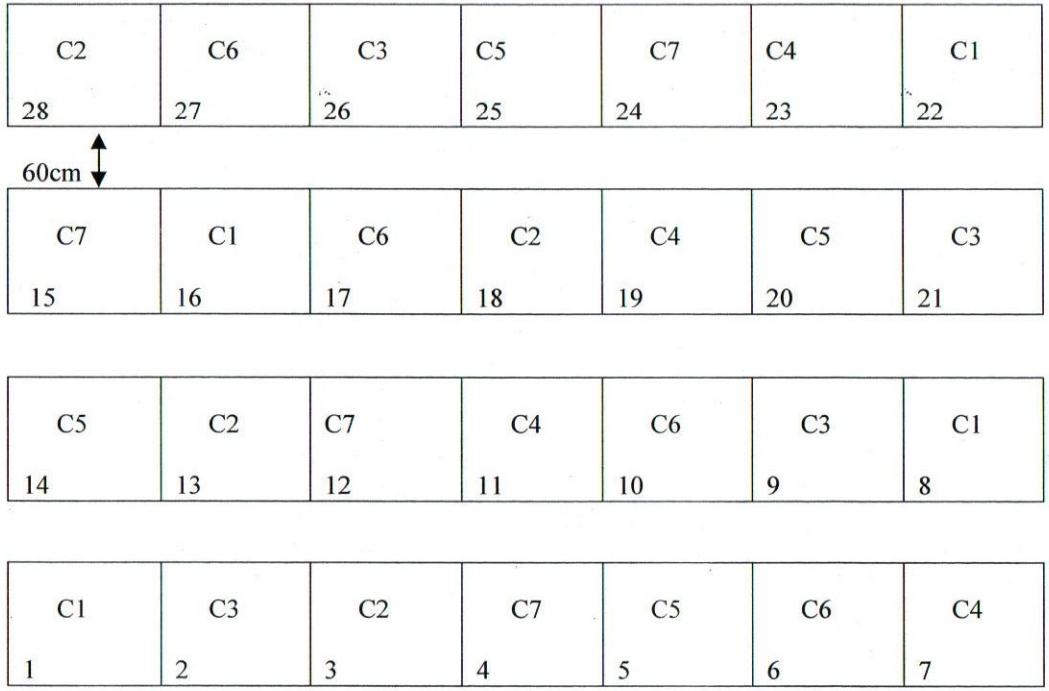
3.3.3. Infestation

Leaflets infested with mites were collected from the mite culture and examined under light microscope. The mites were removed using camel hair brushes leaving only 20 mites per leaflet. The leaflet was then attached on the second leaf of tomato plant using a pin. This was done to all the potted tomato plants used. The mites were allowed to multiply and establish for one and a half months from the date of artificial infestation. Pre-treatment sampling was done the same day before spraying the plants with various treatments. Three leaves from each test plant were picked at random; one from top, middle and bottom. One leaf disc (10 mm in diameter) was punched from each leaf using a cork borer. All motile stages and eggs were counted using a tally counter on both sides of the leaf disc in the laboratory using a dissecting microscope. Second spraying of the plants was done 2 weeks after the first spray.

3.3.4. Variables measured

Mite population density

Pre-treatment sampling was done just before first chemical spray. Further sampling for mite began on the 1st week from the date of 1st chemical spray. This was done on a weekly basis and went on up to 6th week. Three leaves from each test plant were picked at random; one from top, middle and bottom. One leaf disc (10 mm in diameter) was punched from each leaf using a cork borer. All motile stages and eggs were counted with a tally counter on both sides of each leaf disc in the laboratory using a dissecting microscope.



KEY

C1	Mitigan	C5	Chilli extract
C2	Dictator	C6	Vapcothion
C3	Neem	C7	Control (Untreated check)
C4	Ortus		

Figure 3.2: Experiment layout- Effect of pesticides on *Tetranychus evansi* population and damage on tomatoes

EGERTON UNIVERSITY LIBRARY

Leaf damage

Leaf damage was scored on a visual rating of a 1 to 5 scale (Kamau, 1985) as for experiment one where:

1= Clean or healthy plant – **Plate 3.1**

2= Slight damage; a few leaves showing slight yellowing and whitening due to mite feeding (punctures), (<25% of the leaves damaged) –**Plate 3.2**

3=Moderate damage; many leaves showing yellowing and whitening due to mite feeding (punctures), (26-50% of the leaves damaged) – **Plate 3.3**

4=Severe damage; Plant leaves showing yellowing, whitening, desiccation, defoliation and webbing due to mite feeding (punctures). (51-75 % of the leaves damaged) – **Plate 3.4**

5=Very severe damage; webbing, severe defoliation dying of leaves and the entire plant (76-100% of the leaves damaged)

The third and fourth leaves of every test plant were rated first and two successive leaves were included during every successive sampling period. A total number of ten leaves per plant were rated during the sampling period. Damage assessment was done once a week starting on the 1st week from the date of 1st chemical treatment to the eighth week.

Webbing

The percentage of webbing on the plants was based on the whole plant. The plant was divided into four equal parts (quarters). To determine the percentage of webbing, the level of web formation was first determined on the lower quarter before moving to the upper quarters. Formation of webbing by the *T. evansi* on the plants was assessed once every week starting from the fifth week from the date of 1st chemical treatment up to the eighth week. This was done on the same day the mites were counted and leaf damage assessed.

Dead flower and flower buds.

The dead flowers and flower buds of the first four clusters of each plant were counted once every week starting from one week from the onset of flowering.

Yield

The tomatoes were harvested as they matured and were counted and weighed using electronic balance (Mettler Toledo PB602). The damaged fruits by *T. evansi* were also

counted and weighed using the same electronic balance. However they were discarded because they were regarded as having no market value.

3.2.5. Data analysis

Data collected was organized and Analysis of variance (ANOVA) was done using the General linear model (GLM) procedure of SAS 2001 version 8.02. Means were separated using Tukey's Studentized Range Test. Data was analysed using the following complete randomized Design (RCBD) model and ANOVA

Model:

$$Y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij}$$

$$i = 1.....7$$

$$j = 1.....4$$

Where:

Y_{ij} = the expected observation

μ = Overall mean which is constant with all expected observations

τ_i = the effect of chemicals on the expected observations

β_j = the effect of blocking on the expected observation

ϵ_{ij} = random error component, distributed normally N $(0,\sigma^2)$

3.4. Survey on distribution and damage on tomatoes by Red spider mite in Subukia and Rongai division, Kenya

3.4.1. Introduction

Subukia and Rongai divisions are among the divisions in Subukia and Rongai district respectively in Rift Valley Province of Kenya. These divisions are high potential area with annual average rainfall ranging from 800 to 2200 mm. In most of the areas, the soils are deep and moderately to highly fertile. The average annual temperatures range is 9.7 to 21.6 $^{\circ}$ C (Ralph *et al.,* 1983). Subukia and Rongai divisions cover an area of about 424.2 km^2 and 254 km^2 respectively. The agricultural land per house hold is about 2.5 acre in both Subuka in Rongai districts. Both divisions receive bimodal rainfall (Ralph *et al* 1983). The first rains start at the end of March and the second rains start at the end the end of October. Tomatoes are grown throughout the year in the green house and during long and short rains in the open field. In dry months of December to March, tomatoes are grown under irrigation in the open field.

3.4.2. Materials and Methods

A survey was carried out in March 2010 in Subukia and Rongai division to obtain information on key pest of tomato and strategies adopted by farmers for their management. A total of 60 farmers (30 open field and 30 greenhouse) interviewed were randomly selected from the two divisions. The selection of farmer was done in conjunction with the Ministry of Agriculture staff in the respective divisions. Both primary and secondary data were collected in this study. Primary data was obtained from direct interview of the farmers whereas secondary data was obtained from the various Divisional Agricultural Extension offices. A structured questionnaire was administered to each respondent through one farm visit using the most appropriate language or interpreter where necessary. In addition field observations were carried out to verify information provided where the tomato crop was available. The information collected from the farmers was on:

i. Total farm size
ii. Tomato varieties grown
iii. Major pests and diseases of tomato in order of priority
iv. Effect of planting time on Red spider mite

v. Chemicals used by tomato farmers to control red spider mite and other pests of tomato

vi. Type of protective measures during pesticide application

vii. Yield loss due to red spider mite infestation

3.4.3. Data analysis

Data collected was recorded in worksheet. Statistical analysis was carried out using the Statistical Package for Socio-Scientist (SPSS ver.11.5)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Experiment 1: Effect of Red spider mite (*Tetranychus evansi*) on tomato varieties under green house conditions

4.1.1. Mite population

Analysis of variance showed that significantly higher ($P<0.05$) average number of mites was recorded on Money Maker in week 4, 5 and 6 after artificial infestation. However in weeks 7 and 8 after infestation, the average number of mite on this variety was not significantly ($P>0.05$) different from Riogrande (Table 4.1). The lowest total average (2.6) number of mites was recorded on Wild type which was not significantly ($P>0.05$) different from Eden F1, Cal J and Onyx. Variety Anna F1, recorded significantly ($P<0.05$) more total average number of mites than Wild type, Eden F1 and Onyx both of which were not significantly ($P>0.05$) different from Cal J. The total average number of mites (6.4 per 3 leaf disks) was recorded on variety Anna F1 which were significantly ($P<0.05$) less than tomato Money Maker, Riogrande and Roma VFN but significantly more than the rest of the tested tomato varieties. The overall results also showed that tomato Riogrande and Roma VFN were not significantly different ($P>0.05$).

General population increase of mites from week 4 to 8 was highest on Money Maker and Riogrande while the lowest population increase was recorded on Wild type and Onyx. There was also an increase in mite population in week 6 in all the varieties tested except Eden F1. Generally, the average per week of mite population increased significantly ($P<0.05$) every week except from 7^{th} to 8^{th} week after infestation (Table 4.1). This may be due to mite build up to maximum levels and plants were drying up.

The difference in population density of *T. evansi* on tomato varieties tested can be attributed to the different morphological traits such as trichomes and surface waxes as well as secondary plant metabolites (Anathakrishnan, 2001). Compounds from tomato trichome exudates such as methyl ketons and zingiberene have been shown to be toxic to spider mites (Chatzivasileiadis and Sabelis, 1997, 1998., Chatzivasileiadis *et al.*, 1997., Maluf *et al.*, 2001., Cedola and Sanchez, 2003). In the present study, total average mite population density recorded on Money Maker was significantly ($P<0.05$) higher than all the tested varieties while the lowest total average mite population density was recorded

on Wild type. These results can be attributed to different types of trichomes. Money Maker was found to have no type IV trichomes (Glandular) while the wild type was found to have significantly (P>0.05) higher number of type IV trichomes. Similar results have been reported by Isutsa *et al.,* 2006. Glandular trichome types I, IV, VI and VII are known to release secretions on touch that are sticky and toxic (Van haren *et al.*, 1987, Nihoul 1993., Kennedy 2003., Simmons and Gurr, 2005). The secretions immobilize mites or kill them.

The results in this experiment also agree with those reported by Carlos *et al.*, (2009) while working on the incidence of pests in grafts of tomato (*Solanum lycopersicum)* on wild relatives where it was noticed that the type recorded least incidence of pests than the commercial varieties. Similar work was also reported by Silva *et al.,* (1992) where *Lycopersicon hirsutum* var. *glabratum* C. H. Mull was identified as the most resistant genotype to *T. evansi*. More work in support of these results was reported by Wesonga, *et al.* (2005) who reported that, the wild *Lycopersicon* accessions (*L. hirsutum* and *L. peruvianum*) were found to be the most repellent to the spider mites.

4.1.2 Leaf damage

The highest damage was recorded on tomato Money Maker which differed significantly (P<0.05) from all the varieties except in the 8th week after infestation (Table 4.2). The lowest leaf damage was recorded on Wild type which was significantly less except in week six after infestation where there was no significant (P>0.05) different from Cal J and Eden F1. The low leaf damage on the Wild type may be due to low mite population (Table 4.1) leading to low leaf damage (Table 4.2). This may be due to both morphological and chemical characteristics of the wild type. Similar findings were also reported by Isutsa *et al.*, (2006) and Murungi *et al.*, 2009 where Money Maker was found to have no type IV trichomes (glandular) while the wild type was found to have significantly higher number of type IV trichomes. Glandular trichome types I, IV, VI and VII are known to release secretions on touch that are sticky and toxic (Van haren *et al.*, 1987; Nihoul 1993; Kennedy 2003; Simmons and Gurr, 2005). The secretions immobilize mites or kill them. These characteristics of the Wild type may be the reason for less leaf damage in the present study.

Table 4.1: Average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions.

	Weeks after infestation					
Variety	**4**	**5**	**6**	**7**	**8**	**Mean**
Money Maker	8.5a	10.5a	10.5a	15.5a	16.0a	12.2a[×]
Riogrande	1.5cd	5.5b	7.5b	15.5a	15.5a	9.1b
Roma VFN	5.0b	5.5b	6.5bc	12.5b	13.0b	8.5b
Anna F1	2.5c	5.5b	5.5c	8.5c	10.0c	6.4c
Cal J	1.5cd	1.5d	3.5d	5.5d	5.5d	3.5d
Eden F1	0.5d	3.5c	3.5d	3.5e	3.5d	2.9d
Onyx	0.5d	1.5d	1.5e	5.5d	5.5d	2.9d
Wild type	0.5d	0.5d	1.5e	5.0d	5.5d	2.6d
Mean weeks	2.56y[*]	4.20x	5.00x	8.90u	9.32u	6.01
SE	0.57					
CV (%)	19.09					

× Means in the same column followed by the same letter (a, b, c, d, e,) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

* Means in the same row followed by the same letter (u, x, y) are not significantly different using Tukey HSD test, $\alpha = 0.05$

Another reason for less leaf damage on the Wild type may be due to migration of the mite from the wild type to more preferred varieties due its repellency chemicals, similarly, Wesonga, *et al.* (2005), reported that, the wild *Lycopersicon* accessions (*L. hirsutum* and *L. peruvianum*) were found to be the most repellent to the spider mites.

There was no significant different ($P>0.05$) in leaf damage between Anna F1, Riogrande Roma, and Onyx in all the weeks. These four varieties in addition to Cal J and Eden F1 show moderate leaf damage (Table 4.2). Leaf damage was highly significantly correlated with mite population density ($r=+0.498$) ($P<0.05$) an indication that the higher the number of mites per leaf, the more damage caused. There was no significant different ($P>0.05$) on average leaf damage per week between week 4 and 5. This may be attributed to low mite population and therefore less leaf damage. The highest average leaf damage was recorded in week 8 which was significantly ($P>0.05$) higher than all the weeks (Table 4.2). This may be linked to mite population increasing significantly between weeks 4 to 7 (Table 4.1) thus leading to high average leaf damage.

In this experiment, the total average leaf damage was significantly ($P>0.05$) higher on Money Maker and significantly lower on Wild type than all the varieties tested. Higher leaf damage on Money Maker may be attributed to higher mite population feeding on the leaves. Roma VFN seems to be more tolerant to red spider mite (*T. evansi)* than Onyx since it had significantly ($P>0.05$) higher mite population density (Table 4.1) than Onyx and yet the same amount of leaf damage between two varieties was recorded. These results are similar to what was reported by Kamau *et al.*, 1985 who reported that Roma VFN had a higher tolerance to Tomato russet mite.

4.1.3 Webbing

Webbing by the Red spider mite began on the fifth week after artificial infestation. The results showed that webbing was significantly higher ($P<0.05$) on Money Maker which was not significantly different from Anna F1 and Roma VFN in week 5 after infestation (Table 4.3). In week 5 to 8 webbing on Money Maker was significantly ($P<0.05$) higher than Cal J, Eden F1 and Wild type. The percent webbing increased at different rate for each variety with the lowest recorded on Wild type and Eden F1. Low percent webbing in wild type can be attributed to the ability of the Wild type to repel the mites (Wesonga *et al.*, 2005).

Table 4.2: Effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions.

Variety	Weeks after infestation					
	4	5	6	7	8	Mean
Money Maker	3.0a	3.0a	4.0a	5.0a	5.0a	4.0a[×]
Anna F1	2.0b	2.0b	3.0b	3.0b	4.5b	2.9b
Riogrande	2.0b	2.0b	3.0b	3.0b	4.5b	2.9b
Roma V.F.N	2.0b	2.0b	3.0b	3.0b	4.5b	2.9b
Onyx	2.0b	2.0b	3.0b	3.0b	4.5b	2.9b
Cal J	2.0b	2.0b	2.3c	3.0b	4.3b	2.7b
Eden F1	2.0b	2.0b	2.3c	3.0b	4.3b	2.7b
Wild type	1.0c	1.0c	2.3c	2.0c	3.0c	1.8c
Mean weeks	2.00y[*]	2.00y	2.81x	3.13x	4.31u	2.85
SE	0.24					
CV %	16.95					

× Means in the same column followed by the same letter (a, b, c,) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

* Means in the same row followed by the same letter (u, x, y) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

This makes the mites not to form or form low percent webbing. Research work has shown that Wild types (tomato) are more repellent to mites than commercial tomato varieties (Wesonga *et al.,* 2005). The two varieties, Wild type and Eden F1 did not differ significantly ($P>0.05$) in all the weeks except in week 7 after artificial infestation (Table 4.3). There was significant difference ($P<0.05$) in webbing between weeks. The highest percent webbing was recorded in week eight among the tested plants. The mite population and leaf damage was significant positively correlated ($r=+0.548^*$ and $r=+0.705^*$) with percent webbing, respectively. This seems to suggest that the higher the mite population, the higher will be the resultant leaf damage associated with the same causing a higher percent webbing. Low percent webbing in the Wild type in this study may therefore be attributed to low mite population (Table 4.1).

4.1.4 Dead flowers and flower buds

The number of dead flower and flower buds both in protected and infested plants was significantly higher ($P<0.05$) on Wild type (Table 4.4). Higher number of dead flower and flower buds in the wild type both in protected and infested plants may be due to genetic characteristics of the plant. This may also be the reason for high number of dead flower and flower buds in Money Maker and Anna F1 in both protected and infested plants. However, the least (11.3) percent reduction in the number of dead flower and flower buds due to Red spider mite infestation was recorded on the Wild type. Low percent reduction may be attributed to low mite population and low leaf damage (Table 4.1 and 4.2 respectively). Moderate number of dead flowers and flower buds was recorded on Anna F1 and Money Maker in both protected and infested plants.

These two varieties were significantly higher ($P<0.05$) than the rest of the tested varieties except Wild type. The highest (50.8) percent reduction due to mite damage was recorded on these two varieties. The lowest number of dead flower and flower buds was recorded on Onyx in both protected and infested plants. This variety was not significantly different ($P<0.05$) from Eden F1, Roma VFN, Riogrande and Cal J. However moderate (42.1) percent reduction due to mite was recorded on this variety (Table 4.4).

Table 4.3: Effect of *T. evansi* on average percent webbing on tomato varieties grown under green house conditions.

Variety	Weeks after infestation				
	5	6	7	8	Mean
Money Maker	60.0	70.0	80.0	100.0	77.5a[×]
Anna F1	50.0	60.0	90.0	100.0	75.0a
Riogrande	30.0	55.0	90.0	100.0	68.8a
Roma V.F.N	45.0	50.0	70.0	90.0	63.5a
Onyx	30.0	50.0	60.0	100.0	60.0a
Cal J	5.0	20.0	60.0	65.0	37.5b
Eden F1	20.0	30.0	40.0	40.0	32.5b
Wild type	5.0	15.0	20.0	30.0	17.5b
Mean weeks	30.63z[*]	43.75y	63.75x	78.13u	54.06
SE	5.07				
CV %	18.76				

× Means in the same column followed by the same letter (a, b, c, d, and e) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

* Means in the same row followed by the same letter (u, x, y .z) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

Average number of dead flower and flower buds increased significantly ($P< 0.05$) from 5th week to 8th week. This may be because the mite population density increased significantly from week 4 to week 7 (Table 4.1).The highest average number of dead flower and flower bud was recorded in week 8 which was significantly higher ($P< 0.05$) than all the weeks (Table 4.3). Leaf damage, percent webbing and mite population were significantly positively correlated (r=+0.230*, r = +0.270* and r=+0.221* respectively) with dead flowers. This implies that high mite population may cause high number of dead flower and flower buds leading to yield loss because the flowers that could have been transformed to yield are lost due to mite infestation.

4.1.5 Yield

The lowest yield in both infested and protected was recorded in Wild type. This may be due to the genetic potential of the Wild type. However in the infested plants, the amount of yield recorded on Wild type was not significantly lower than Money Maker and indication that Money Maker yield may have been adversely reduced by mite infestation. This is further supported by highest yield loss that was recorded on the same variety (Table 4.5). The results show that in the protected plants thereO was no significant ($P>0.05$) difference between Money Maker and Eden F1. However, in the infested plants the yields recorded on Money Maker was significantly ($P<0.05$) lower than Eden F1.

This further shows that Money Maker is more susceptible to mite attack compared to Eden F1. In the infested plants Money Maker was not significantly ($P>0.05$) lower than Roma VFN and Riogrande. However, in the protected plants, the yield recorded on Money Maker was significantly higher than these varieties. This may be due to Money Maker being indeterminate while the two varieties are determinate. The highest yield in

the infested plants was recorded in Eden F1 which was not significantly higher than Anna F1. However, in the protected plants, the yield recorded in Anna F1 was significantly higher than Eden F1 and all the varieties. This may be attributed to Anna F1 being indeterminate variety and also a hybrid. This may be also be the reason as to why there was no significant (P>0.05) difference in yields between Anna F1, Onyx, and Cal J varieties in the infested plants. The yields in, Cal J and Onyx in the protected plants were significantly lower than Anna F1 although they were not significantly different from each other. Yield was significantly (P>0.05) negatively correlated with dead flowers and flower buds and mite population density (r =-0.54329*) and (r = -0.2907*) respectively. Leaf damage was also negatively correlated with yield (r = -0.476*). In the present study, a tomato variety with high mite infestation seems to record low yield. For instance Money Maker had significantly (P<0.05) higher total average mite population density than other test plants and recorded the highest % yield loss due to mite infestation. Similar results were reported by Knapp *et al.*, (2003). The low yield may be due to high mite population density which cause more leaf damage and hence reduce photosynthesis in the leaves by reducing both stomatal and mesophyll conductance (Welter, 1989., Victor and Lewis, 1997).

Table 4.4: Effect of Red spider mites (*T. evansi)* infestation on flower buds and flowers of tomato varieties grown under green house conditions.

	Average number of dead flowers and flower buds		
Variety	**Protected**	**Infested**	**% Reduction**
Anna F1	30.0b[×]	45.3b	50.8
Money Maker	31.3b	46.8b	49.6
Eden F1	16.0c	23.5c	46.9
Roma V.F.N	18.0c	26.3c	45.8
Riogrande	16.5c	23.8c	43.9
Cal J	16.5c	23.5c	42.4
Onyx	14.3c	20.3c	42.1
Wild	50.8a	56.5a	11.3
Mean weeks	24.18x[*]	33.25u	
SE	2.64	1.93	
CV %	26.23	11.65	

× Means in the same column followed by the same letter (a, b, c, d, and e) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

* Means in the same row followed by the same letter (u, x, y .z) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

Table 4.5: Effect of *T. evansi* infestation on yield of tomato varieties grown under green house conditions.

Variety	Average yield in grams / plant		
	Infested	Protected	% Yield loss
Money Maker	292.0ef[x]	1221.8b[x]	76.1
Anna F1	593.2ab	1842.4a	67.8
Roma V.F.N	419.9cde	981.0cd	57.2
Riogrande	353.0ed	1072.9c	67.1
Eden F1	719.5a	1284.9b	44.0
Onyx	449.6bcd	893.8d	49.7
Cal J	515.2bc	900.7cd	42.8
Wild	182.0 f	224.7e	19.0
Mean weeks	440.55u[*]	1052.78x	
SE	48.35	51.49	
CV %	21.94	9.78	

× Means in the same column followed by the same letter (a, b, c, d, e and f) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

* Means in the same row followed by the same letter (u, x,) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

4.2. Experiment 2: Effect of tomato variety on development time from egg to adult, fecundity and longevity of Red spider mite (*T. evansi*) under laboratory conditions.

4.2.1. Development time from egg to adult of *T. evansi*

There was no significant difference (P>0.05) on incubation period, and duration of larval stage in all the varieties (Table 4.6.1). Since the mites were not feeding on the host plant and therefore there was possibly neither morphological nor chemical effect on the mite development at this stage. However, there was significant difference (P<0.05) on duration of protonymph, and deutonymph stages and as well as adult survival among tomato varieties (Table 4.6.1 and Table 4.6.2). The significance difference in the duration of time taken on these stages (protonymph, duetonymph and adult) may be because at these life stages the mite had started feeding on the host plant. The difference in duration may therefore be attributed to the different morphological traits such as trichomes and surface waxes as well as secondary plant metabolites on different tomato varieties (Anathakrishnan, 2001). The mortality rate of protonymph, deutonymph and adult stages was highest in Wild type with 44.4%, 70.0% and 66.7% respectively and lowest in Money Maker with 15.0%, 23.5% and 23.1%, respectively. The difference in mortality rate in the present study may be due to difference in host plant characteristic.This is similar to what was reported by Chatzivasileiadis and Sabelis (1997; 1998), Chatzivasileiadis *et al.*, (1997), Maluf *et al.*, 2001; Cedola and Sanchez (2003), where compounds from tomato trichome were reported to produce exudates such as methyl ketons and zingiberene that were reported to be toxic to spider mites. High densities of glandular type IV trichomes on *L. hirsutum*, and non-glandular type V trichomes on *L. esculentum* were also found by Simmons and Gurr (2005). Glandular trichome types I, IV, VI and VII are known to release secretions on touch that are sticky and toxic (Van haren *et al.*, 1987, Nihoul, 1993, Kennedy, 2003, Simmons and Gurr, 2005). The secretions immobilize mites or kill them.

The total development period (egg to adult) ranged between 8.9 to 11.0 days Table 4.6.1 and 4.6.2). These results seem to agree with work done by Silva (1954) which reported that the development from egg to adult on tomato leaves ranged from 6.5 to 11.5 days. Meyer (1996) also reported that the life cycle is 9 to 12 days resulting to 24-30 generations in a year. The difference in time taken for eggs to hatch and larva that completed the cycle

indicated that development and population increase of *T. evansi* depends on host type. In this case Money Maker is a more suitable host compared to Wild type and other commercial varieties tested because 50% of the larvae reached the adult stage. Similar results were also reported by Isutsa *et al.*, (2006) where it was reported that 58 % of the larvae on Money Maker reached adult stage. Host plants can exert profound effects on the biology of spider mites including *T. evansi* (Jeppson *et al.*, 1975). In this study the average ratio of male to female was 1:2.6. This is less compared to what was reported by Qureshi *et al* (1969) that the ratio of male to female was about 1:10. These difference may be due to difference in test plant varieties used and also different laboratory conditions i.e. temperature and relative humidity. However, the results seems to be almost similar to work done by Moutia (1958) who reported that the sex ratio on tomato plants in the field was 1:3.3. The short life cycle and high ratio of female to male indicate that on suitable host and favorable climatic conditions *T. evansi* can reproduce rapidly and cause severe crop losses. In the present study, highest mortality was recorded on Wild type while lowest mortality was recorded on variety Money Maker. Similar results were also reported by Snyder and Carter (1984; 1985) where it was reported that mite survival was lower in *L. hirsutum* var. *hirsutum* that possessed fewer type VI trichomes than *L. esculentum,* and concluded that trichome type VI could be responsible for the high levels of resistance in this species.

4.2.2. Fecundity and longevity of *T. evansi*

The average number of eggs laid per female mite was significantly (P>0.05) higher on Money Maker which was not significantly different from Riogrande (Table 4.7). The least number of eggs was recorded on Wild variety which was significantly (P>0.05) different from all the varieties. These results agree with the research work reported by Isutsa *et al.*, (2006) where the highest total number of eggs laid by an individual female mite was observed on Money Maker. From the results, Money Maker seems to be a preferred host plant for egg laying as compared to wild type. Similar results were also reported by Murungi *et al.,* (2009) where preference to Money Maker was attributed to trichome density and plant emitted volatiles. This may be attributed to the different morphological traits such as trichomes and surface waxes as well as secondary plant metabolites (Anathakrishnan, 2001). The Wild type may also be releasing some chemicals that repel the mite away and therefore not laying eggs on them. These reports agree with the work done by by Wesonga, *et al.* (2005) who reported that, the wild *Lycopersicon* accessions (*L. hirsutum* and *L. peruvianum*) were found to be the most repellent to the spider mites.

Table 4.6.1 Effect of tomato varieties on duration (days) of incubation, larvae and protonymph stages of Red spider mite (*T. evansi)*

		Incubation period	Larvae		Protonymph	
Variety	**No. of Eggs**	**Duration (mean no of days)**	**Total no**	**Duration (Mean no of days)**	**Total no**	**Duration (Mean no of days)**
Cal J	20	4.1a	18	2.8a	13	1.7ab
Onyx	20	4.1a	19	2.7a	14	1.7ab
Roma VFN	20	4.2a	18	2.8a	13	2.0ab
Riogrande	20	4.1a	20	2.8a	16	2.0ab
Money Maker	20	4.1a	20	2.8a	17	2.3a
Eden F1	20	4.3a	20	2.8a	16	2.1ab
Anna F1	20	4.2a	20	2.7a	14	1.7ab
Wild type	20	4.3a	18	2.6a	10	1.0b
Mean		4.18		2.76		1.83
SE		0.30		0.14		0.15
CV %		22.4		16.37		25.0

Means in the same column followed by the same letter are not significantly different using Tukey HSD test, $\alpha = 0.05$.

Table 4.6.2: **Effect of tomato varieties on duration (days) of deutonymph stage, a dult stage, sex and mortality of Red spider mite (*T. evansi*).**

	Deutonymph		Adult				
Variety	**Total no**	**Duration) (Mean no of days**	**Total no**	**Total duration (Egg to Adult)**	**Sex Male**	**Sex Female**	**Mortality (%) (Egg to Adult)**
Cal J	7	1.3ab*	5	9.9a	1	4	75
Onyx	7	1.8a	4	10.3a	2	2	80
Roma VFN	5	1.3ab	3	10.3a	-	3	85
Riogrande	12	1.5ab	9	10.4a	2	7	55
Money Maker	13	1.8a	10	11.0a	3	7	50
Eden F1	9	1.3ab	5	10.5a	2	3	75
Anna F1	9	1.3ab	6	9.9a	2	4	70
Wild type		1.0b	1	8.9b	-	1	95
Mean		1.41		10.17			
SE		0.14					
CV %		31.33					

*Means in the same column followed by the same letter are not significantly different using Tukey HSD test, $\alpha = 0.05$.

Table 4.7: Effect of tomato varieties on fecundity and longevity of *T. evansi*

Variety	Fecundity (Mean no. of eggs laid /female)	Average Longevity days
Cal J	32.0b*	7.5b
Onyx	23.0c	7.2b
Roma	23.9c	6.7b
Riogrande	48.6a	8.2b
Money Maker	52.4a	12.8a
Eden F1	31.3b	7.6b
Anna	33.2b	7.4b
Wild type	9.1d	4.8c
Mean	31.94	7.78
SE	1.48	0.34
CV %	19.03	13.8

*Means in the same column followed by the same letter are not significantly different using Tukey HSD test, $\alpha = 0.05$.

4.3. Experiment 3: Evaluation of pesticides against Red spider mite (*T. evansi)*

4.3.1. Effect of acaricides on *Tetranychus evansi* population

The plants were sprayed twice with the first spray done immediately after pre-treatment sampling and second spray done immediately after week two sampling. After the first spray, there was a decline in population density of *T. evansi* in week 1 and 2. After the 2nd chemical treatment, there was further decline in population density of *T. evansi* in week 3 (Table 4.8). However, two weeks after the second chemical treatment, there was increase in mite population. The mite population increased in all the treatments with week 6 recording the highest mite population density (Table 4.8). The decline in mite population after the 1st and 2nd spray may be due to miticidal effect. Increase in population in the subsequent weeks after the second spray may be because the chemical residual effect had been reduced and therefore allowing mite populations build up.

Total average mean number of mites per leaf disc recorded on Chilli extract was significantly ($P<0.05$) less than in the control plants. The results suggest that crude extracts from pepper fruits can be explored for developing natural products for use as biodegradable alternatives to synthetic acaricides. Red spider mite number decreased after extracts application and remained relatively low in the treated plots as compared to the untreated (control) plot. The non significant results were attributed to low concentration of capsaicin and capsaicinoids in the solution due to their low solubility in water. Capsaicin and capsaicinoids are slightly soluble in water but soluble in oils and alcoholics (George *et al.*, 2006). Another attribute could be low potency of the extracts on the leaves of tomato because no surfactant was used. In addition, the rates used could have been low. The highest total average mite population counts was recorded on control plots which was not significantly ($P>0.05$) different from Neem treated plants. However, the mite population in Neem treated plants was not significantly different ($P>0.05$) from the mite population in Chilli treated plants (Table 4.8). Vapcothion treated plants recorded significantly ($P<0.05$) lower number of mite counts compared to the other treatments. This may be because Vapcothion has Dicofol which has a high residual effect and Tetradifon which is non – systemic ovicide acaricide against eggs and initial stages by contact. These results are similar to the work reported by Yigit and Erkilic, (2003). They observed that a combination of Dicofol plus Tetradifon controlled mites effectively than Dicofol alone. This was

followed by Mitigan treated plants which was not significantly different (P>0.05) from Dictator plus treated plants. Mitigan has been reported to be more persistent than propargite (Pree *et al.*, 1992). According to Pree *et al.*, (1992), the mortality on Dicofol treated foliage was >50% for more than 15 days where as the mortality in propargite was also >50% but the effect only lasted for 10 days after application.

Generally, synthetic acaricides were more effective in controlling *T. evansi* than the biopesticides (Neem and Chili). These results are similar to what was reported by Grace *et al,* 2005 where it was noted that synthetic acaricide (Omite) was more effective in controlling *T. evansi* than biopesticides (Neem). However, although not effective as the synthetic acaricide, the biopesticides can be included in the pest management programmes for mites in tomato crops.

4.3.2. Effect of acaricide treatment against *T. evansi* on leaf damage of tomatoes

Leaf damage score was only recorded on week 8 since from week 1 to week 7 there was no significant (P>0.05) difference between chemical treatments. In this experiment, the highest total average leaf damage was recorded on the control treatment which was not significantly (P>0.05) different from Chilli extract and Neem treated plants. However, this was significantly (P <0.05) higher than Mitigan, Dictator plus, Ortus and Vapcothion treated plants (Table 4.9). These results showed that synthetic acaricides were more effective than biopesticides. Similar findings were also reported by Grace *et al., (2005)* who reported that synthetic acaricide (Omite) was more effective in controlling *T. evansi* than biopesticides (Neem). The lowest total average leaf damage was recorded on Vapcothion and Mitigan treated plants. However this was not significantly (P>0.05) different from Dictator plus and Ortus treated plants. The damage caused by *T. evansi* on tomato leaves showed a significant positive correlation with mite population counts (r = +0.3367*) an indication that the higher the number of mite population, the more the damage is caused on the plant leaf. This means that control strategy should be aimed at preventing mite population build up to reduce leaf damage and eventual crop loss.

4.3.3. Effect of acaricide treatment against *T. evansi* on average percent webbing

The lowest average percent webbing was recorded on Vapcothion treated plants which was not significantly (P>0.05) different from Mitigan, Dictator plus and Ortus (Table 4.10).

Table 4.8: Effect of acaricides on *T. evansi* population under green house conditions

			Weeks after first spray application and average no. of mites/3 leaf disc (10mm diameter)							
Chemical	**Active ingredient**	**Rate (l/ha)**	**Pre-treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**Mean**
Mitigan	Dicofol 185g/l	1.0	10.5a[×]	3.3a	3.0a	0.3a	3.3a	11.3bc	15.3d	6.7d
Dictator plus	Tetradifon 21.2%, Propergite 7.5%	1.0	10.0a	5.0a	2.3a	2.3a	2.3a	12.3bc	18.0cd	7.4cd
Neem	Azadirachtin 0.03%	1.0	9.0a	7.0a	5.5a	4.3a	6.5a	23.5a	36.5a	13.2ab
Ortus	Fenpyroximate 50g/l	1.0	9.0a	4.8a	3.3a	2.8a	4.0a	14.8b	24.3bc	8.7c
Chili		4kg	8.8a	6.5a	5.8a	3.3a	5.8a	24.0a	29.5b	11.9b
Vapcothion	Dicofol 8%, Tetradifon 25%	1.0	8.25a	2.5a	1.8a	0.3a	1.8a	7.5c	11.3d	4.8e
Control (Untreated)			9.3a	6.8a	6.5a	5.5a	6.5a	25.5a	38.5a	14.1a
Mean weeks			9.0x[*]	5.13y	4.03yz	2.69z	4.31yz	16.99w	24.77u	9.56
SE			1.61							
CV (%)			33.7							

× Means in the same column followed by the same letter (a, b, c, d, e) are not significantly different using Tukey HSD test, $\alpha = 0.05$.
* Means in the same row followed by the same letter (u, w, x; y .z) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

Table 4.9: Effect of acaricide treatment against *T. evansi* on leaf damage of tomatoes rated on scale 1-5

Chemical	Active ingredient	Rate (l/ha)	Pre-treatment	Eight weeks after First spray application
Mitigan	Dicofol 185g/l	1.0	2.8a[×]	1.3b
Dictator	Tetradifon 21.2%, Propergite 7.5%	1.0	2.5a	1.5b
Neem	Azadirachtin 0.03%	1.0	2.8a	3.5a
Ortus	Fenpyroximate 50g/l	1.0	3.0a	2.0b
Chili		4kg	3.0a	4.0a
Vapcothion	Dicofol 8%, Tetradifon 25%	1	2.5a	1.3b
Control (untreated)			2.8a	4.3a
Mean			2.77u*	2.56u
SE			0.22	0.44
CV (%)			17.49	32.39

× Means in the same column followed by the same letter (a, b) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

* Means in the same row followed by the same letter (u) are not significantly different using Tukey HSD test, $\alpha = 0.05$..

Low percent webbing on Vapcothion treated plants may be due to low mite population build up on Vapcothion treated plants (Table 4.8). Generally, from the results of this study, synthetic acaricide treated plants seems to have relatively low percent webbing than biopesticide treated plants. These results may be relate to a study done by Grace *et al.*, (2005) where it was noted that synthetic acaricide (Omite) was more effective in controlling *T. evansi* than biopesticides (Neem). However, in the present study, the rate of webbing was significantly ($P<0.05$) lower for Vapcothion treated plants during the 6^{th} 7^{th} and 8^{th} weeks after spray application. The highest average percent webbing was recorded in the control (untreated plants) which was not significantly ($P>0.05$) different from Chilli extract and Neem treated plants.

Average percent webbing was significantly positively correlated with mites population counts and leaf damage due to mite feeding ($r=+0.6144$ and $r= +0.5734$) respectively. Average percent webbing was significantly different for each week except between week 7 and 8 (Table 4.10). This may be because the mite population increased gradually from week 5 to week 6 and in week 7 and 8 the plants had started drying up and thus there was limited food for the mites and this may have caused mite population to remain the same.

4.3.4. Effect of acaricide treatment against *T. evansi* on damage of flowers buds and flowers

Significantly higher ($P<0.05$) number of dead flowers and flower buds were recorded in the control plants than the rest of the treatments in week 8 (Table 4.11). In week 7, Vapcothion recorded significantly lower ($P<0.05$) number of dead flowers and flower buds than all the treatments while Neem treated plants and control plants recorded significantly higher ($P<0.05$) number of dead flowers and flower buds than the rest of the treatments. Total average number of dead flowers and flower buds was recorded on Vapcothion treated plants (9.4) which was significantly lower ($P<0.05$) than the rest of the treatments while Neem recorded significantly higher ($P<0.05$) total average number of dead flowers and flower buds than all the treatments. There was significant ($P<0.05$) positive correlation ($r=+0.54767*$) between mite population and dead flowers and flower buds. The number of dead flowers and flower buds increased significantly ($P<0.05$) every week from 5^{th} to 8^{th} week (Table 4.11). This may be due mite population build up with time and possibly migrated to flowers because of better nutrition. In week 8, there was no significance

different (P>0.05) between Chilli, Dictator, Mitigan, Ortus and Neem treated plants. This implies that Chilli extracts has some acaricidal effects against Red spider mite *T. evansi*. This is in conformity with the findings of Greenville-Reynolds Industry (1995) in Pennsylvania, manufacturers of "Hot Pepper Wax". This product has proved effective against pests including white flies, spider mites, cabbage loopers, lace bugs and some other soft-bodied insects (Greenville-Reynolds, 1995). George *et al.,* (2006), while working on toxity and repellency of hot pepper extracts to spider mite *Tetranychus urticae* Koch, reported that concentrated extracts of hot pepper increased repellency and the crude extracts from accessions Grif-9169 was found to cause 45 % mortality to spider mite.Using repellent chemicals for crop protection is a unique way to prevent insects and spider mites from laying eggs on target plants and prevent plant leaf and fruit damage (George *et al* 2006)

4.3.5. Effect of acaricide treatment against *T. evansi* on the yield of tomatoes

Significant differences (P<0.05) were observed between the treatments (Table 4.12). Significantly, lowest (P<0.05) yield was recorded on control plants while higher yield was recorded on Vapcothion treated plants which had significantly higher (P<0.05) yields than Neem and Chilli extract treated plants. There was no significant (P>0.05) difference between plants treated with Mitigan, Dictator plus, Neem, Ortus and Chilli extract. There was significant (P>0.05) negative correlation between yield and leaf damage due to mite attack and number of dead flowers and flower buds (r =-0.486 and r = -0.313 respectively). The highest yield was recorded on Vapcothion treated plants. This may be because Vapcothion has Dicofol which has a high residual effect and Tetradifon which is non – systemic ovicide accaricide against eggs and initial stages by contact. This also may be the reason behind low mite population and low leaf damage that was observed on Vapcothion treated plants (Table 4.8 and 4.9). It can therefore be argued that high yield on Vapcothion treated plants were due to less mite damage. These results are similar to what was reported by Yigit and L. Erkilic (2003). They observed that a combination of Dicofol plus Tetradifon controlled mites effectively than Dicofol alone. In the present study, Neem and Chilli extract treated plants gave significantly (P<0.05) higher yield than control (untreated). This implies that biopesticides although not effective as the synthetic acaricide, can be included in the integrated pest management programmes

Table 4.10: Effect of acaricide treatment against *T. evansi* on average percent webbing.

			Weeks after first spray application				
Chemical	**Active ingredient**	**Rate (L/ha)**	**5**	**6**	**7**	**8**	**Mean**
Mitigan	Dicofol 185g/l	1.0	30.0b[×]	30.0b	75.0a	75.0a	52.5b
Dictator plus	Tetradifon 21.2%, Propergite 7.5%	1.0	30.0b	60.0a	60.0a	60.0a	52.5b
Neem	Azadirachtin 0.03%	1.0	30.0b	75.0a	100.0a	100.0a	76.3a
Ortus	Fenpyroximate 50g/l	1.0	30.0b	30.0b	75.0a	75.0a	52.5b
Chili		4kg	75.0a	75.0a	90.0a	90.0a	82.5a
Vapcothion	Dicofol 8%, Tetradifon 25%	1.0	30.0b	30.0b	45.0b	45.0b	37.5b
Control (untreated)			75.0a	90.0a	90.0a	90.0a	86.3a
Mean weeks			42.86y[*]	55.71x	76.43u	76.43u	62.86
SE			7.39				
CV (%)			24.84				

× Means in the same column followed by the same letter (a, b) are not significantly different using Tukey HSD test, $\alpha = 0.05$.
* Means in the same row followed by the same letter (u, x, y) are not significantly different using Tukey HSD test, $\alpha = 0.05$.

Table 4.11: Effect of acaricide treatment against *T. evansi* on damage of flowers buds and flowers /plant

			Weeks after first spray application/ dead flowers and flower buds				
Chemical	**Active ingredient**	**Rate (l/ha)**	**5**	**6**	**7**	**8**	**Mean**
Mitigan	Dicofol 185g/l	1.0	9.0ab×	9.0b	12.0cde	23.0bc	15.2d
Dictator plus	Tetradifon 21.2%, Propergite 7.5%	1.0	5.0bcd	11.0b	17.0bc	20.0c	14.6d
Neem	Azadirachtin 0.03%	1.0	13.0a	14.5ab	22.0a	26.0b	20.3b
Ortus	Fenpyroximate 50g/l	1.0	1.0d	15.0ab	16.0cd	23.0bc	15.6d
Chili		4kg	7.0bc	16.0a	16.0cd	23.0bc	17.0c
Vapcothion	Dicofol 8%, Tetradifon 25%	1.0	3.0cd	9.0b	9.0e	13.0d	9.4e
Control (untreated)			9.0ab	9.0b	21.0ab	45.0a	25.8a
Mean weeks			6.71z*	11.93y	16.14x	24.71u	14.88
SE			1.10				
CV (%)			13.04				

× Means in the same column followed by the same letter (a, b, c, d, e) are not significantly different using Tukey Studentized Range Test ($\alpha = 0.05$).

* Means in the same row followed by the same letter (u, x, y, z) are not significantly different using Tukey Studentized Range Test ($\alpha = 0.05$).

Table 4.12: Effect of acaricide treatment against Red spider mite (*T. evansi*) on the yield of tomatoes

Chemical	Active ingredient	Rate (l/ha)	Yield in grams
Mitigan	Dicofol 185g/l	1.0	306.45ab*
Dictator	Tetradifon 21.2%, Propergite 7.5%	1.0	305.08ab
Neem	Azadirachtin 0.03%	1.0	240.17b
Ortus	Fenpyroximate 50g/l	1.0	298.61ab
Chilli		4kg	239.82b
Vapcothion	Dicofol 8%, Tetradifon 25%	1.0	369.05a
Control (untreated)			156.87c
Mean			273.72
SE			25.06
CV (%)			18.31

* Means in the same column followed by the same letter (a, b, c) are not significantly different using Tukey Studentized Range Test ($\alpha = 0.05$).

4.4. Survey on distribution and damage of tomatoes by Red spider mite in Subukia and Rongai divisions, Kenya

4.4.1 Tomato varieties grown

Majority of the open field tomato farmers (93.3%) grew the tomato variety Riogrande (Figure 4.1). This was followed by Onyx (56.7%), Cal J at 36.7%. Only 3.3% of the farmers grew other varieties (Figure 4.1). These results are different from what was reported by Waiganjo *et al.,* (2006) where majority of the farmers in Kirinyaga were reported to grow Onyx (81%) and Riogande (42%). The difference in the results may be attributed to difference in farmers' preference and targeted market in these tomato growing regions. Majority of green house tomato famers grow Anna F1 (96.7%) with only 6.7% growing other varieties namely Nomenetta and Money Maker in the green house. Among other reasons, Nomenetta was perceived to weigh more per unit tomato fruit compared to Anna F1. Farmers who grew Money Maker preferred it because the seeds are cheaper compared to Anna F1. However, although the seeds are expensive, farmers reported that Anna F1 yield more and have a long harvesting period compared to other tomato varieties.

4.4.2 Important pests of tomato as listed by farmers

Most of farmers (96.7%) perceived the Red spider mite (*T. evansi*) as the most important pets of tomato followed by African boll worm (*Helicorverpa armigera)* (71.7%) White flies (*Bemesia tabaci*) (68.3%), Thrips (*Megalurothrips sjostedti*) (46.7%), Aphids (18.3%), and Leaf miner (*Liriomyza trifoli*) (11.7%) (Figure 4.2). The results are similar to a survey report of tomato farmers in Kirinyaga district by Waiganjo *et al* 2006 where 91.7% of the respondents perceived Red spider mite as an important pest of tomato. In the present study, 68.3% and 46.7% perceived White flies and Thrips respectively as important pests of tomato. In Eastern and Central Africa regional priotization of tomato pests, Red spider mite was considered the most dangerous pest of tomato (Varela *et al.*, 2003). However, Waiganjo *et al* 2006 reported that 58.7% and 68.6% of famers in Kirinyaga felt that Whiteflies and Thrips respectively were important pests of tomato.

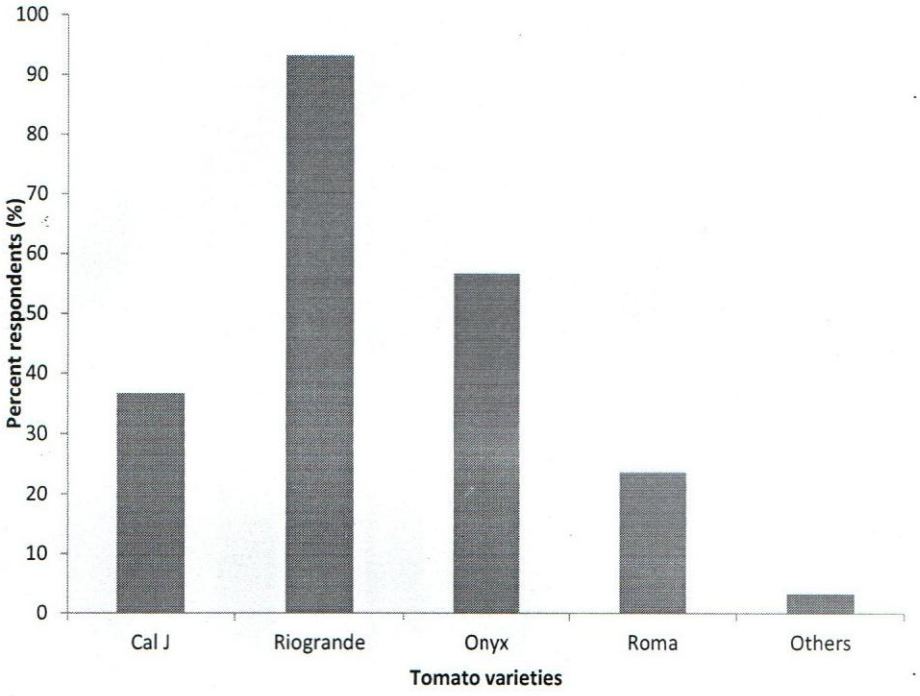


Figure 4.1: Tomato varieties grown by open field tomato farmers in Subukia and Rongai divisions, Kenya

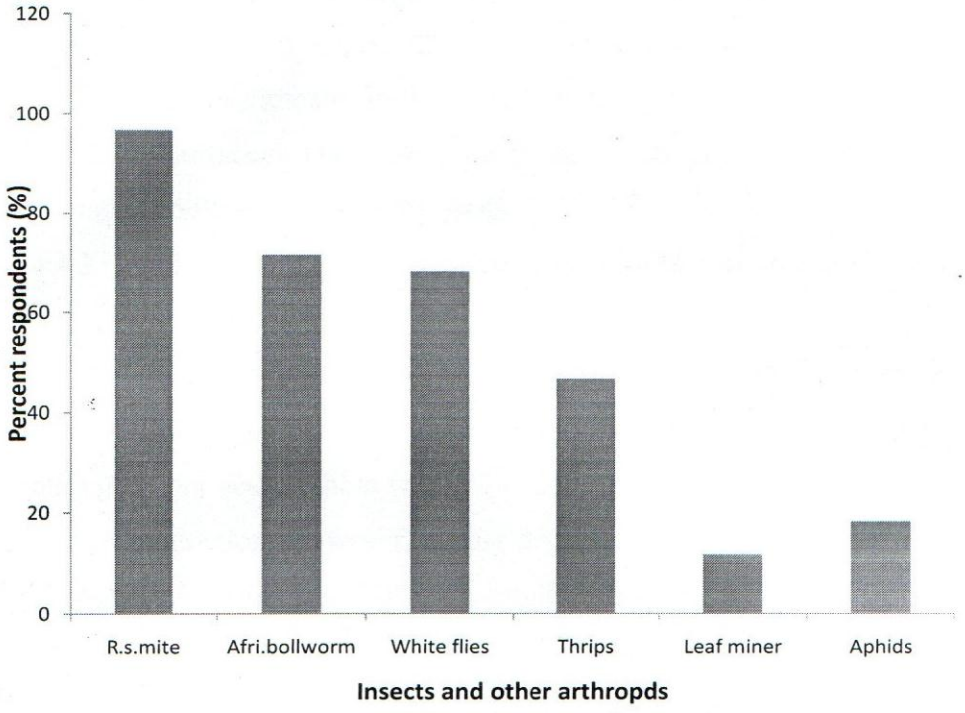


Figure: 4.2: Important insect pests and other arthropods as perceived by tomato farmers in Subukia and Rongai divisions, Kenya

In the present study, although 71.7% of the respondents perceived African bollworm as an important pest of tomato, a report of tomato production in Mvomero district in Tanzania by Amon *et al.,* (2006) reported that African bollworm was the most important pest of tomato. In the same report, Whiteflies and Thrips were reported to be of less importance. The difference in the results may be attributed to difference in climatic conditions of the study areas.

4.4.3 Effect of tomato growing season on Red spider mite infestation and crop loss

The open field tomato farmers indicated that majority (70%) grew tomato in the dry season (December to March) (Table 4.13). This was because farmers believed that during the dry season there was low incidence of fungal diseases and this lowered there cost of production. However, during dry season, Red spider mite infestation was high (75-99% infestation), and if not controlled, the farmers reported that this may lead to serious crop damage (> 50 % crop loss). During the short rains, 53.3% of the farmers grew tomatoes. Farmers indicated that this was because of availability of land after the main crop has been harvested and also relatively low incidence of fungal diseases. However, during the short rains, there was moderate Red spider mite infestation (50-74%) which if not controlled would lead to crop loss of between 25 - 50%. During the long rains, farmers perceived they experienced low incidence of Red spider mite infestation (23.3%) but only 16.7 % grow tomato in the open field.

4.4.4 Pesticides used by farmers in Subukia and Rongai divisions for the control of Red spider mite

All the tomato farmers interviewed used pesticides for their tomato production. The highest pesticide used for the control of Red spider mite was Polythrin (85%) and Vapcothion (81.7%) (Table 4.14). Surprisingly; some farmers used insecticides for the control of Red spider mites. This may be because of lack of knowledge about the pest and therefore there is a need for farmers' general capacity building on the pest and its control.

Table 4.13: Effect of tomato growing season on Red spider mite infestation and crop loss

Growing season	Percent respondents	Percent Red spider mite infestation	Percent crop Damage due to red spider mite infestation
Long rains (March-August)	16.7	**	**
Short rains September-December	53.3	***	***
Dry season	70	****	****

KEY

Red spider mite infestation	Crop damage	Symbol
Very low (0-24%)	No damage	*
Low (25-49%)	Non important damage (< 25%)	**
Moderate (50-74%)	Important damage (25-50%)	***
High (75-99%)	Serious damage (>50%)	****

Table 4.14: Pesticide used by farmers in Subukia and Rongai divsions for the Control of Red spider mite

Chemical Trade Name	Active ingredient	Percent farmers using
Polytrine	Profenofos + Cypermethrin	85
Vapcothion	Tetradifon + Dicofol	81.7
Dictator plus	Tetradifon + Propergite	71.7
Mitigan	Dicofol	45
Dynamec	Abamectin	38.3
Ortus	Fenpyroximate	13.3
Alfix	Alphacypermethrin	6.7
Dimethoate	Dimethoate	5
Karate	Lambdacyhalothrin	3.3
Actara	Thiamethoxam	1.7

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

The effect of Red spider mite *T. evansi* on evaluated tomato varieties showed significant ($P<0.05$) difference in terms of susceptibility. Tomato variety, Money Maker was highly susceptible and Wild tomato was most resistant. In the present study, only eight tomato varieties were evaluated and there is therefore need to evaluate more tomato varieties to identify high yielding and less susceptible varieties that can be recommended to farmers. Varietal resistance could become an integral part of an Integrated Pest Management (IPM) programme.

The development, fecundity, adult longevity and survival of *T. evansi* varied with varieties. It was evident that antibiotic effect existed especially in Wild tomato variety. Tomato variety Anna F1 had higher yields in spite of high mite population and damages an indication of tolerance to mite damage. The present study did not study the mechanisms of resistance and there is a need to comprehensively study the mechanisms and sources of resistance.

Evaluation of pesticides against Red spider mite *T. evansi* indicated that Vapcothion (Dicofol 8%, Tetradifon 25%) is more effective. However, continuous use of one type of chemical should be avoided since the mites develop resistance against prolonged use of one chemical very fast. There is also need to establish spray interval and optimum number of chemical sprays against Red spider mite per cropping season. In the present study only six pesticides were evaluated there is therefore need for other pesticides e.g. Polytrine to be evaluated.

Total average mean number of mites per leaf disc recorded on Chilli extract was significantly ($P<0.05$) less than in the control plants. The results suggest that crude extracts from pepper fruits can be explored for developing natural products for use as biodegradable alternatives to synthetic acaricides. There is also need to further investigate the use of chilli extracts in terms of the dosage and frequency of application. The bio-pesticides are suitable since they are relatively safe and environmentally friendly. Other plant extracts like spider plants which has been used to control *T. urticae* in flowers need to be evaluated.

Field survey in Rongai and Subukia divisions; show that Red spider mite is a major pest of tomato. This implies that the pest may be a serious pest in all places in Kenya which are

climatically and topographically similar. Farmers use many acaricides to control Red spider mite. There is therefore need to recommend suitable ones and rates of application. In addition, there is need to address a holistic approach to important pests hence develop suitable Integrated Pest management IPM package for growing tomatoe.

REFERENCES

Amon, P. M., Kallunde, P. S., Kizito, K. M., Julita, B. and Magdalena, N. W. (2006). Baseline survey report of tomato production in Mvomero District –Morogoro region, Tanzania. Sokoine University of Agriculture, Tanzania.

Ananthakrishnan, T.N. (2001). Insects and plant defense dynamics. Science Publishers Inc., Enfield, NH, USA.

Avidov, Z. and Harpaz, I. (1969). Plant pests of Israel. Israel University Press, Jerusalem, pp 25-27.

Bitton, S. and Nakash, J. (1986). Control of Red spider mites by the Presacious Mite *Phytoseiulus persimilis* in an open field of eggplants and anti choke (globe). Hassalch 66 (4). 682 - 684.

Calkings, H.P. (1978). Improving small-scale tomato production in the tropics. Proceedings of the First International Symposium on tropical tomato, Oct 23-27, 1978. Asian Vegetable and Development Center Publication, pp 22-32.

Carlos Alvarez –Hernandez, Juan. (2009). Univ Michoacán a, Escuela Ciencias Agropecuarias, Mariano Jimenez S-N Michoacán 60660, Mexico.

Carriere, Y., Deland, J P., Roff, D.A and Vincent, C. (1994). Life History, Costs associated with the evaluation of insecticides resistance. Royal Society of London. Ps. 253, pp 35-45.

Cedola, V.C., and Sanchez, N.E. (2003). Effect of tomato pubescence on development, survival and fecundity of *Tetranychus urticae* Koch and *Neoseiulus californicus* (McGregor) (Acari: Tetranychedae, Phytoseiidae). Acarologia 3:255-260.

Chatzivasileiadis, E.A., and Sabelis, M.W. (1997). Toxicity of methyl ketons from tomato trichomes to *Tetranychus urticae* Koch. Experimental and Applied Acarology 21:473-484.

Chatzivasileiadis, E.A., and Sabelis, M.W. (1998). Variability in susceptibility among cucumber and tomato strains of *Tetranychus urticae* Koch to 2-tridecanone from tomato trichomes: Effects of host plant shift. Experimental and Applied Acarology 22:455-466.

Craemer, C., Dippenaar – Schoeman, A., Smith Meyer, L., Uyeckermann, E., Van Berg Van De A., Merule, M. (1998). Mite on Tomatoes. Collecting, Preserving, Identification and Control. A Manual for a practical course in acaroloogy held in Pretoria, South Africa, pp 28-29.

De Ponti, O. M. B. (1977). Resistance in *Cucumis sativus* L to *Tetranychus urticae* Koch: The Role of Plant Breeding in Integrated Control. Euphytica, 26:633-640.

Di Mascio, P., Kaiser, S. and Sie, H. (1989). Lycopen as the most efficient biological carotenoid singlere oxygen quencher. Arch. Biochem. Biohys. 274: 532-538.

Duverney, C., Kade, N., Ngueye-Ndiaye, A. (2005). Essais preliminaries pour limiter les degats de tetranychidae sur les cultures maraicheres dans le sine-saloum (Senegal).In: Comptes rendus de colloque international sur les acariens des cultures de l' AFPP. Agro. Montepeller, France, 24-25 October 2005.

El-Jaouani, N. (1988). Contributions a la connaisance des acriens phytophages au Maroc et etude bio-ecologique det *Tetranychus evansi* Baker et Pritchard (Acarina: Tetranychidae).Thesis Institute Agronomique et Vetrinaire Hassan II, Rabat.

Ennis, W. B. Jnr. (Ed). (1979). Introduction to crop protection. American Society of Agronomy and Crop Science. Science Society of American. Inc. Madison, Wisconsin.

FAO, (2003). State of Food and Agriculture. Food and Agriculture Organization. Rome, Italy.

George, F. A., Janet, E.M. and John, C. S. (2006). Toxity and Repellency of hot pepper extracts to spider mite, *Tetranychus urticae* Koch. Journal of Environmental Science and Health Part B, 41:1383-1391

Good, D. E. and Snyder, J.C. (1988). Seasonal variation of leaves and mite resistance of Lycopersion interspecific hybrids. Hort. Science. 23 (5): 891-894.

Gutierrez, J. and Etienne, J. (1986). Les tetranychidae de lile de la Re'union et quelques-uns de leurs predateurs. Agron Trop 41: 84-91.

Grace, G. K., Shibairo, S.I., Knapp, M., Nderitu, J.H., Njoroge, K. (2005). Evaluation of biopesticides in control of red spider mite (*T. evansi*) on tomatoes (*L. esculentum*).University of Nairobi, Kenya.

Green ville –Rynolds development co-operation (1995). Building NO. 7, 721 First Street, Rynolds industrial park. Green ville, PA.

Helle, W. and Sabelis, W. M. (1985). Spider mites, their biology, natural enemies and control, Vol. 1 B Elsevier, Amsterdam: 141-160.

Hill, D.S. (1987). Agricultural insect pests of tropical regions and their control. Cambridge University Press.

ICIPE.2003. Development of environmentally friendly management methods for

Red spider mites in small scale tomato production systems in Eastern and Southern Africa. Final Project Report (phase 1) pp 187.

Impe, G. and Van Hance, T. 1993. A technique for testing varietal susceptibility to the mite *Tetranychus urticae* (Acari: Tetranychidae). Agronomie: 13 (8) 739-749.

Isutsa, D. K., Wesonga, J. M., Onyango, M. O. A., Njoroge, J. B. M., Waiganjo, M. M., Agong, S. G., Fricke, A., Hau, B. and Stuetzel, H. 2006. Proceedings of the Fifth Workshop on Sustainable Horticultural Production in the Tropics, Egerton University, Njoro, Kenya.

Jennings, P. R. and Maxwell, F.G. (1980). Breeding plants resistance to insects. John Wiley and Sons.

Jepson, R.L., Keifer, H.H. and Baker, W.E. (1975). Mites injurious to economic plants. University of California press.

Kamau, A.W. (1985). The biology and control of tomato russet mite, Acolops Lycopersci (Massee) (Acarina: Eryophyidae) in Kenya, PhD Thesis, University of Nairobi.

Keizer, M. and Zuurbeir, J. (2001). Red spider mite. Namibian crop pests, Vol. 37.University of Florida press.

Kielkiewies, M. (1996). Dispersal of *Tetranychus cinnabarinas* on various tomato cultivars Entomologia Experintalis and Aaplicata 80 (1). 254-257.

Kaloo, G. (19880. Insect resistance in vegetables crops in: Vegetable Breeding, Vol. 2. CRC Press. Inc., Fla, USA, Pp 95-140.

KARI (1996) Annual report.

Kennedy, G.G. (2003). Tomato, pests parasitoids and predators: Titrophic interactions involving the genus *Lycopersicon.* Annual Review of Entomology 48:51-72

Knapp, M. and Kahenge, S. (2003). Effect of different neem formulations on the two-spotted mite. *Tetranychus urticae* Koch, on the tomato (*Lycopersicon esculentum* Mill). Insect Sci. Application. 23: pp 1-7

Knapp, M., Wagener, B. and Navajas, M. (2003). Molecular discrimination between spider mite *Tetranychus evansi* (Baker and Pritchard), an important pest to tomatoes in southern Africa and the closely related species *T. urticae* Koch.

Krainacker, D. A. and Carey, J. R. (1990). Adulatory dispersal and life history to food deprevation in two-spotted spider mites. Entomologia Experintalis and Aaplicata 56: 139-144.

Maluf, W. R., Campos, G, A. and Das Gracas, C. M. (2001). Relationships between trichome types and spider mites (*Tetranychus envansi*) repellence in tomatoes with respect foliar Zingiberence Contents. Euphytica. 121 (1). 73-80.

Mariatou, D. and Kwaramba, J. (1999). Review of vegetable IPPM potential in Zimbabwe: A case study of Mashona land East province. Working document for the FAO IPPM Global Facility Network .36 pp

Mathews, G. A. and Tunstall, L. (1994). Insect pests of cotton. CAB International, Wallingford, UK, pp 307-311.

Meyer, M. K. D. (1996). Mite pests and their predators on cultivated plants in South Africa. Vegetables and berries. Plant Protection Research Institute Handbook No. 6, ARC – Plant Protection research Institute. Pretoria.

McKinlay, R.G. (1992). Vegetables crop pest. Macmillan Academic and Professional Ltd. Hound mills. Basingstoke, Hampshire RG2 2x S and London, pp 3 007-311.

Ministry of Agriculture and JICA. (2000). Manual for Vegetable Growing, pp. 40-49.

MOARD. (2000). Ministry of Agriculture and Rural Development production statistics.

(1990-2000).

Mountia, L.A. 1958. Contributing to study of some phytophagous mites and their predators in Mauratius. Bull. Entomol. Res. 49:59-75.

Murungi, L. K., Knapp, M., Masinde, P. W., Onyambu, G., Gitonga, L., and Agong, S.G. 2009. Host-Plant acceptance, fecundity and longevity of *Tetranychus evansi* (Acari: Tetranychidae) on selected tomato accessions. Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.

Nihoul, P. (1993). Controlling glass house climate influences the interaction between tomato glandular trichome spider mite and predatory mite. Crop protection 12:443-447

Nihoul, P., Van Impe, G. and Hance, T. (1991). Characterizing indices of damage to tomato by the two-Spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) to achieve biological control. Journal of Horticultural Science 66:643-648.

Panda, N. and Khush, G.S. (1995). Host plant resistance to insects. CAB International and International Rice Research Institute. CAB International, Wallingford, pp 34.

Patricia, L.T., James, H.W. (1999). Ecological effects of pest resistance genes in managed ecosystems. Virginia polytechnic institute and state university Blacksburg, Virginia. pp 33-36.

Pimentel, D. H., Acuay, M., Blotnen, P., Rice, M., Silva, J., Nelson, V., Lipner, S., Diordano, A., D'Mmore, M. (1992). Environmental and economic costs of pesticide use. *Bio. Sci.* 42, 750-760.

Pree, D.J., Marshall, D.B., McGarvey, B.D. (1992). Residual toxity of Dicofol, formetanate HCL, Propergite, Hexythiazox, and Clefentezine to European Red spider mite on peach. Entomologist Society of Canada, Vol. 124.

Quereshi, A. H., Oatman, E.R. and Fleschner, C.A. (1969). Biology of the spider mite, *Tetranychus evansi*. Annals of Entomological society of America 62:899-902.

Ralph, J. S. H., Hornetz, B. and Shisanya, C. (1983). Natural conditions and farm management information.Vol.11.Part B: Ministry of Agriculture, Nairobi Kenya.

Sabelis, M. W. (1985). Sampling techniques. In: W. Helle & M. W. Sabelis (eds), Spider mites, their Biology, Natural Enemies and Control. Vol.1A. Elsevier, Amsterdam: 337-350.

Sabelis, M.W. and Dicke, M. (1985). Long-range dispersal and searching behavior. In: Helle, W and Sabelis, W. M. (eds). Spider mites, their biology, natural enemies and control, Vol. 1 B Elsevier, Amsterdam: 141-160.

Smith Meyer, M. K. P. (1987). African tetranychidae (Acari: Prostigmata) - with reference to the genera. Entomol mem Dep Agric Wat Supply Rep S. Afri 69:1-175.

SAS Institute. 2001. SAS/SAT, Version 8.02. SAS Institute Inc; Cary, NC., USA.

Saunyama, I. G. M. and Knapp, M. (2003). The effect of pruning and trellising of tomatoes (*Lycopersicon esculentum* Mill) on red spider mite (*Tetranychus evansi* Baker and Pritchard) incidence and crop yield in Zimbabwe. Afri. Crop Sci. J. 11, 269-277.

Silva, C. A. D., Da Lourancao, A.L. and De Moraes, G.J. 1992. Resistancia de tomateiro ao acaro vermelho *Tetranychus evansi* Baker and Pritchard. Acari: Tetranychedae *An. Soc. Ent. Brasileira*, 21:147-156

Simmons, A. T. and Gurr, G. M. 2005. Trichomes of *Lycopersicon* species and their hybrids: Effect on pests and natural enemies. Agricultural and Forest Entomology 7:265-276.

Snyder, J. C and Carter, C.D.1984. Leaf trichomes and resistance of *Lycopericon hirsutum* and *L. esculentum* to spider mites *Tetranychus urticea* Koch. *J. Amer. soc. Hort. Sci.* 109:837-843.

Snyder, J. C and Carter, C. D. 1985.Trichomes on leaves of *Lycopericon hirsutum* and *L. esculentum* and their hybrids. Euphytica 34: 53-64.

Stoner, A. K. 1992. Bibliography of plant resistance to Arthropods in vegetables. Phytoparasitica 20: Pp 125-180.

Suski. Z. W. and A. J. Naegele, (1996). Light response in the two-spotted mite. II: Behavior of the 'sedentary' and dispersal' phases. In: Naegele, J, A. (eds) Recent advances in Acarology. Cornell Univ. Press, New York: 445-453.

Van Haren, R., Steenhuis, M., Sabelis, M.W. and De Ponti, O. (1987). Tomato stems trichomes and dispersal success of *Phytoseiulus persimilis* relative to its prey *Tetranychus urticae*. Experimental and applied Acarology 3:115-121.

Varela, A. A., Seif, A. A., and Loehr, B. (2001). Integrated pest management manual for potatoes ICIPE/GTZ, Nairobi.

Varela, A. A., Seif, A.A., and Loehr, B., (2003). A guide to IPM in tomato production in Eastern and Southern Africa. ICIPE Science Press, Nairobi, pp 21-26.

Victor, O. S. and Lewis, J. W. (1997). Growth analysis of Cotton crops infested with spider mites. Crop science Journal 37:481-491.

Waiganjo, M. M., Wabule, N. M., Nyonmgesa, D., Kibaki, J. M., Onyango, I., Wepukhulu, S.B. and Muthoka, N.M. (2006).Tomato production in Kirinyaga district, Kenya, A baseline survey report. KARI Thika, Kenya.

Wekesa, V. W., Nguya, K. M., Knaap, M., and Hamadi, I.B. (2005). Pathogenecity of *Beauveria bassiana* and *Metarhizium anosopliae* to tobacco spider mite *Tetranychus evansi.*

Welter, S. C. (1989). Arthropod impact of plant gas exchange. Insect and plant interactions Vol. 1 CRC Press, Boca Raton, FL, pp 135-150.

Wesonga, J. M., Masinde, P. W., Losenge, T., Ngamau, K., Agong, S.G., Anjichi, V., Fricke, A., Hau, B. and Stützel, H. (2005). Proceedings of the Fourth Workshop on Sustainable Horticultural Production in the Tropics. Department of Horticulture, Moi University, Eldoret, Kenya.

Yang, P. M., Les, S. Y. and Jolliffe, F. (2004). Farmers' knowledge perceptions and practices in transgenic Bt Cotton in small producer systems in northern China. Crop Protection journal.

Yigit, A. and Erkilic, L. 2003. Studies on the chemical control of *Tetranychus cinabarrinus* Boised (Acarina: Tetranychidae), a pest of straw berry in the east Mediterranean region of Turkey. Crop protection journal.

APPENDICES

Appendix 1: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	8.75000000	0.87500000	3.50	0.0075
Error	21	5.25000000	0.25000000		
Corrected Total	31	14.00000000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.625000	25.00000	0.500000	2.000000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	8.00000000	1.14285714	4.57	0.0031
REP	3	0.75000000	0.25000000	1.00	0.4123

Appendix 2: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 4.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	226.5000000	22.6500000	41.82	<.0001
Error	21	11.3750000	0.5416667		
Corrected Total	31	237.8750000			

R-Square	Coeff Var	Root MSE	Pop mean
0.952181	28.72117	0.735980	2.562500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	224.8750000	32.1250000	59.31	<.0001
REP	3	1.6250000	0.5416667	1.00	0.4123

Appendix 3: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 5.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	8.25000000	0.82500000	9.90	<.0001
Error	21	1.75000000	0.08333333		
Corrected Total	31	10.00000000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.825000	14.43376	0.288675	2.000000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	8.00000000	1.14285714	13.71	<.0001
REP	3	0.25000000	0.08333333	1.00	0.4123

Appendix 4: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 5.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	294.7500000	29.4750000	40.59	<.0001
Error	21	15.2500000	0.7261905		
Corrected Total	31	310.0000000			

R-Square	Coeff Var	Root MSE	Population mean
0.950806	20.05101	0.852168	4.250000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	294.0000000	42.0000000	57.84	<.0001
REP	3	0.7500000	0.2500000	0.34	0.7936

Appendix 5: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	17.75000000	1.77500000	11.93	<.0001
Error	21	3.12500000	0.14880952		
Corrected Total	31	20.87500000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.850299	13.71585	0.385758	2.812500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	11.37500000	1.62500000	10.92	<.0001
REP	3	6.37500000	2.12500000	14.28	<.0001

Appendix 6: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	278.7500000	27.8750000	33.93	<.0001
Error	21	17.2500000	0.8214286		
Corrected Total	31	296.0000000			

R-Square	Coeff Var	Root MSE	Population mean
0.941723	18.12654	0.906327	5.000000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	272.0000000	38.8571429	47.30	<.0001
REP	3	6.7500000	2.2500000	2.74	0.0690

Appendix 7: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 7

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	28.50000000	2.85000000	19.95	<.0001
Error	21	3.00000000	0.14285714		
Corrected Total	31	31.50000000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.904762	12.09486	0.377964	3.125000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	19.50000000	2.78571429	19.50	<.0001
REP	3	9.00000000	3.00000000	21.00	<.0001

Appendix 8: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 7.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	678.2500000	67.8250000	45.04	<.0001
Error	21	31.6250000	1.5059524		
Corrected Total	31	709.8750000			

R-Square	Coeff Var	Root MSE	Population mean
0.955450	13.73060	1.227173	8.937500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	670.8750000	95.8392857	63.64	<.0001
REP	3	7.3750000	2.4583333	1.63	0.2120

Appendix 9: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions in week 8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	10.75000000	1.07500000	5.47	0.0005
Error	21	4.12500000	0.19642857		
Corrected Total	31	14.87500000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.722689	10.27716	0.443203	4.312500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	9.37500000	1.33928571	6.82	0.0003
REP	3	1.37500000	0.45833333	2.33	0.1032

Appendix 10: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions in week 8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	723.2500000	72.3250000	30.61	<.0001
Error	21	49.6250000	2.3630952		
Corrected Total	31	772.8750000			

R-Square	Coeff Var	Root MSE	Population mean
0.935792	16.50723	1.537236	9.312500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	697.8750000	99.6964286	42.19	<.0001
REP	3	25.3750000	8.4583333	3.58	0.031

Appendix 11: Analysis of variance for effect of Red spider mite (*T. evansi)* on leaf damage rated on a 1-5 scale on tomato varieties grown under green house conditions (Average from week 4 to week 8)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	42	181.1000000	4.3119048	18.48	<.0001
Error	117	27.3000000	0.2333333		
Corrected Total	159	208.4000000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.869002	16.94898	0.483046	2.850000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	49.6000000	7.0857143	30.37	<.0001
WK	4	117.1500000	29.2875000	125.52	<.0001
VAR*WK	28	6.6500000	0.2375000	1.02	0.4521
REP	3	7.7000000	2.5666667	11.00	<.0001

Appendix 12: Analysis of variance for average number of Red spider mites (*T. evansi*) /3 leaf discs (d=10mm) on tomato varieties grown under green house conditions (Average from week 4 to week 8)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	42	3307.800000	78.757143	59.77	<.0001
Error	117	154.175000	1.317735		
Corrected Total	159	3461.975000			

R-Square	Coeff Var	Root MSE	Population mean
0.955466	19.09233	1.147926	6.012500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	1829.775000	261.396429	198.37	<.0001
WK	4	1135.350000	283.837500	215.40	<.0001
VAR*WK	28	329.850000	11.780357	8.94	<.0001
REP	3	12.825000	4.275000	3.24	0.0245

Appendix 13: Analysis of variance for average number of dead flowers and flower buds of protected tomato varieties grown under green house conditions.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	962.224725	96.222472	3.46	0.0079
Error	21	583.471875	27.784375		
Corrected Total	31	1545.696600			

R-Square	Coeff Var	Root MSE	Flowers (P) mean
0.622518	26.21780	5.271089	20.10500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	898.1281500	128.3040214	4.62	0.0029
REP	3	64.0965750	21.3655250	0.77	0.5242

Appendix 14: Analysis of variance for average number of dead flowers and flower buds of infested tomato varieties grown under green house conditions.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	5590.812500	559.081250	37.31	<.0001
Error	21	314.656250	14.983631		
Corrected Total	31	5905.468750			

R-Square	Coeff Var	Root MSE	Flowers (I) mean
0.946718	11.65266	3.870870	33.21875

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	5460.718750	780.102679	52.06	<.0001
REP	3	130.093750	43.364583	2.89	0.0593

Appendix 15: Analysis of variance for yield of infested tomato varieties grown under green house conditions.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	879744.248	87974.425	9.41	<.0001
Error	21	196329.965	9349.046		
Corrected Total	31	1076074.213			

R-Square	Coeff Var	Root MSE	Yield mean
0.817550	21.93799	96.69046	440.7444

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	812726.7900	116103.8271	12.42	<.0001
REP	3	67017.4584	22339.1528	2.39	0.0976

Appendix 16: Analysis of variance for yield of protected tomato varieties grown under green house conditions.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	5889705.000	588970.500	55.53	<.0001
Error	21	222720.500	10605.738		
Corrected Total	31	6112425.500			

R-Square	Coeff Var	Root MSE	Yield mean
0.963563	9.783557	102.9842	1052.625

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VAR	7	5782953.000	826136.143	77.90	<.0001
REP	3	106752.000	35584.000	3.36	0.0383

Appendix 17: Analysis of variance for average percent webbing on tomato varieties grown under green house conditions in week 5.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	12106.25000	1210.62500	5.05	0.0009
Error	21	5031.25000	239.58333		
Corrected Total	31	17137.50000			

R-Square	Coeff Var	Root MSE	Webbing mean
0.706419	50.54197	15.47848	30.62500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VAR	7	11487.50000	1641.07143	6.85	0.0003
REP	3	618.75000	206.25000	0.86	0.4767

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VAR	7	11487.50000	1641.07143	6.85	0.0003
REP	3	618.75000	206.25000	0.86	0.4767

Appendix 18: Analysis of variance for average percent webbing on tomato varieties grown under green house conditions in week 6.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	11243.75000	1124.37500	4.76	0.0013
Error	21	4956.25000	236.01190		
Corrected Total	31	16200.00000			

R-Square	Coeff Var	Root MSE	Webbing mean
0.694059	35.11469	15.36268	43.75000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VAR	7	10950.00000	1564.28571	6.63	0.0003
REP	3	293.75000	97.91667	0.41	0.7441

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VAR	7	10950.00000	1564.28571	6.63	0.0003
REP	3	293.75000	97.91667	0.41	0.7441

Appendix 19: Analysis of variance for average percent webbing on tomato varieties grown under green house conditions in week 7.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	17256.25000	1725.62500	15.46	<.0001
Error	21	2343.75000	111.60714		
Corrected Total	31	19600.00000			

R-Square	Coeff Var	Root MSE	Webbing mean
0.880421	16.57165	10.56443	63.75000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VAR	7	16750.00000	2392.85714	21.44	<.0001
REP	3	506.25000	168.75000	1.51	0.2405

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VAR	7	16750.00000	2392.85714	21.44	<.0001
REP	3	506.25000	168.75000	1.51	0.2405

Appendix 20: Analysis of variance for effect of tomato varieties on incubation period of *T, evansi*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.55000000	0.07857143	0.09	0.9987
Error	72	63.00000000	0.87500000		
Corrected Total	79	63.55000000			

R-Square	Coeff Var	Root MSE	Incubation mean
0.008655	22.40513	0.935414	4.175000

Source	DF	Sum of Squares	Mean Square	F Value	Pr >
VARIETY	7	0.55000000	0.07857143	0.09	0.9987

Appendix 21: Analysis of variance for effect of tomato varieties on larvae period of *T, evansi*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.40000000	0.05714286	0.28	0.9591
Error	72	14.60000000	0.20277778		
Corrected Total	79	15.00000000			

R-Square	Coeff Var	Root MSE	Lava mean
0.026667	16.37486	0.450309	2.750000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VARIETY	7	0.40000000	0.05714286	0.28	0.9591

Appendix 22: Analysis of variance for effect of tomato varieties on deutonymph period of *T. evansi.*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	5.28750000	0.75535714	3.86	0.0013
Error	72	14.10000000	0.19583333		
Corrected Total	79	19.38750000			

R-Square	Coeff Var	Root MSE	Deutonymph mean
0.272727	31.32960	0.442531	1.412500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VARIETY	7	5.28750000	0.75535714	3.86	0.0013

Appendix 23: Analysis of variance for effect of tomato varieties on protonymph period of *T. evansi*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	10.88750000	1.55535714	7.32	<.0001
Error	72	15.30000000	0.21250000		
Corrected Total	79	26.18750000			

R-Square	Coeff Var	Root MSE	Protonymph mean
0.415752	25.43323	0.460977	1.812500

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VARIETY	7	10.88750000	1.55535714	7.32	<.0001

Appendix 24: Analysis of variance for effect of tomato varieties on fecundity of *T, evansi*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	13638.88750	1948.41250	89.00	<.0001
Error	72	1576.30000	21.89306		
Corrected Total	79	15215.18750			

R-Square	Coeff Var	Root MSE	Fecundity mean
0.896400	14.76608	4.679002	31.68750

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VARIETY	7	13638.88750	1948.41250	89.00	<.0001

Appendix 25: Analysis of variance for effect of tomato varieties on longevity of *T, evansi.*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	360.1500000	51.4500000	44.21	<.0001
Error	72	83.8000000	1.1638889		
Corrected Total	79	443.9500000			

R-Square	Coeff Var	Root MSE	Longevity mean
0.811240	13.87571	1.078837	7.775000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
VARIETY	7	360.1500000	51.4500000	44.21	<.0001

Appendix 26: Analysis of variance for effect of acaricide treatment against Red spider mite (*T. evansi*) on yield of tomatoes.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	126739.5203	14082.1689	5.60	0.0010
Error	18	45233.0825	2512.949		
Corrected Total	27	171972.6028			

R-Square	Coeff Var	Root MSE	Yield mean
0.736975	18.31404	50.12932	273.7207

Source	DF	Type I SS	Mean Square	F Value	Pr > F
CHEM	6	110765.9333	18460.9889	7.35	0.0004
WEEK	0	0.0000			
CHEM*WEEK	0	0.0000			
REP	3	15973.5870	5324.5290	2.12	0.1335

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CHEM	6	110765.9333	18460.9889	7.35	0.0004
WEEK	0	0.0000			
CHEM*WEEK	0	0.0000			
REP	3	15973.5870	5324.5290	2.12	0.1335

Appendix 27: Analysis of variance for effect of acaricide treatment on average *T, evansi* population (Pre-treatment)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	42.8571429	4.7619048	0.54	0.8278
Error	18	159.1428571	8.8412698		
Corrected Total	27	202.0000000			

R-Square	Coeff Var	Root MSE	Population mean
0.212164	33.03808	2.973427	9.000000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
CHEM	6	28.00000000	4.66666667	0.53	0.7800
REP	3	14.85714286	4.95238095	0.56	0.6481

Appendix 28: Analysis of variance for effect of acaricide treatment against Red spider mite (*T. evansi*) on leaf damage of tomatoes.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	5.67857143	0.63095238	0.65	0.7443
Error	18	17.57142857	0.97619048		
Corrected Total	27	23.25000000			

R-Square	Coeff Var	Root MSE	Leaf mean
0.244240	35.92813	0.988024	2.750000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CHEM	6	1.00000000	0.16666667	0.17	0.9814
REP	3	4.67857143	1.55952381	1.60	0.2249

Appendix 29: Analysis of variance for effect of acaricide treatment on average *T, evansi* population in week 1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	77.1071429	8.5674603	3.38	0.0133
Error	18	45.5714286	2.5317460		
Corrected Total	27	122.6785714			

R-Square	Coeff Var	Root MSE	Population mean
0.628530	31.15531	1.591146	5.107143

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
CHEM	6	74.42857143	12.40476190	4.90	0.0039
REP	3	2.67857143	0.89285714	0.35	0.7877

Appendix 30: Analysis of variance for effect of acaricide treatment on average *T, evansi* population week 2.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	88.7142857	9.8571429	6.06	0.0006
Error	18	29.2857143	1.6269841		
Corrected Total	27	118.0000000			

R-Square	Coeff Var	Root MSE	Population mean
0.751816	31.88832	1.275533	4.000000

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
CHEM	6	85.00000000	14.16666667	8.71	0.0002
REP	3	3.71428571	1.23809524	0.76	0.530

Appendix 31: Analysis of variance for effect of acaricide treatment on average *T, evansi* population week 3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	96.7857143	10.7539683	7.55	0.0002
Error	18	25.6428571	1.4246032		
Corrected Total	27	122.4285714			

R-Square	Coeff Var	Root MSE	Population mean
0.790548	45.16201	1.193567	2.642857

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CHEM	6	90.92857143	15.15476190	10.64	<.0001
REP	3	5.85714286	1.95238095	1.37	0.2837

Appendix 32: Analysis of variance for effect of acaricide treatment on average *T, evansi* population week 4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	99.5714286	11.0634921	3.31	0.0147
Error	18	60.1428571	3.3412698		
Corrected Total	27	159.7142857			

R-Square	Coeff Var	Root MSE	Population mean
0.623435	42.65133	1.827914	4.285714

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
CHEM	6	94.71428571	15.78571429	4.72	0.0047
REP	3	4.85714286	1.61904762	0.48	0.6972

Appendix 33: Analysis of variance for effect of acaricide treatment on average *T, evansi* population in week 5.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	1380.392857	153.376984	7.10	0.0002
Error	18	388.571429	21.587302		
Corrected Total	27	1768.964286			

R-Square	Coeff Var	Root MSE	Population mean
0.780340	27.38821	4.646214	16.96429

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CHEM	6	1257.714286	209.619048	9.71	<.0001
REP	3	122.678571	40.892857	1.89	0.1668

Appendix 34: Analysis of variance for effect of acaricide treatment on average *T, evansi* population in week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	2703.250000	300.361111	8.55	<.0001
Error	18	632.000000	35.111111		
Corrected Total	27	3335.250000			

R-Square	Coeff Var	Root MSE	Population mean
0.810509	23.94126	5.925463	24.75000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CHEM	6	2672.000000	445.333333	12.68	<.0001
REP	3	31.250000	10.416667	0.30	0.8273

Appendix 35: Analysis of variance for effect of acaricide treatment against Red spider mite (*T, evansi*) on leaf damage of tomatoes (Eight weeks after first spray application)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	44.82142857	4.98015873	7.38	0.0002
Error	18	12.14285714	0.67460317		
Corrected Total	27	56.96428571			

R-Square	Coeff Var	Root MSE	Leaf mean
0.786834	32.39096	0.821342	2.535714

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
CHEM	6	42.71428571	7.11904762	10.55	<.0001
REP	3	2.10714286	0.70238095	1.04	0.3982

Appendix 36: A SURVEY ON RED SPIDER MITE (*Tetranychus evansi*) AND FARMERS CONTROL MEASURES ON TOMATO IN SUBUKIA AND RONGAI DIVISION

1) Farmers name/survey no .....sex.....age.....location.....
   sub-location.....
2) Size of land in acres.....
3) Type of crop grown. (in order of priority)

Type of crop	Acres in acres
i.....	.....
ii.....	.....
iii.....	.....
iv.....	.....

4) How long have been growing tomatoes.....
5) How many times do you plant in a year.....Which months.....
6) When do most farmers grow tomatoes.....
   Reasons.....
7) Which varieties do you grow (in order of priority)

Variety	Yield/Acre	Reasons
i.....	.....	.....
ii..... ...	.....	.....
iii.....	.....	.....
iv.....	.....	.....

8) Which of the varieties do you grow in the following seasons
   i. Short rain .....
   ii. Long rain.....
   iii. Off season.....

9) Which are major diseases (in order of priority)
   i.....
   ii.....
   iii.....
   iv.....

10) Which are major insect mite pests (in order of priority)

i.....

ii.....

iii.....

iv.....

11) Does your tomato crop get infested with red spider mite

i. YES

ii. NO

12) How would you rate Red spider mite infestation in the following seasons (Use 1 to 5)

Season	**Rate of infestation**				
	Very low	**Low**	**Moderate**	**High**	**Very high**
Short rain					
Long rain					
Off season					

13) How would you rate the yield loss due to mites in the following seasons

Season	**Rate of yield loss**				
	Very low	**Low**	**Moderate**	**High**	**Very high**
Short rain					
Long rain					
Off season					

14) Of the tomato varieties you grow how susceptible are they to spider mite

Variety	Susceptibility to spider mite				
	Very low	Low	Moderate	High	Very high

15) When are first symptoms of mite attack noted……..

16) Which fungicides do you use to control mites

CHEMICAL	PRICE/LITRE	FREQUENCY OF APPLICATION
i……	……	……
ii……	……	……
Iii……	……..	……
iv……	……	……

17) Which insecticides do you use to control mites

CHEMICAL	PRICE/LITRE	FREQUENCY OF APPLICATION
i……	……	……
ii……	……	……
Iii……	……..	……
iv……	……	……

18) Do you mix chemicals……if yes give reasons……..

19) Give safety precautions you take when spraying……

……

20) When do you harvest tomatoes after spraying……..

21) Other pest management practices

.....

.....

.....

.....

22) Field observations

.....

.....

.....

.....

.....

EGERTON UNIVERSITY LIBRARY