EFFICACY OF LEAF EXTRACTS OF *Artemisia annua* AND *Thevetia peruviana* AGAINST *Aphis fabae* AND NON-TARGET ORGANISMS ON *Solanum scabrum*

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree award.

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a thesis entitled `` Efficacy of leaf extracts of *Artemisia annua* Linn. and *Thevetia peruviana* Pers. against *Aphis fabae* Scopoli. and non-target organisms on *Solanum scabrum* Miller.''.

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DEDICATION

I dedicate this work to my husband David Wekesa and our lovely daughter Annabel Nanjala and son Arnold Simiyu who greatly supported me emotionally. May almighty God bless them abundantly.

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ABSTRACT

African nightshade (*Solanum scabrum* Miller*)* is a vegetable, widely distributed throughout the tropics including East Africa. It is an important vegetable in Kenya but consumer demands have not been met due to low yields and partly due to attack by *Aphis fabae* Scopoli. The aphids cause serious damage through sucking plant cell sap from phloem leaving the plant weakened, dehydrated, stunted in growth and eventually under heavy infestation the leaves curl making the vegetables unattractive to consumers. Synthetic insecticides have been used but the aphids developed resistance. They are also a risk to human health and they kill important non-target organisms e.g. predators, parasites and pollinators. These reasons have led to the quest for use of extracts from plants to control aphids. The objective of this study was to evaluate the efficacy of leaf extracts of *Artemisia annua* Linn. and *Thevetia peruviana* (Pers.) Schumann for the control of *A. fabae* infesting *S. scabrum*, its yield output and impact of extracts on non-target organisms during short and long rain season from September to December 2015 and from March to July, 2016 respectively. Field experiments were carried out in Masinde Muliro University of Science and Technology's Main Campus farm. A randomized complete block design (RCBD) of six treatments and three replicates was used. The treatments used were *A. annua* 0.5%, *A. annua* 1%, *T. peruviana* 0.15%, *T. peruviana* 0.3%, Albaz 10 EC insecticide and water. The African nightshade (*S. scabrum*) used as test crop and seeds were obtained from Kenya Seed Company. *A. annua* and *T. peruviana* leaves were each obtained from two farm each. The *S. scabrum* plants were sprayed thrice at an interval of two weeks. Parameters collected were *A. fabae* population density, leaf damage caused by aphids, plant height (cm), leaf width (cm), number of flowered plants per plot, number of plants with formed fruits per plot, number of plants with ripened fruits per plot and total weight of fresh and dry leaves, stems and seeds (Kgs) per plot and diversity of non-target organisms. Results showed that leaf extracts of *A. annua* 1% concentration significantly ($p < 0.0001$) reduced the aphid population density, had significantly higher mean weight per plot of dry leaves (0.60, 0.63 kg per plot), stems (2.62, 2.97 kg per plot) and seeds (1.36, 1.57 kg per plot) and lower number of damaged leaves per plot (24.67, 15.00) for short and long rains respectively. Leaf extracts of *A. annua* 0.5% concentration had significantly ($p < 0.0001$) the highest aphid population density per plot, the lowest mean weight per plot of dry leaves (0.38, 0.41 kg per plot), stems (1.82, 1.91 kg per plot) and seeds (0.92, 1.07 kg per plot) and highest number of damaged leaves per plot (49.33, 36) for short and long rains respectively when compared to those treated with leaf extracts. Plots treated with leaf extracts of *A. annua* 0.5% and *T. peruviana* 0.15% recorded higher population of bees, beetles and black ants. Plots treated with leaf extracts of *A. annua* 1% and *T. peruviana* 0.3% recorded lower population of bees, beetles and black ants. The results of this study indicated that leaf extracts of *T. peruviana* 0.3% and *A. annua* 1% had the potential to for control of *A. fabae* infesting *S. scabrum* while leaf extracts of *A. annua* 0.5% and *T. peruviana* 0.15% conserved non-target organisms.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
CAN	Calcium Ammonium Nitrate.
cm	centimeters
DAP	Diammonium Phosphate.
g	grams
IPM	Integrated Pest Management.
Kg	kilograms
LC_{50}	Concentration of chemical that kills 50% of sample population.
LC_{90}	Concentration of chemical that kills 90% of sample population.
RCBD	Randomized Complete Block Design.
WHO	World Health Organisation.

Non-target organisms –refers to all species directly and indirectly exposed to insecticide which are not the targets.

CHAPTER ONE

INTRODUCTION

1.1. Background

Production, consumption and marketing of traditional vegetables in Kenya has changed from subsistence to commercial production because of the increase in the number of consumer population (Opala *et al*., 2013). This is attributed to the high nutritive and medicinal value of these vegetables (Opala *et al*., 2013). Due to high demand, most farmers are now growing indigenous vegetables as an income generating venture.

Solanum scabrum is the most commonly eaten species of nightshades. The species grows very fast and it is characterized by large purple berries and broad leaves (Ashilenje *et al*., 2012). A market survey in Kakamega town showed that *S. scabrum* is among the top ten important vegetables, and is ranked third in terms of quantities traded (Abukutsa, 2007). The vegetable can grow in home gardens or can be intercropped with cereals like millet, sorghum or maize or other vegetables (Ng'etich *et al*., 2014, Carnot *et al*., 2017). Broad leaved type is preferred by consumers because the leaves are less bitter compared with *Solanum nigrum* (Khattak *et al*., 2012).

Solanum scabrum is valued for its medicinal value in relief of dropsy fever, swellings, cough, rheumaltagia, asthma, wounds, ulcer, vomiting and skin disease (Suganthy and Sakthivel, 2012; Khattak *et al*., 2012; Ontita *et al*., 2016). It reduces malnutrition in women of child bearing age, young children by providing vitamin A, vitamin C, iodine, zinc, selenium, carotenes, folic acid and riboflavin (Musyimi *et al*., 2012; Kamga *et al*., 2013; Ronoh *et al*., 2017).

Although *S. scabrum* is a favourite of many consumers, farmers face challenges of low productivity which is evidenced by low leaf yield attributed to serious direct feeding damage by piercing and sucking of plant sap by aphids. The aphids usually attack the underside of the leaf and cause the leaves to curl resulting in stunted growth (Carnot *et al*., 2017). Once the vegetables are curled it leads to poor marketability since consumers don't prefer vegetables with low quality leaves. In case young plants are attacked they wilt and eventually they fail to grow (Ashilenje *et al.*, 2011). A study conducted in Western Kenya revealed that *S. scabrum* is highly attacked by aphids because it is more succulent and it is not bitter as compared to *S. nigrum* (Ashilenje *et al.*, 2011). Aphids are also known for transmitting viral diseases to crops such as beans, peas, beets, crucifers, cucurbits, dahlia, potato, tobacco, tomato and tulip. The viruses include the persistent beet yellow net virus (BYNV), tomato mosaic virus, tobacco mosaic virus and potato leaf roll virus (PLRV) (Meradsi and Laamari, 2016).

Synthetic insecticides have been used to control aphids on farms but they are associated with various environmental and health hazards (Sharma and Signhivi, 2017). They are potential risk to human health as they cause acute or chronic poisoning and chronic diseases eg cancer, respiratory problems and fertility problems (Mustafa *et al*., 2017). They are not environmentally friendly as they kill important micro-organisms in the soil such as beneficial fungi and bacteria, macro organisms in water bodies and non-target organisms that are beneficial, which include pollinators, parasites and predators (Aktar *et al*., 2009, Ruchika and Kumar, 2012). Botanical insecticides have many advantages as compared to synthetic insecticides. For example they have low mammalian toxicity effects, human health and environmental friendly, are cheap and locally available (Sharma and singhivi, 2017).

However, information on the effectiveness of plant extracts such as those of *A. annua* and *T. peruviana* on *A. fabae* population, yield of *S. scabrum* and also on non-target organisms is still limited. Therefore, the objective of this study was to determine if *A. fabae* infesting *S. scabrum* can be controlled effectively by applying of leaf extracts of *A. annua* and *T. peruviana* and the impact of these extracts on non-target organisms.

1.2. Problem statement

The demand for *S. scabrum* vegetable is high but the yields are low. This is partly due to attack by *A. fabae* which damages the vegetable by sucking plant sap thereby causing the leaves to be crinkled, flaccid and stunted in growth (Taylor, 2013, Ashilenje *et al.*, 2011). The leaves appear curled and become unattractive to consumers. When young plants or seedlings are infested by aphids, they wilt and die thus leads to yield losses. *A. fabae* also transmit various viral diseases to crops such as beans, cowpeas and groundnuts (Ashilenje *et al.*, 2011, Meradsi and Laamari, 2016). Although synthetic insecticides have been used to control aphids they have several detrimental effects like pollution of environment, aphids have developed resistance, are expensive, are poisonous to human beings and kill beneficial non-target organisms like pollinators, predators and parasites (Sharma and singhivi, 2017, Ruchika and Kumar, 2012). As a result, there is need for further research, to obtain environmentally friendly, cheap, effective and easily available botanical insecticides for control of *A. fabae* with the aim of improving *S. scabrum* yield production. This study used leaf extracts of *A. annua* and *T. peruviana* which to control *A. fabae* infesting *S. scabrum*.

1.3. Justification

S. scabrum is a local vegetable which is highly nutritious and is known to have medicinal value. The leaves are used as vegetable, treatment of diseases such as diarrhoea, jaundice, asthma, leprosy, liver cirrhosis and skin problems (Suganthy and Sakthivel, 2012; Khattak *et al*., 2012), provision of nutrients which include vitamins, riboflavin, zinc, selenium, carotene, protein, sulphur, iodine, iron and potassium and are a source of dyes (Ashilenje *et al*., 2011; Ronoh *et al*, 2017).

The vegetables are easily available and cheap in village markets, but expensive in under-supplied urban markets, indicating that they have potential to become commercially important and can increase in their market share. Many farmers are growing it due to high sale price offered in the markets as compared to other vegetables like cowpeas and kales. The yields of *S. scabrum* are low in Western Kenya partly due to damage by *A. fabae*. The aphids multiply very fast due to their ability to reproduce both sexually and asexually.

Controlling the aphids using synthetic insecticides is expensive and continuous use leads to insecticide resistance among aphids, death of non-target useful insects like pollinators (Ruchika and Kumar, 2012). Synthetic insecticides have negative effects on the environment such as soil, water and air and leave chemical residues in agricultural and animal products (Surganthy and Sakthivel, 2012). Furthermore, parasitoids which offer biological control of aphids could get killed by spraying insecticides. Besides, *S.*

scabrum is plucked regularly hence control with synthetic insecticides can lead to food poisoning as they take long time to break down (Mia *et al*., 2014). Therefore, an alternative method of aphid control is needed. The use of botanical insecticides remains a safe and ecofriendly method of controlling aphids to overcome problems associated with use of synthetic insecticides. One of the possible approaches, is the use of plant extracts which would repel aphids or deter their feeding and in the process, reduce their number on plants. There is limited information on use of *A. annua* and *T. peruviana* leaf extracts to control of *A. fabae* infesting *S. scabrum*, on non-target organisms and on yield of *S. scabrum*.

1.4. Objectives

1.4.1. General Objective

To evaluate effectiveness of leaf extracts of *A. annua* and *T. peruviana* in the control of *A. fabae*, on yield of *S. scabrum* and impact on beneficial organisms.

1.4.2. Specific Objectives

i. To determine the effect of leaf extracts of *A. annua* and *T. peruviana* on population of *A. fabae* infesting *S. scabrum* .

ii. To evaluate the growth and yield outputs of *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana.*

iii. To evaluate impact of extracts of *A. annua* and *T. peruviana* on non-target organisms in *S. scabrum*.

1.5. Hypothesis

i. Leaf extracts of *A. annua* and *T. peruviana* did not reduce population of *A. fabae* infesting *S. scabrum*.

ii. Leaf extracts of *A. annua* and *T. peruviana* have no effect on growth and yield outputs of *S. scabrum*.

iii. Leaf extracts of *A. annua* and *T. peruviana* did not reduce non-target organisms when applied to *S. scabrum*.

CHAPTER TWO

LITERATURE REVIEW

2.1. Importance of African nightshade

2.1.1. Importance of African nightshade as a medicinal plant

Solanum scabrum has the following medicinal value; antiseptic, anti-inflammatory expectorant, cardio tonic, digestive, diuretic, laxative, sedative, asthma, leprosy, hemorrhoids and protection of the liver in cases of toxicity induced by drugs and chemicals (Atanu *et al.,* 2010; Khattak *et al*., 2012).

Fresh juice prepared from leaves of *S. scabrum* is used for treatment of fever, alleviating pain, treatment of diarrhoea and jaundice in children, skin problems, wounds, cancerous sores, tumors, liver cirrhosis and used by infants having abdominal upsets (Khattak *et al*., 2012; Musyimi *et al*., 2012). Raw fruits when chewed and swallowed are used to treat stomach ulcers heart disease, swollen glands and teething problems. The roots are useful in treatment of hepatitis (Atanu *et al.*, 2010).

2.1.2. Nutritional value of African nightshade

Solanum scabrum is rich in nutrients such as vitamins, riboflavin, zinc, selenium, carotene, protein and iodine (Ronoh *et al*, 2017). African nightshade contains protein methionine that has sulphur element that is required by cartilage in joints, increases healing process for patients with arthritis and strengthens nails. The leaves of *S. scabrum* contain 87.2 g water, 1.0 mg iron, 4.3 g protein, 38 calories, 5.7 g carbohydrates, 1.4 g fibre, 442 mg calcium, 20 mg ascorbic acid, and 3660 µg ß-Carotene, 75 mg phosphorus, and 0.59 mg riboflavin per 100 g fresh weight (Kamga *et al.*, 2013). *Solanum scabrum* has been used to reduce malnutrition in women of child bearing age, young children, pregnant, nursing mothers, for people with iron deficiencies and malaria patients (Musyimi *et al*., 2012).

2.2. Description, symptoms of infestation of black bean aphid *(Aphis fabae* Scopoli)

Aphids are an important group of plant pests that infests *S. scabrum*. There are about 4700 species of aphids in the world. Out of these, about 450 species have been recorded from crop plants but only about 100 have successfully exploited the agricultural environment to the extent that they are of significant economic importance (Pawar, 2015). The main aphid species include black bean aphid (*Aphis fabae* Scopoli*)*, pea aphid *(Acyrthosiphon pisum* Harris*)*, cowpea aphid (*Aphis craccivora* Koch*),* green citrus aphid *(Aphis spiraecola* Patch*)*, green peach aphid *(Myzus persicae* Sulzer*)* and mealy cabbage aphid (*Brevicoryne brassicae* Linn*)* (Pawar, 2015).

Black bean aphid mainly attacks beans and other vegetables including *S. scabrum*. It is a tiny black insect with a broad, soft body, a member of the order Homoptera and family Aphididae. It has a specialized piercing and sucking mouth parts with which it sucks the juice from plants phloem. It is a tiny plump insect about two millimeters long with a small head and bulbous abdomen and usually occurs in large numbers as a colony. Many adults are devoid of wings and occur as apterae. Winged forms are long, slender and have shiny black heads and thoraxes. The antennae are less than two-thirds of the length of the body. Near the rear of the abdomen are a pair of slender, elongated tubes known as cornicles whose function is the production of a defensive waxy secretion ((Meradsi and Laamari, 2016).

Apart from *A. fabae*, *S. scabrum* is infested by spider mites, ants, thrips, black beetles, caterpillars, grasshopper and crickets which damage the leaves by boring holes (Carnot *et al*., 2017; Suganthy and Sakthivel, 2012).

2.3. Economic importance of *A. fabae*

Black bean aphid cause leaves of *S. scabrum* to curl and hinder leaf expansion hence reduce photosynthetic area which later affect further growth. *Aphis fabae* may cause a considerable reduction in leaf width and hence yield, and when young plants are infested they fail to expand fully (Carnot *et al*., 2017). It causes damage such as direct feeding. The plants lose vigour, flowers are damaged and pod development in beans may be retarded. Spring sown field beans can be damaged severely with considerable loss of yield (Taylor, 2013). It is known to transmit more than 30 viruses, mainly of the non-persistent variety of beans, peas, beets, crucifers, cucurbits, dahlia, potato, tobacco, tomato and tulip, and the persistent beet yellow net virus (BYNV) and potato leaf roll virus (PLRV) (Meradsi and Laamari, 2016). Aphids produce large amount of honey dew which often turns black with the growth of sooty mold fungus. These are unsightly, thus reduce the surface area of the plant available for photosynthesis and may reduce the value of the crop. The leaves of vegetables also curl thus reducing their marketability (Carnot *et al*., 2017).

2.4. Control strategies used against aphids

Aphid control strategies that have been used include use of botanical insecticides on crops like cabbage, *S. nigrum,* cowpeas (Suganthy and Sakthivel, 2012). Aphids have been controlled using insecticides such as bifenthrin, cyfluthrin, malathion, extracts of neem, pyrethrin and insecticidal soap on vegetables. Although synthetic insecticides kill natural enemies of aphids (Foster and Obermeyer, 2010), natural enemies of aphids such as predators e.g. hoverflies, ladybird beetles, true bugs, lacewings, aphid midge and ground beetles, parasitic wasps like braconids and Ichneumonids have also been used (Bessin and Obrycki, 2011). Aphids have been controlled by regular monitoring to discover aphid infestation early to avoid population build up to levels that cause a lot of damage. Cultural methods for aphid control in vegetables include: management of alternate hosts e.g. weeds, pruning those plants that have localized aphid population on few curled leaves, use of less nitrogenous fertilizers as high levels of nitrogen favor aphid reproduction, growing seedling under protective covers to prevent aphid transmitted viruses, use of silver colored reflective mulches reduces aphid transmitted viruses and knocking off aphids using strong spray of water (Foster and Obermeyer, 2010). Thus this study tested the use of *A. annua* and *T. peruviana* leaf extracts to control *A. fabae* on *S. scabrum.*

2.5. Plants with insecticidal activity

Neem seed kernel extract 5%, aqueous extract of *Andrographis paniculata* Burm. 2%, aqueous extract of *Vitex negundo* L. 2%, Neem oil (Azadirachtin 1%), Pungam oil 3 ml / litre and mineral oil 3 ml / litre have been used against aphids, thrips, leaf miners and defoliators infesting *Solanum nigrum* L. Neem oil and *Andrographis paniculata* recorded maximum reduction in pest population (Suganthy and Sakthivel, 2012). Aqueous and alcoholic extracts of *Melia azedarach* L., *Lantana camara* L., *A. annua* L. and *Cannabis sativa* L. were found effective against the diamondback moth, *Plutella xylostella* L infesting cauliflower crop (Kumar *et al*., 2009). *Azadirachta indica* Juss, *Melia azedarach* L., *Lantana camara* L., *Cannabis sativa* Linn., *Ricinus communis* Linn., *Solanum nigrum* Linn., *Nerium indicum* Mill. and *Eucalyptus species* were found to be effective against the cabbage white butterfly, *(Pieris brassicae* L.) (Sharma and Gupta, 2009). *Jatropha curcas* L. seeds essential oil has been used to control cowpea aphid at concentration of 5% and 7.5% (Habou *et al*., 2011). Studies have been done using neem seed extracts 2.5%, garlic crude extracts 5%, turmeric crude extracts 3.5%, henge 2.5% against tomato fruit worm, *Helicoverpa armigera* Hubner. and neem was found to be most effective (Jawad *et al.*, 2013). Plant extract of *Petiveria alliacea* L. and *Tephrosia vogelii* Hook. have been used against *Maruca vitrata* Fabricius, *Megalurothrips sjostedti* and *Riptortus dentipes* F. infesting cowpea on the field at concentrations of 5%, 10% and 20 % with 20% recording highest mortality of the pests (Alao *et al*., 2011). Home made organic pesticides derived from wild plants *Solanum pindiriforme* L., *Lippia javanica* L., Garlic, *Allium sativum* L. and Tobacco, *Nicotiana tobacum* Mill. have been effective on Aphid *Brevicoryne brassica* L. (Mhazo *et al.*, 2011). *Mammea siamensis* Anders. has been found as an effective botanical against diamond back moth and also exhibited no negative impact on honey bee and earthworms but was toxic to tilapia fingerlins (Issakul *et al.*, 2011). Several plants have insecticidal properties but information on use of leaf extracts of *A. annua* and *T. peruviana*on to control *A. fabae* on *S. scabrum* is lacking.

2.6. Artemisia annua and *Thevetia peruviana* plant extracts

2.6.1. *Artemisia annua*

Artemisia annua is an annual herb native to Asia, is mostly found in China. *Artemisia annua* and is cultivated in China and Vietnam as a source of artemisinin. It is cultivated in Romania as a source of essential oils. Cultivation of *A. annua* has greatly expanded in Africa, especially in Kenya, Tanzania and Nigeria, to support the production of the antimalarial artemisinin. Cultivation of *A. annua* in Africa was started after the World Health Organization (WHO) recommended Artemisinin Combination Therapies (ACT) as a replacement of artemisinin monotherapy in the fight against multi-drug resistant *Plasmodium falciparum* causing malaria (Ferreira *et al.*, 2008). Research also shows that artemisinin drugs are effective against cancer, leishmaniasis and trypanosomiasis (Sen *et al*., 2008). Oil extract of *Artemisia seiberi* has been used to control woolly apple aphid (Ateyyat *et al*., 2012). Water and alcohol extract of *Artemisia dracunculus* L, *Artemisia absinthium* L., *Artemisia vulgaris* L. were effective in control of *Aphis spiraephaga* L. with water extracts of *Artemisia absinthium* registering 80% mortality. Water extracts of *Artemisia vulgaris* have been used to control red spider mite in tea (Mamun and Ahmed, 2011). *Artemisia herba-alba* Asso. has been used in Sudan at a concentration of 5% and 10% using water extract on *Trogoderma granarium* Everts larvae (Yousif and Satti, 2012). Studies indicate that *A. annua* has chemical compounds which consist of volatile and non-volatile constituents. Volatile constituents include essential oils. The main non-volatile ingredients include sesquiterpenoids, flavonoids and coumarins. Sesquiterpenoids include artemisinin, artemisinin I, artemisinin II, artemisinin III, artemisinin IV, artemisinin V, artemisic acid, artemisilactone, artemisinol and epoxyarteannuinic acid (WHO, 2008). 1% and 0.625% concentration of *A. annua* has been used to control Lesser mulbery pyralid in Iran (Khosravi *et al*., 2010). *A. annua* 1% has been used to control green peach aphid on potato plants (Dancewiz and Gabrys, 2008). *A. annua* plant has been shown in plate 1 below. Several studies have been conducted using various species of Artemisia but insecticidal activity of *A. annua* on *A. fabae* infesting *S. scabrum* has not yet been studied.

Plate 1: *Artemisia annua* plant

2.6.2. *Thevetia peruviana*

Thevetia peruviana commonly known as yellow oleander is a medicinal plant which is a native of Central and South America, but now frequently grown throughout the tropics. It is a shrub or small tree that bears yellow or orange-yellow, trumpet like flowers and its fruit is deep red/black in color (Neeram and Anal, 2014). It contains a milky sap containing a compound called Thevetin that is used as a heart stimulant. It is also used in treatment of various disorders in human beings such as malarial fever, jaundice, headache, skin disorders, colds, diabetes, liver toxicity, fungal infection, microbial infection, inflammation, pyrexia and relieves pain (Ahmad *et al*, 2017). Its leaf is long, lance shaped and green colour. Leaves are covered in waxy coating to reduce water loss. *Thevetia peruviana* is cultivated as an ornamental plant and planted as large flowering shrub or tree standards in garden and parks in temperate climates. Crude extracts of *T. peruviana* have been effective against black pod disease, caused by *Phytophthora megakarya* Brasier. which is the most important field crop disease in cocoa beans production and causes losses (Ambang *et al.*, 2010). Crude extract of *T. peruviana* have been effectively used against mosquito larvae and it is recommended for mosquito control programme (Sathish *et al.*, 2015). The foliage is grazed on by livestock, especially goats. Studies also indicate that *T. peruviana* consists of the following phytochemical constituents: Alkaloids, steroidal glycosides, phenols, flavonoids and terpenoids (Sathish, 2015). Studies indicate that *T. peruvi*ana has effectively been used at low concentration for example in control of *Callosobruchus maculatus* F. in stored beans at concentration of 0.025 to 0.2 grams using methanol as solvent. Concentration of 0.015 to 0.035g have been used to control scarab beetles in India with a lethal concentration of 0.025 (Theurkar, 2014). Concentration of 0.05 to 0.0125 % have been used to control mosquito larva (*Aedes aegypti* L.*)* with a lethal concentration LC 50 of 0.0369 % and LC 90 of 0.0518% (Suresh, 2013). *Thevetia peruviana* plant has been shown in plate 2 below. The fact that *T. peruviana* is a locally available plant value can be added to it to control aphid on *S. scabrum* to farmers.

Also the fact that *A. annua* and *T. peruviana* are medicinal plants its worth researching on them to determine their insecticidal properties at varying concentration. Thus the objective of this work was to study the effect of various concentrations of *A. annua* and *T. peruviana* leaf extracts on *A. fabae*, predators of aphids and pollinators of *S. scabrum.*

Plate 2: *Thevetia peruviana* plants at flowering (http://www.wellgrowhorti.com).

2.7. Effects of plant extract on yield of vegetables

Piper rectrofractum Trel. and *Annona squamosal* L. plant extracts are effective in reducing the larval population of cabbage web worm *Crosidolomia pavonana* Fabricious. and a diamond black moth *Plutella xylostella* L. in cabbage. The cabbage damage decreased as yield increased (Dadang *et al*., 2011). Plant extracts of sweetsop, chilli pepper, garlic, ginger, neem and tobacco have been effective against the insect pests of cowpea variety IT86D-719 and also increased the yield. Extracts of *Tephrosia vogelii* Hook. and *Petiveria alliacea* L. have been effective in control of pests of cow pea including *Meglurothrips sjostedti* Tryborn., *Maruca vitrata* Fabricius. *Clavigralla* t*omentoscollis* Stat. and *Riptortus dentipes* Fabricius. at a concentration of 20%. There was also increase in grain yield (Alao *et al*., 2011). Effects of plant extract on yield of cabbage and cowpea has been studied but nobody has done any studies using *S. scabrum.*

2.8. Effect of plant extracts on non-target organisms.

2.8.1. Effect of plant extracts on pollinators

Studies show that bees are pollinators of tomato *Solanum lycopersicum* L. and led to high productivity and quality of seeds and fruits (Vinicius-Silva *et al.,* 2017). Occurrence of cross-pollination is another factor responsible for the wide morphogenetic variation in *Solanum spp.* Pollination is important in production of fruit which gives rise to seeds **(**Foster and Obermeyer, 2010).

Bees *Apis millifera* L. (adult workers) subjected to the diet exposed to botanicals of citronella oil, eucalyptus oil, garlic extract, neem oil, or rotenone suffered mortality rate of 42% to 60% compared with that subjected to uncontaminated food control (Xavier *et al.*, 2015).

2.8.2. Effects of plant extracts on predator of aphids

African night shade benefits from predators, for example lady bird beetles since they prey on both the larva and adults of aphid species. A survey was done in Mid Country Sri Lanka, where several species of predatory coccinellids (lady bird beetles) were identified feeding on aphids of the vegetables (Mayannage *et al*., 2009). Soldier beetles and big-eyed bug adult are predators of aphids and other insects (Merrill, 2014). Syrphid flies and lacewing are predators of aphids (Home Garden Seed Association, 2015). Ground beetles and aphid midges are predators of aphids, caterpillars and ground insects which protect vegetables from damage by insects (Bessin and Obrycki, 2011).

Mortality of lady beetles in bean fields was observed when treated with neem oil (Mollah *et al*, 2013). Rotenone and neem reduced the numbers of adult anthocorid *Orius laevigatus* Fieber. a predator of flower thrips, *Frankliniella occidentalis* Pergande (Bonsignore and Vacante, 2012).

2.8.3. Effects of plant extracts on parasites of aphids

Parasitic wasps in the family of Braconidae are parasites of aphids, besides white flies, caterpillars and cabbage loopers (Home Garden Seed Association, 2015). Ichneumonid wasps in the Family Ichneumonidae are parasites of aphids, besides caterpillars in vegetable crops, diamondback moth, cabbage looper, tobacco hornworm and corn earworm. Various vegetables benefit from Ichneumonid wasps, including solanaceous crops and sweet corn (Bessin and Obrycki, 2011).

When larvae of *Ephestia kuehniella* Zeller. as parasitoid hosts were treated with Azadirachtin, very few adult parasitoids emerged which indicated a strong detrimental effect on the parasitoid (Tunca *et al.*, 2014). Very high mortalities of parasitoid *Venturia canescens* were revealed with use of pyrethrum (Tunca *et al.*, 2012). High mortality of egg-larval parasitoid *Chelonus oculator* Panzer. (Braconidae) occured when subjected to pyrethrum (Tunca *et al.*, 2014). Oil of *Azadirachta indica* (Meliaceae) has had repellent effects on the parasitoid *Uscana lariophaga* Steffan. (Hymenoptera: Trichogrammatidae) (Tunca *et al*., 2012).

This study identified the major non-target organisms that are beneficial to *S. scabrum* and the effect when sprayed with leaf extracts of *A. annua* and *T. peruviana.*

2.8.4. Effects of synthetic insecticides on non-target organisms

In brinjal *(Solanum melongena* L.), spraying with cypermethrin and imidacloprid caused higher mortality of coccinellids, braconid wasps and predatory spiders compared to those sprayed with neem (*Azadirachta indica* L.) (Ghananand *et al*., 2011). Studies carried out to investigate the effects of chemicals on soil arthropods in agricultural area in USA found out that higher number of predators such as coccinelids and spiders were present in non-sprayed fields compared to fields sprayed with insecticides and herbicides (Amalin *et al*., 2009).

Honey bees (*Apis millifera*) have abnormal foraging when subjected to the pesticide imidacloprid and don't return to site the same way as untreated bees (Yang, 2008). Bees lost navigation and foraging skills when subjected to sub lethal doses of neonicotinyl insecticide (Krischik, 2014).

Insecticide amitraz was found to be harmful to the parasitoid wasp, *Encarsia formosa* Gahan. used to control the whitefly, *Trialeurodes vaporariorum* Westwood. (Chitgar and Ghadamyari, 2012). Mortality of *Aphidius ervi*, an important parasitoid of the pea aphid, (*Acyrthosiphon pisum*) was observed after use of insecticides dimethoate, imidacloprid and pirimicarb (Araya *et al.,* 2010). The harmful effects of insecticides to human beings include: potential risk to human and life form particularly health effects like immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities and cancer (Aktar *et al.,* 2009). Use of synthetic insecticides such as cypermethrin and thiamethoxam led to decrease in microbial activity in Romania. Micro-organisms such as nitrifying bacteria, azotobacter and ammonifying bacteria decreased in soil (Marioara *et al.,* 2015). Insecticides sprays and drifts contaminate soil, air and non-target plants (Rosendahl *et al*., 2009). Insecticides kill non-target organisms like birds, fish, and beneficial insects (Aktar *et al.,* 2009).

Studies indicate that, insecticides reduce population of non-target organism hence this study determined if leaf extracts of *A. annua* and *T. peruviana* have an impact on non-target organisms.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Site

Field experimental study was conducted within Masinde Muliro University of Science and Technology (MMUST) farm and at the Microbiology Laboratory in the Department of Biological Sciences, in Kakamega County, Western Kenya (latitude N 00 17.104’, longitude E 034^0 45.874’). MMUST is located at an altitude of 1561 metres above sea level. The study area has two rain seasons, the long rain season (April – August) and the short rain season (September – December). Mean annual rainfall is 1,800 mm, average annual temperature of 20.8°C and relative humidity ranges between 30% and 100%. The soils in MMUST have been classified as Nitisols with the properties as described in Table 1.

Table 1: Experimental plot soil composition

Nutrient	Concentration
% organic carbon	2.5
% total nitrogen	0.25
Total Phosphorus (ppm)	18.9
Potassium (cmolc kg-1)	0.41
Sodium (cmolc kg-1)	0.1
Calcium (cmolc kg-1)	2.3
Magnesium (cmolc kg-1)	0.8
Zinc (ppm)	1.9
Iron (ppm)	0.37
Soil Ph	4.2

Source: (Naluyange *et al*., 2014)

3.2. Experimental design

The experimental design was a randomized complete block design (RCBD) with six treatments and three replicates. Eighteen 18 plots measuring 3m by 3m were used. The blocks were three. The six treatments that were used included the following;

T1 – *Artemisia annua* leaf extract 0.5%.

T2 – *Artemisia annua* leaf extract 1%.

T3- *Thevetia peruviana* leaf extract 0.15%.

T4- *Thevetia peruviana* leaf extract 0.3 %.

T5- Water.

T6- Albaz 10 EC (Alpha cypermethrin 100g/L).

The African nightshade variety used was *S. scabrum* species. The experiment was conducted during the short rain season from September to December 2015 and long rains from March to July 2016.

3.3. Planting material and planting

3.3.1. Planting material

The seeds of *S. scabrum* variety were obtained from Kenya Seed Company in Kakamega town. The seeds are whitish cream, approximately 1mm in diameter. *Solanum scabrum* is preferred by farmers, consumers and aphids since the leaves are large and are not bitter as compared to *Solanum nigrum.*

3.3.2. Preparation of nursery bed

A nursery bed measuring one metre by five metres was established. The bed was prepared to a fine tilth. The seeds were planted in shallow drills and then covered with soil lightly to a depth of two centimetres since they are small seeds. A light mulch was applied but was later removed when seedlings were 3cm tall.

3.3.3. Preparation of plots and transplanting

The experimental plots were 18. Each plot measured 3m by 3m. Paths of 50 cms were used in between the plots. The distance in between the blocks was 1m. The seedbed was ploughed and harrowed to a fine tilth, and all perennial weeds were removed. Transplanting was done after 4 weeks when the seedlings height was between 10-15cm. A spacing of 50 by 30 cm was used that is 50cm inter row to another and 30 cm inter plant. This produced a total population of 40 plants per plot. During transplanting, DAP at a rate of 60 kg phosphorus per hectare was used (Opala *et al*., 2013). Well rotten farm yard manure at a rate of 7.5 tonnes per hectare (Ng'etich *et al*., 2014) was thoroughly mixed with the topsoil in each planting hole. One seedling was planted per hole and soil was firmed. The plots were rain-fed. Weeding was done every two weeks. Top dressing was done using Calcium Ammonium Nitrate (CAN) at a rate of 200kg nitrogen per hectare (Ng'etich *et al*., 2014) when plants had six to seven leaves per plant.

3.4. Botanical extract and insecticides

3.4.1. Collection and preparation of *A. annua* and *T. peruviana* leaf extracts

a. Collection

Fresh leaves of *A. annua* and *T. peruviana* were collected from two farms within Kakamega county. They were taken to the laboratory washed with water, air-dried under a shade for two (2) weeks so as to lower the initial moisture content to enable its prolonged storage life. *Thevetia peruviana* leaves took a long time to dry due to its thick waxy cuticle.

b. Preparation of *A. annua* and *T. peruviana* leaf dust

Dust was prepared by crushing the dried leaves of *A. annua* and *T. peruviana* separately using a pulverizer. The dust was passed through a 25 mm mesh diameter to obtain fine and uniform dust. The dust was preserved separately in an air-tight condition in polythene bags.

c. Extraction

Both leaf extract of *A. annua* and *T. peruviana* were prepared separately as follows: 600 g of *A. annua* dust and 600 g of *T. peruviana* dust were used; 150 g of dried powder of *A. annua* and *T. peruviana* were weighed separately using an electric weighing balance and put into two one litre conical flask and extracted by maceration with 750 ml of methanol which means ratio of dust to methanol of 1:5. The mixtures were each shaken for 48 hours using a shaking machine at 100 revolutions per minute at room temperature. The mixtures were filtered separately using Whatman no. 4 filter paper to obtain the filtrate. Methanol was evaporated from the filtrate by rotary evaporator shown in plate 3 below at 45ºC under reduced pressure which produced crude methanol extract (Khosravi *et al*., 2010).

The crude extract was weighed using an electric balance as follows: 20 g of *A. annua* and 6 g *T. Peruviana* which were each dissolved in one litre of distilled water to get stock solution and then further dilutions were made using distilled water to come up with concentrations of *T. peruviana* 0.15%, *T. peruviana* 0.3%, *A. annua* 0.5% and *A. annua* 1%. *A. annua* 1% has been used to control green peach aphid on potato plants (Dancewiz and Gabrys, 2008). Concentrations of 0.015g, 0.02g, 0.025g, 0.03g and 0.035g have been used to control scarab beetles in India (Theurkar, 2014). Concentrations of 0.05, 0.025 and 0.0125% have been used to control mosquito larva (Suresh, 2013).

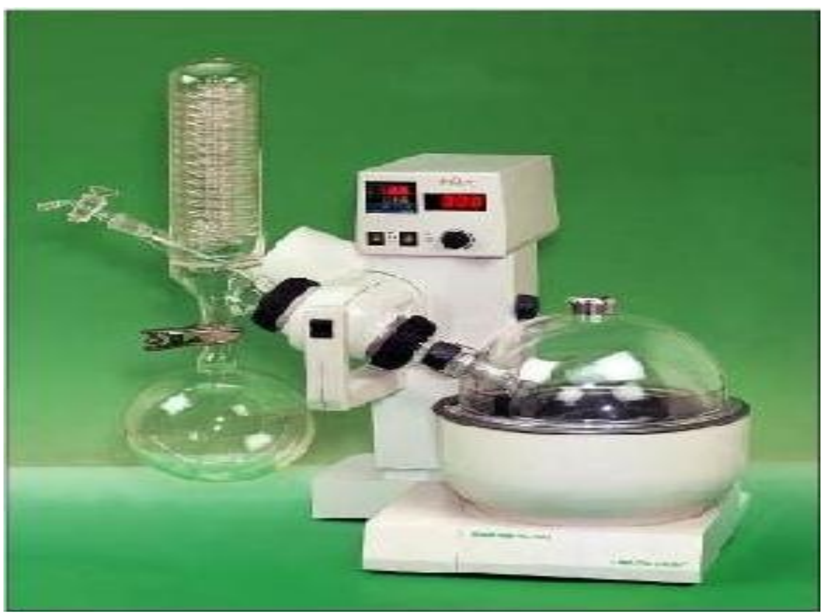


Plate 3: Rotary evaporator for removing solvent methanol.

3.4.2. Dilution of Albaz 10 EC.

Albaz 10 EC was bought from Kenya Farmers Association and diluted as per the recommended dose which was 1 ml in 2 litres of water.

3.4.3. Spraying.

Spraying of the botanical insecticides of *T. peruviana* 0.15%, *T. peruviana* 0.3 %, *A. annua* 0.5% and *A. annua* 1%, water and Albaz 10 EC were each carried out using a hand sprayer at intervals of 14 days. Spraying was done early in the morning to prevent decomposition of leaf extracts. The negative controls were sprayed at the same time using distilled water. The *S. scabrum* plants were sprayed three times during the experimental period.

3.5. Data Collection

3.5.1. Sampling of *Aphis fabae* population

Ten plants were randomly selected per plot and tagged for counting the *A. fabae* population density. Counting was done on these tagged plants using a tally counter to ensure that the aphids are not tampered with.

Population density of *A. fabae* was taken before spraying after which spraying was applied. Subsequent data of *A. fabae* population density was taken at an interval of 3 days as follows: days 1, 4, 7, 10 and 13. On 14th day spraying was done and data collection was carried out in the following order: days 15, 18, 21, 24 and 27.

3.5.2. Sampling of growth and yield parameters

Assessment of damage caused by *A. fabae* was started five weeks after transplanting the plants on to the seedbed. Leaf damage caused by *A. fabae* on *S. scabrum* was assessed by direct inspection of plants per plot. The plants were inspected to see if they were infested by turning the leaves. Crinkling of leaves in mid vein and wilting was inspected and then the number of leaves damaged per plant counted.

Growth parameters included plant height (cm), leaf width (cm), number of flowered plants, number of plants with formed fruits, number of plants with ripened fruits and total weight of fresh and dry leaves, stems and seeds (Kgs) per plot.

Five plants were randomly selected and tagged, to determine height per plot in all the treatments. Plant height was measured from ground level to the tip of the terminal bud at an interval of one week after spraying. Leaf width was also measured at an interval of one week by measuring the first two fully expanded leaves from the terminal bud of the selected plants. The stage of flowering of the plants per treatment was determined by physically counting the number of plants that had flowered after spraying on weekly intervals. Fruit formation was taken per treatment by counting number of plant with formed fruits and finally plants with ripened fruits. The yield component consisted of fresh and dry weight of leaves, stems and seeds per plot. Weighing was done using a weighing scale. Drying was done using a sun drier.

3.5.3. Sampling of non-target organisms

Diversity of all non-target organisms was assessed in the field by observing and counting all organisms that were found on plots and recording them. Non-target organisms included predators and pollinators. Deliberate inspection and observation in the plots was done and scoring done. Scoring was done at a time limit of a half an hour per plot. A sweep net was used to collect flying insects and beneficial ones were counted from the catch which included honey bees and bumble bees. Three sweeps were done three times per plot and collections put in a labelled specimen bottle which was covered with a muslin cloth to allow aeration and ensure they don't escape. Ants, ladybird beetles and scarab beetles were collected, counted and placed in specimen bottles which had been labelled as per treatment. Thereafter the collected insects were taken to MMUST Microbiology laboratory for identification under a microscope. Taxonomic key adopted by (Dotson *et al*., 2010), was used.

3.6. Data Analysis

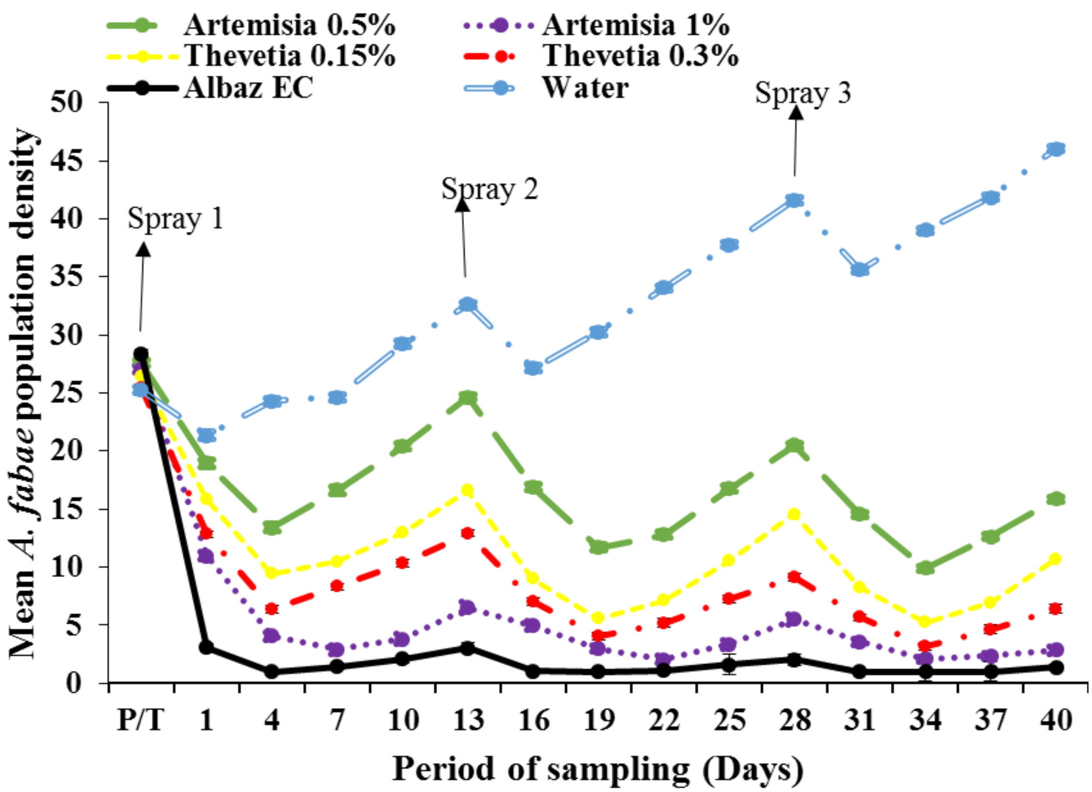
Statistical analysis was conducted using IBM SPSS software statistic version 20. ANOVA was used to compare the means and Turkey Post hoc test values were used to separate the significantly different means at $p \leq 0.05$. Descriptive statistics included means and standard errors for numerical data such as *A. fabae* population density, plant height, leaf width, non-target organisms population density and fresh and dry weight of seeds, stems and leaves.

CHAPTER FOUR

RESULTS

4.1. Effect of leaf extracts of *A. annua* and *T. peruviana* on population of *A. fabae* infesting *S. scabrum.*

During the short rains there were significant differences ($p<0.0001$) in aphid population density among the six treatments (Figure 1).

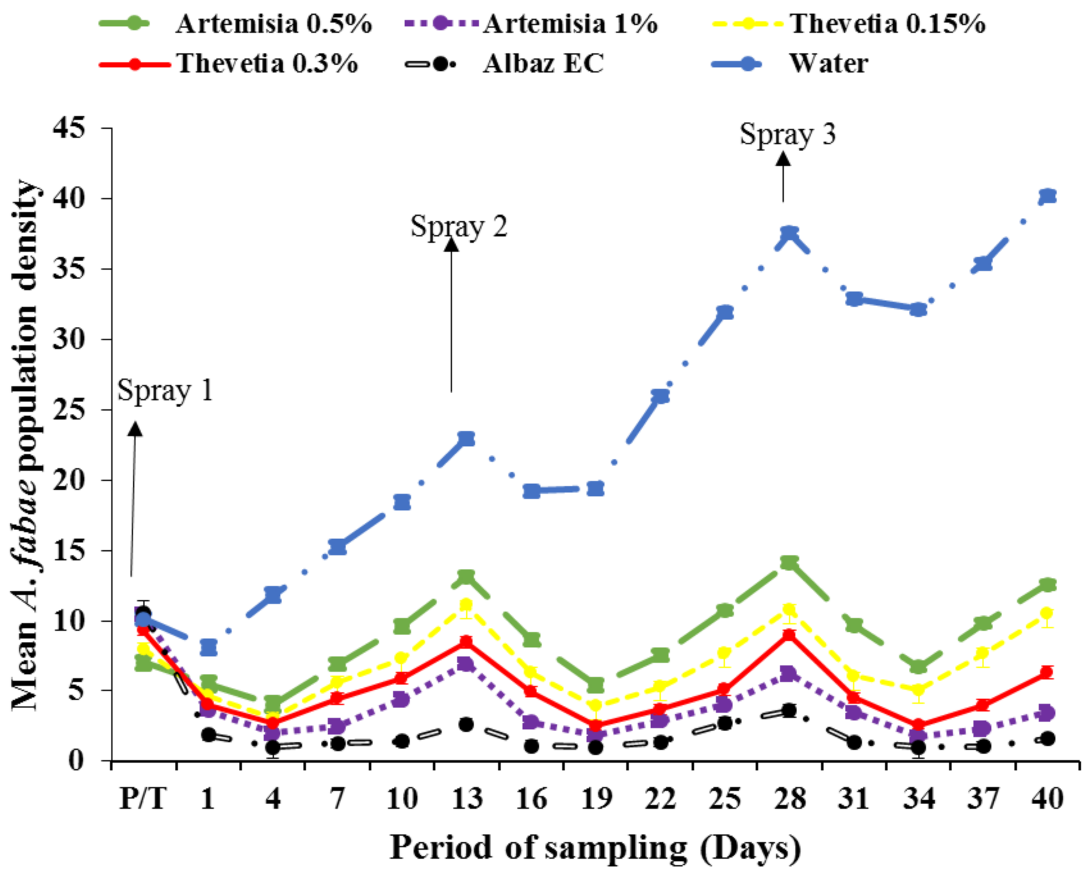


P/T refers to pretreatment sample of aphid population density taken before first spraying.

Figure 1: Mean (± SE) number of *A. fabae* population density on *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short rains season.

The results showed that application of all the leaf extracts and Albaz 10 EC significantly (p<0.0001) reduced the population density of *A. fabae*, throughout the period of forty days when compared to water. Among the leaf extracts, *A. annua* 1% concentration had highest reduction of *A. fabae* population density throughout the season where as *A. annua* 0.5% concentration was significantly (p<0.0001) the lowest in reduction of population density of *A. fabae*. *Artemisia annua* 0.5% and *T. peruviana* 0.15% concentrations recorded significantly (p<0.0001) lower reduction in *A. fabae* population density when compared to *A. annua* 1% and *T. peruviana* 0.3% concentrations. The plots treated with Albaz 10 EC had significantly (p<0.0001) the highest reduction of population density of *A. fabae* when compared to those treated with leaf extracts. The plots treated with water recorded the highest population density of *A. fabae* throughout the sampling period when compared to those treated with leaf extracts.

During long rains among the leaf extracts *A. annua* 1% concentration had significantly (p<0.0001) highest reduction of *A. fabae* population. *Artemisia annua* 0.5% concentration was significantly (p<0.0001) the lowest in reduction of population density of *A. fabae*. The plots treated with water recorded the highest population density of *A. fabae* compared to those treated with leaf extracts (Figure 2). The long rains had a significantly (p<0.0001) lower aphid population density when compared to the short rains season.



P/T refers to pretreatment sample of aphid population density taken before first spraying.

Figure 2: Mean (± SE) number of *A. fabae* population density on *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during long rains season.

The plots treated with Albaz 10 EC had significantly ($p<0.0001$) highest reduction of population density of *A. fabae* when compared to those treated with leaf extracts for both long and short rain seasons. The plots treated with water recorded the highest population density of *A. fabae* throughout the three sprays for both long and short rain seasons when compared to those treated with leaf extracts. There were significant differences in aphid population densities among all the treatments (df = 179; F= 100.63; $p< 0.0001$) for short and long rain seasons respectively (Figure 1 and 2).

4.2. Leaf damage of *S. scabrum* treated with leaf extracts of *A. annua and T. peruviana* during short and long rains season.

During the short rains season, leaf damage caused by aphid infestation was significantly ($p<0.0001$) higher in plots treated with *A. annua* 0.5% concentration which had a mean of 49.33 damaged leaves per plot (Table 2).

Table 2: Mean (±SE) number of damaged leaves per plot on *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rain seasons.

Treatments	Number of damaged leaves
Short rains season	
A. annua 0.5%	49.33±0.88b
A. annua 1%	24.67±1.20ef
T. peruviana 0.15%	42.67±1.70c
T. peruviana 0.3%	27.00±0.58e
Albaz 10 EC	10.67±2.96i
Water	71.33±0.33a
Long rains season	
A. annua 0.5%	36.00±0.58d
A. annua 1%	15.00±0.58gh
T. peruviana 0.15%	30.00±0.58de
T. peruviana 0.3%	20.00±0.58fg
Albaz 10 EC	10.33±0.33i
Water	65.67±0.33a
Test values; (df = 11; F= 287.96 ; p< 0.0001)	

Means with same letters within same column are not significantly different at ($p \leq 0.05$).

The means are compared within the columns for all the seasons.

Leaf damage was lower in plots treated with *A. annua* 1% concentration which had a mean of 24.67 damaged leaves per plot. Leaf damage was significantly ($p<0.0001$) higher in plots treated with *T. peruviana* 0.15% concentration as compared to those treated with *T. peruviana* 0.3% concentration. The plots treated with water exhibited the highest mean number of damaged leaves as compared to those treated with leaf extracts. Leaf damage was significantly ($p<0.0001$) lower in plots treated with Albaz 10 EC as compared to those treated with leaf extracts.

During the long rains, leaf damage caused by aphid infestation was significantly ($p<0.0001$) higher in plots treated with *A. annua* 0.5% concentration which had a mean of 36 damaged leaves per plot (Table 2). Leaf damage was lower in plots treated with *A. annua* 1% concentration which had a mean of 15 damaged leaves per plot. The plots treated with water exhibited the highest mean number of damaged leaves as compared to those treated with leaf extracts. Leaf damage was significantly ($p<0.0001$) lower in plots treated with Albaz 10 EC as compared to those treated with leaf extracts.

Leaf damage was significantly ($p<0.0001$) higher during short rains as compared to long rains season. Leaf damage was similar in plots treated with Albaz 10 EC as compared to those treated with leaf extracts for both the long and short rain seasons (Table 2) ($df = 11$; $F= 287.96$; $p< 0.0001$).

4.3. Effect of leaf extracts of *A. annua* and *T. peruviana on S. scabrum* growth and yield parameters.

4.3.1. Plant height

During the short rains season, there were significant differences ($p < 0.0001$) in plant height between the six treaments (Table 3). The plants treated with *A. annua* 1% concentration were significantly ($p < 0.0001$) the tallest when compared to other leaf extracts with a mean height of 124.48 cm being recorded. The plants treated with leaf extracts of *A. annua* 0.5% concentration were significantly the shortest with a mean height of 111.76 cm being recorded. Plants treated with leaf extracts of *T. peruviana* 0.3% and *A. annua* 1% concentrations were taller when compared to plants treated with leaf extracts of *T. peruviana* 0.15% and *A. annua* 0.5% concentrations. Plants treated with water recorded were significantly ($p < 0.0001$) shorter when compared to leaf extracts. Plants treated with Albaz 10 EC were significantly ($p < 0.0001$) taller when compared to plants treated with leaf extracts.

During the long rains season there were significant differences ($p < 0.0001$) in plant height between the six treaments (Table 3). Plants treated with *A. annua* 1% concentration were significantly ($p < 0.0001$) the tallest when compared to other leaf extracts with a mean height of 127.11 cm being recorded. The plants treated with *A. annua* 0.5 % concentration were significantly the shortest with a mean height of 116.68 cm being recorded. Plants treated with water recorded were significantly ($p < 0.0001$) shorter when compared to leaf extracts. Plants treated with Albaz 10 EC were significantly ($p < 0.0001$) taller when compared to plants treated with leaf extracts.

The *S. scabrum* plants were significantly taller during the long rains season as compared to the short rains seasons. Water had similar mean height in both the long and short rain seasons. There were significant differences in plant height among all the treatments in both short and long rain seasons (df = 83; F = 254.39; $p < 0.0001$) (Table 3).

Table 3: Mean (±SE) plant height (cm) per plant of *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rain seasons.

Treatments	P/T	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Grand mean
				Short rains season				
A.annua 0.5%	76.53±1.51a	84.33±0.69b	99.33±1.79g	109.20±2.51h	121.40±2.38h	125.46±2.28g	133.26±2.45g	111.76±0.03d
A.annua 1%	76.60±1.52a	86.20±1.53b	105.47±1.67d	124.13±1.69c	136.73±1.82c	142.67±1.43b	151.67±0.76b	124.48±0.04ab
T.peruviana 0.15%	79.00±1.67a	84.20±1.55b	101.40±1.37f	113.67±1.68g	125.60±1.66g	130.33±1.69f	138.60±1.54f	115.81±0.05cd
T.peruviana 0.3%	79.10±1.67a	85.31±1.01b	103.07±1.67e	121.60±2.50e	128.80±2.30e	137.13±2.10d	145.60±0.91c	119.29±0.04bc
Albaz 10 EC	77.13±1.50a	87.00±1.94b	105.00±2.39d	126.33±2.04b	140.27±1.38b	149.00±0.73a	161.73±0.72a	127.58±0.04ab
Water	78.66±1.67a	83.07±1.38b	98.60±0.91h	107.60±1.05h	112.60±0.75j	120.60±0.49h	127.22±0.66h	111.03±0.07d
				Long rains season				
A.annua 0.5%	70.47±2.30a	84.27±2.37b	106.53±1.42d	117.93±2.61f	126.27±2.33f	131.07±2.28e	133.40±2.29g	116.68±0.03cd
A.annua 1%	71.67±2.63a	90.53±1.43a	113.40±2.48b	126.13±1.69b	136.43±3.44c	143.67±3.17b	146.53±3.13c	127.11±0.04ab
T.peruviana 0.15%	74.13±1.30a	85.60±0.90b	107.27±1.94d	121.73±1.43e	132.53±1.66d	138.20±1.57d	141.53±1.56e	122.29±0.05ab
T.peruviana 0.3%	73.67±0.90a	90.13±0.90a	110.00±1.90c	122.80±1.65d	136.53±1.10c	140.73±0.90c	143.67±0.91d	123.16±0.04ab
Albaz 10 EC	70.87±1.61a	89.93±1.30a	114.20±1.89a	132.13±2.05a	143.73±1.79a	150.87±1.56a	153.90±1.56a	130.79±0.04a
Water	72.20±1.67a	83.07±0.88b	105.20±1.29d	113.87±1.26g	119.47±0.75i	123.47±1.30f	126.40±0.66i	111.91±0.07d

Test values; df = 83; F = 254.39; P< 0.0001)

Means with same letters within same column are not significantly different at (p≤ 0.05), The means are compared within the columns for all the seasons.

4.3.2. Leaf width

During the short rains season there were significant differences ($p < 0.0001$) in leaf width of the fully expanded leaf of terminal shoot between the six treaments (Table 4). The plants treated with *A. annua* 1% concentration had significantly ($p < 0.0001$) the widest leaf width of 5.21 cm being recorded when compared to other leaf extracts. The plants treated with *A. annua* 0.5% concentration had significantly ($p < 0.0001$) the narrowest leaf width of 4.42 cm being recorded. Plants treated with leaf extracts of *T. peruviana* 0.3% and *A. annua* 1% concentrations had wider leaf width as compared to *S. scabrum* plants treated with leaf extracts of *T. peruviana* 0.15% and *A. annua* 0.5% concentrations. The plants treated with water recorded a significantly ($p < 0.0001$) lower leaf width when compared to leaf extracts. The plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) wider leaf width when compared to plants treated with leaf extracts.

During the long rains season there were significant differences ($p < 0.0001$) in leaf width of the fully expanded leaf of terminal shoot between the six treaments (Table 4). The plants treated with *A. annua* 1% concentration had significantly ($p < 0.0001$) the widest leaf width of 5.46 cm being recorded when compared to other leaf extracts. The plants treated with *A. annua* 0.5% concentration had significantly ($p < 0.0001$) the narrowest leaf width of 4.36 cm being recorded. The plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) wider leaf width when compared to plants treated with leaf extracts. The plants treated with water recorded a significantly ($p < 0.0001$) lower leaf width when compared to leaf extracts.

The *S. scabrum* plants had wider leaf width during the long rains season as compared to the short rains seasons. Plants treated with water and *A. annua* 0.5% concentration had similar mean leaf width in both the long and short rain seasons. During the long rains plants treated with *T. peruviana* 0.3% concentration had wider leaf width compared to short rains season. There were significant differences in leaf width among all the treatments in both short and long rain seasons (df = 83; F= 196.83; $p < 0.0001$) (Table 4).

Table 4: Mean (±SE) leaf width (cm) per plant of *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rain seasons.

Treatment	P/T	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Grand mean
Short rains season								
A.annua 0.5%	4.03±0.04g	4.12±0.03g	4.20±0.03h	4.32±0.04h	4.48±0.03h	4.63±0.03h	4.78±0.04h	4.42±0.03de
A.annua 1%	4.15±0.04e	4.55±0.05c	4.93±0.04h	5.13±0.03e	5.33±0.05d	5.55±0.05d	5.73±0.04d	5.21±0.04bc
T.peruviana 0.15%	4.11±0.03f	4.38±0.04f	4.55±0.03f	4.68±0.03g	4.83±0.03g	5.02±0.05f	5.17±0.05f	4.77±0.05d
T.peruviana 0.3%	4.19±0.04c	4.48±0.04d	4.72±0.06e	4.92±0.04f	5.10±0.03e	5.32±0.05e	5.48±0.04e	5.00±0.04c
Albaz 10 EC	4.17±0.06d	4.58±0.10b	4.90±0.08c	5.17±0.05d	5.57±0.04c	5.95±0.07b	6.13±0.04a	5.38±0.04ab
Water	3.90±0.04i	4.07±0.04h	4.01±0.03d	4.22±0.04dj	4.25±0.03de	4.33±0.03j	4.42±0.02k	4.23±0.07de
Long rains season								
A.annua 0.5%	3.90±0.04i	4.07±0.05h	4.17±0.05g	4.23±0.05i	4.40±0.04i	4.57±0.03i	4.72±0.04i	4.36±0.03de
A.annua 1%	4.37±0.06a	4.71±0.07a	5.05±0.05a	5.37±0.05a	5.70±0.06a	5.90±0.06b	6.03±0.04b	5.46±0.04a
T.peruviana 0.15%	4.27±0.04b	4.43±0.04e	4.53±0.04d	4.68±0.05g	4.84±0.05f	4.97±0.06g	5.07±0.06g	4.75±0.05d
T.peruviana 0.3%	4.29±0.03b	4.53±0.02c	4.92±0.06b	5.28±0.07b	5.52±0.08c	5.63±0.08c	5.75±0.07c	5.27±0.04ab
Albaz 10 EC	4.35±0.03a	4.55±0.03c	4.85±0.03d	5.25±0.05c	5.65±0.05b	6.00±0.07a	6.33±0.04a	5.44±0.04a
Water	3.95±0.03h	4.02±0.03i	4.08±0.03i	4.13±0.02i	4.25±0.03j	4.37±0.03j	4.53±0.02j	4.23±0.07de

Test values: (df = 83; F= 196.83; P< 0.0001)

Means with same letters within same column are not significantly different at (p>0.05), The means are compared within the columns for all the seasons.

4.3.3. Flowering stage

During the short rains season there were significant differences ($p < 0.0001$) in flowering among the six treatments (Table 5).

Table 5: Mean (±SE) number of *S. scabrum* plants per plot with flowers when treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rains season.

Treatments	Week 1	Week 2	Week 3	Grand mean
Short rains season				
A. annua 0.5%	7.0±0.6b	2.7±0.63e	32.3±0.7f	20.7±0.6e
A. annua 1%	7.0±0.6b	27.0±0.2a	37.0±0.3b	23.8±0.6b
T. peruviana 0.15%	8.0±0.6a	22.7±0.6e	34.0±0.2e	21.6±0.6d
T. peruviana 0.3%	6.0±0.6c	25.3±0.7b	35.7±0.3d	22.3±0.6c
Water	6.0±0.6c	20.3±0.6g	30.7±0.3h	19.0±0.2f
Albaz 10 EC	8.0±0.6a	27.0±0.3a	38.3±0.6a	24.4±0.3a
Long rains season				
A. annua 0.5%	6.7±0.3	20.3±0.3g	31.3±0.3g	19.4±0.3f
A. annua 1%	7.7±0.6b	24.7±0.9c	36.0±0.9c	22.8±0.2c
T. peruviana 0.15%	7.0±0.3b	21.7±0.3f	32.7±0.3f	20.4±0.2e
T. peruviana 0.3%	7.0±0.3b	23.7±0.6d	34.3±0.6e	21.7±0.3d
Water	6.7±0.6c	19.0±0.6h	30.0±0.6h	18.5±0.6g
Albaz 10 EC	7.0±0.6b	25.0±0.6b	38.0±0.6a	23.6±0.6b

Means with same letters within same column are not significantly different at ($p>0.05$), The means are compared within the columns for all the seasons.

Plots treated with *A. annua* 1% concentration recorded a significantly ($p < 0.0001$) higher number of plants per plot that had flowered with a mean of 23.8 being recorded when compared to other leaf extracts. Plots treated with *A. annua* 0.5% concentration had significantly $p < 0.0001$) lower number of plants that had flowered with a mean of 20.7 being recorded. *Thevetia peruviana* 0.3% concentration had higher number of plants per plot that had flowered as compared to *T. peruviana* 0.15% concentration. Plants treated with water recorded a significantly ($p < 0.0001$) the least number of plants per plot that had flowered when compared to those treated with leaf extracts with a mean of 19 being recorded. Plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) higher number of plants per plot that had flowered when compared to the *S. scabrum* plants treated with leaf extracts.

During the long rains season there were significant differences ($p < 0.0001$) in flowering among the six treatments (Table 5). Plots treated with *A. annua* 1% concentration recorded a significantly ($p < 0.0001$) higher number of plants per plot that had flowered with a mean of 22.8 being recorded when compared to other leaf extracts. Plots treated with *A. annua* 0.5% concentration had significantly ($p < 0.0001$) lower number of plants that had flowered with a mean of 19.4 being recorded. *Thevetia peruviana* 0.3% concentration had higher number of plants per plot that had flowered as compared to *T. peruviana* 0.15% concentration. Plants treated with water recorded a significantly ($p < 0.0001$) the least number of plants per plot that had flowered when compared to those treated with leaf extracts with a mean of 18.5 being recorded. Plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) higher number of plants per plot that had flowered when compared to the *S. scabrum* plants treated with leaf extracts.The long rains season had higher number of plants that had flowered as compared to those of the short rains season. There were significant differences in flowering among all the treatments in both short and long rain seasons (df = 35; F= 334.30; p< 0.0001) (Table 5).

4.3.4. Fruit formation

During the short rains season, there were significant differences (p< 0.0001) in fruit formation among the six treatments (Table 6).

Table 6: Mean (±SE) number of *S. scabrum* plants per plot with fruits when treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rains season.

Treatments	Week 1	Week 2	Week 3	Grand mean
Short rains season				
A. annua 0.5%	7.0±0.6e	14.3±0.9i	26.0±0.7j	15.8±0.6h
A. annua 1%	9.7±0.6c	19.7±0.6f	30.7±0.6e	20.3±0.6d
T. peruviana 0.15%	8.0±0.6d	17.0±0.6h	27.3±0.6i	17.4±0.6g
T. peruviana 0.3%	8.7±0.6d	18.0±0.7g	28.7±0.3f	18.4±0.3f
Water	5.2±0.3f	11.7±0.9j	20.0±0.9k	12.2±0.6i
Albaz 10 EC	8.0±0.3d	20.0±0.8e	32.0±0.6c	20.0±0.8d
Long rains season				
A. annua 0.5%	9.3±0.6c	21.3±0.3d	27.7±0.3g	19.4±0.3e
A. annua 1%	11.7±0.7a	24.7±0.9b	33.3±0.9b	23.2±0.2b
T. peruviana 0.15%	9.0±0.3c	24.3±0.3b	30.0±0.3e	21.1±0.3c
T. peruviana 0.3%	10.0±0.3b	23.3±0.6c	31.0±0.3d	21.5±0.3c
Water	8.3±0.3d	20.0±0.6e	26.0±0.8h	18.1±0.6f
Albaz 10 EC	11.3±0.3a	26.3±0.6a	36.0±0.8a	24.5±0.6a

Means with same letters within same column are not significantly different at (p>0.05), The means are compared within the columns for all the seasons.

Plots treated with *A. annua* 1% concentration recorded a significantly ($p < 0.0001$) higher number of plants per plot that had formed fruits with a mean of 20.3 being recorded when compared to other leaf extracts. Plots treated with *A. annua* 0.5% concentration had significantly ($p < 0.0001$) lower number of plants that had formed fruits with a mean of 15.8 being recorded. *Thevetia peruviana* 0.3% concentration had higher number of plants per plot that had formed fruits as compared to *Thevetia peruviana* 0.15% concentration. Plants treated with water recorded a significantly ($p < 0.0001$) the least number of plants per plot that had formed fruits when compared to those treated with leaf extracts with a mean of 12.2 being recorded. Plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) higher number of plants per plot that had formed fruits when compared to the *S. scabrum* plants treated with leaf extracts.

During the long rains season, there were significant differences ($p < 0.0001$) in fruit formation among the six treatments (Table 6). Plots treated with *A. annua* 1% concentration recorded a significantly ($p < 0.0001$) higher number of plants per plot that had formed fruits with a mean of 23.2 being recorded when compared to other leaf extracts. Plots treated with *A. annua* 0.5% concentration had significantly ($p < 0.0001$) lower number of plants that had formed fruits with a mean of 19.4 being recorded. *Thevetia peruviana* 0.3% concentration had higher number of plants per plot that had formed fruits as compared to *T. peruviana* 0.15% concentration. Plants treated with water recorded a significantly ($p < 0.0001$) the least number of plants per plot that had formed fruits when compared to those treated with leaf extracts with a mean of 18.1 being recorded. Plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) higher number of plants per plot that had formed fruits when compared to the *S.*

scabrum plants treated with leaf extracts.The long rains season had higher number of plants that had formed fruits as compared to those of the short rains season. There were significant differences in fruit formation among all the treatments in both short and long rain seasons (df = 35; F= 334.30; p< 0.0001) (Table 6).

4.3.5. Fruit ripening

During the short rains season there were significant differences (p< 0.0001) in fruit ripening between the six treatments (Table 7).

Table 7: Mean (±SE) number of *S. scabrum* plants per plot with ripened fruits when treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rains season.

Treatments	Week 1	Week 2	Week 3	Grand mean
Short rains season				
A. annua 0.5%	3.3±0.3g	10.0±0.6g	17.7±0.7h	10.3±0.3h
A. annua 1%	7.0±0.6c	15.7±0.6d	24.3±0.8e	15.7±0.2d
T. peruviana 0.15%	5.0±0.3e	12.0±0.8f	21.3±0.6g	12.8±0.6g
T. peruviana 0.3%	6.3±0.6d	13.7±0.7e	22.3±0.3f	14.1±0.3e
Water	2.3±0.6h	9.0±0.6h	16.0±0.8i	9.1±0.6i
Albaz 10 EC	8.0±0.3b	17.3±0.8b	26.3±0.6c	17.2±0.8b
Long rains season				
A. annua 0.5%	5.0±0.8e	13.7±0.3e	22.0±0.6f	13.6±0.3f
A. annua 1%	7.7±0.6c	17.7±0.9b	27.0±0.8b	17.4±0.2b
T. peruviana 0.15%	6.7±0.3d	15.7±0.3d	24.7±0.8e	15.7±0.3d
T. peruviana 0.3%	6.7±0.3d	16.3±0.6c	25.0±0.8d	16.0±0.3c
Water	4.0±0.6f	12.3±0.6f	21.0±0.3g	12.4±0.6g
Albaz 10 EC	9.0±0.6a	18.7±0.6a	28.3±0.8a	18.7±0.6a

Means with same letters within same column are not significantly different at (p>0.05), The means are compared within the columns for all the seasons.

Plots treated with *A. annua* 1% concentration recorded a significantly ($p < 0.0001$) higher number of plants per plot that had ripened fruits with a mean of 15.7 being recorded when compared to other leaf extracts. Plots treated with *A. annua* 0.5% concentration had significantly $p < 0.0001$) lower number of plants that had ripened fruits with a mean of 10.3 being recorded. *Thevetia peruviana* 0.3% concentration had higher number of plants per plot that had ripened fruits as compared to *T. peruviana* 0.15% concentration. Plants treated with water recorded a significantly ($p < 0.0001$) the least number of plants per plot that had ripened fruits when compared to those treated with leaf extracts with a mean of 9.1 being recorded. Plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) higher number of plants per plot that had ripened fruits when compared to the *S. scabrum* plants treated with leaf extracts.

During the long rains season, there were significant differences ($p < 0.0001$) in fruit fripening among the six treatments (Table 7). Plots treated with *A. annua* 1% concentration recorded a significantly ($p < 0.0001$) higher number of plants per plot that had ripened fruits with a mean of 17.4 being recorded when compared to other leaf extracts. Plots treated with *A. annua* 0.5% concentration had significantly ($p < 0.0001$) lower number of plants that had ripened fruits with a mean of 13.6 being recorded. *Thevetia peruviana* 0.3% concentration had higher number of plants per plot that had ripened fruits as compared to *T. peruviana* 0.15% concentration. Plants treated with water recorded a significantly ($p < 0.0001$) the least number of plants per plot that had ripened fruits when compared to those treated with leaf extracts with a mean of 18.1 being recorded. Plants treated with Albaz 10 EC recorded a significantly ($p < 0.0001$) higher number of plants per plot that had ripened fruits when compared to the *S.*

scabrum plants treated with leaf extracts.The long rains season had higher number of plants that had ripened fruits as compared to those of the short rains season. There were significant differences in fruit ripening among all the treatments in both short and long rain seasons (df = 35; F= 334.30; p< 0.0001) (Table 7).

4.3.6. Weight of leaves, stems and seeds

There were significant differences (p< 0.0001) among all treatments in the yield of fresh and dry leaves, stems and seeds of *S. scabrum* (Table 8). During the short rains season, plants treated with *A. annua* 1% concentration had significantly (p< 0.0001) highest weight of fresh and dry leaves, stems and seeds per plot (Table 8). These was followed by plants treated with *T. peruviana* 0.3% and *T. peruviana* 0.15%. The plants treated with *A. annua* 0.5% concentration had significantly (p< 0.0001) lowest weight of fresh and dry leaves, stems and seeds per plot. All the plants treated with leaf extracts resulted into higher yield as compared to those treated with negative control (water). Plants treated with Albaz 10 EC had the highest yield of both fresh and dry leaves, seeds and stems per plot as compared to those treated with leaf extracts. Plants treated with water had significantly lowest yield as compared to those treated with leaf extracts.

During the long rains season there were significant differences (p< 0.0001) among all treatments in the yield of fresh and dry leaves, stems and per plot of *S. scabrum* (Table 8). The plants treated with *A. annua* 1% concentration had significantly (p< 0.0001) highest weight of fresh and dry leaves, stems and seeds per plot (Table 8). These was followed by plants treated with *T. peruviana* 0.3% and *T. peruviana* 0.15%. The plants treated with *A. annua* 0.5% had significantly (p< 0.0001) lowest weight of fresh and dry leaves, stems and seeds per plot. The plants treated with Albaz 10 EC had the highest yield of both fresh and dry leaves, seeds and stems per plot as compared to those treated with leaf extracts. Plants treated with water had significantly lowest yield as compared to those treated with leaf extracts.

The long rains season had a slightly higher yield of fresh and dry leaves, stems and seeds as compared to those of short rains season. There were significant differences in weight of fresh and dry leaves, stems and seeds among all the treatments in both short and long rain seasons. (df = 11; F= 102.60- Fresh leaves; F=52.20- Dry leaves; F= 76.96-Fresh seeds; F= 68.49- Dry seeds; F= 68.49- Fresh stems; F=117.75-Dry stems; $p < 0.0001$) (Table 8).

Table 8: Mean (± SE) weight (Kg) per plot (9m^2) of fresh and dry leaves, stems and seeds of *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rains season.

	Short rains season					
	Fresh weight(Kg)			Dry weight(Kg)		
Treatments	**Leaves**	**Stems**	**Seeds**	**Leaves**	**Stems**	**Seeds**
A. annua 0.5%	0.58±0.01f	7.10±0.18gh	15.12±0.30ef	0.38±0.01gh	1.82±0.03hi	0.92±0.03ghi
A. annua 1%	0.89±0.04bc	10.65±0.12cd	21.14±0.65bc	0.60±0.04cd	2 .62±0.12de	1.36±0.08cd
T. peruviana 0.15%	0.63±0.02ef	8.74±0.10ef	15.53±0.59ef	0.41±0.01fgh	1.95±0.03ghi	1.04±0.03fgh
T. peruviana 0.3%	0.78±0.02cde	9.10±0.20e	1 7.84±0.58de	0.50±0.01def	2.20±0.03fgh	1.13±0.02fg
Albaz 10 EC	1.17±0.04a	12.82±0.48b	25.33±0.67a	0.74±0.03ab	3.23±0.10b	1.72±0.07ab
Water	0.44±0.02h	5.45±0.13i	11.74±0.30g	0.32±0.02h	1.41 ±0.04j	0.74±0.03i
	Long rains season					
A. annua 0.5%	0.65±0.01ef	7.43±0.18gh	15.79±0.40ef	0.41±0.02fgh	1.91±0.06ghi	1.07±0.03fgh
A. annua 1%	0.98±0.04b	11.53±0.20c	22.46±0.60b	0.63±0.04bc	2.97±0.07cd	1.57±0.04bc
T. peruviana 0.15%	0.74±0.01def	8.74±0.10ef	17.27±0.50de	0.46±0.01efg	2.24±0.06efg	1.20±0.03ef
T. peruviana 0.3%	0.86±0.02bcd	9.69±0.50de	19.24±0.50c	0.53±0.01cde	2.50±0.01ef	1.34±0.04de
Albaz 10 EC	1.29±0.03a	14.14±0.42a	27.07±0.89a	0.81±0.04a	3.63±0.13a	1.91±0.06a
Water	0.56±0.01fg	6.19±0.14h	12.78±0.18fg	0.35±0.01gh	1.59±0.05i	0.89±0.01hi

Test values (df = 11; F= 102.60- Fresh leaves; F=52.20- Dry leaves; F= 76.96-Fresh seeds; F= 68.49- Dry seeds; F= 68.49- Fresh stems; F=117.75-Dry stems; p< 0.0001)

Means with same letters within same column are not significantly different at (p≤ 0.05), The means are compared within the columns for all the seasons.

4.4 Effect of leaf extracts of *A. annua* and *T. peruviana* on non-target organisms.

4.4.1 Effect of leaf extracts of *A. annua* and *T. peruviana* on bee pollinators.

Bees comprised of honey bees and bumble bees. During the short rains, there were significance differences ($p<0.0001$) in the population of bees between the treatments. Among the leaf extracts the plots treated with *A. annua* 1% concentration had the highest reduction in the population of bees with a mean of 7.17 bees per plot. These was followed by *T. peruviana* 0.3% and *T. peruviana* 0.15% concentrations (Table 9). Plots treated with *A. annua* 0.5% concentration had the least reduction in the population of bees with a mean of 10.33 bees per plot. Plots treated with water recorded the highest population of bees when compared to leaf extracts. Plots treated with Albaz 10 EC significantly ($p<0.0001$) reduced the number of bees when compared to leaf extracts.

During the long rains there were significance differences ($p<0.0001$) in the population of bees between the treatments. Among the leaf extracts the plots treated with *A. annua* 1% concentration had the highest reduction in the population of bees with a mean of 7.17 bees per plot. These was followed by *T. peruviana* 0.3% and *T. peruviana* 0.15% concentrations (Table 9). Plots treated with *A. annua* 0.5% concentration had the least reduction in the population of bees with a mean of 13.92 bees per plot. Plots treated with water recorded the highest population of bees when compared to leaf extracts. Plots treated with Albaz 10 EC significantly ($p<0.0001$) reduced the number of bees when compared to leaf extracts.

The population of bees on plots treated with *A. annua* 1% concentration, water and Albaz 10 EC was statistically similar in both the long and short rain seasons (Table 9). Plots treated with *A. annua* 0.5%, *T. peruviana* 0.3% and *T. peruviana* 0.15% concentrations had higher population of bees in long rains season as compared to short rains seasons. Plots treated with *A. annua* 1% concentration had less bees as compared to plots treated with *A. annua* 0.5% concentration during both seasons. Plots treated with *T. peruviana* 0.3% concentration had less bees as compared to plots treated with *T. peruviana* 0.15% concentration in both seasons. This results indicate that leaf extracts of *A. annua* 0.5% and *T. peruviana* 0.15% concentrations have a lesser negative impact on bees as compared to Albaz 10 EC as more bees landed on the plots. There were significant differences in population of bees among all the treatments in both short rains and long rain seasons (df = 47; F= 18.28; p< 0.0001) (Table 9).

Table 9: Mean (±SE) number of bees per plot on *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rain seasons.

	Before spraying	After spraying			
Short rains season					
Treatments	**P/T(Day0)**	**(Day2)**	**(Day16)**	**(Day31)**	**Grand mean**
A.annua 0.5%	11.00±2.08b	9.33±1.21d	9.00±1.15b	12.00±1.16b	10.33±0.72cd
A.annua 1%	13.33±1.45a	4.67±0.88h	5.00±1.15d	5.67±1.16e	7.17±0.82de
T.peruviana 0.15%	12.00±0.58b	7.00±2.01f	7.33±0.33c	9.33±0.88c	8.92±0.79de
T.peruviana 0.3%	15.00±1.15a	5.33±0.88g	5.67±0.33d	6.33±0.33d	8.08±1.00cd
Albaz 10 EC	12.33±1.45b	2.33±0.33i	3.00±0.58e	4.00±0.33f	5.42±1.26e
Water	14.67±0.88a	14.67±2.09a	15.00±0.58a	16.67±0.33a	15.25±0.84ab
Long rains season					
A.annua 0.5%	15.33±1.21a	10.00±0.58c	16.33±0.66a	14.00±1.16a	13.92±0.82abc
A.annua 1%	11.00±2.09b	4.33±0.33h	7.33±0.88c	6.00±0.58d	7.17±0.89de
T.peruviana 0.15%	13.00±1.15a	7.33±0.88e	13.00±0.58a	11.00±1.16b	11.08±0.82bcd
T.peruviana 0.3%	13.33±0.88a	5.67±0.33g	9.33±0.33b	9.00±0.58c	9.33±0.85de
Albaz 10 EC	10.33±088c	2.33±0.66i	4.33±0.88d	5.00±1.00e	5.50±0.95e
Water	15.67±1.45a	12.00±0.58b	18.67±0.33a	17.00±1.00a	15.83±0.84a

Test values (df = 47; F= 18.28; P< 0.0001)

Means with same letters within same column are not significantly different at (p≤ 0.05), the means are compared within columns for all seasons.

4.4.2. Effect of leaf extracts of *A. annua* and *T. peruviana* on beetles predators.

Beetles comprised of scarab and ladybird beetles. During the short rains there were significance differences ($p<0.0001$) in the population of beetles between the treatments. (Table 10). Among the leaf extracts the plots treated with *A. annua* 1% concentration had the highest reduction in the population of beetles with a mean of 0.92 beetles per plot. These was followed by *T. peruviana* 0.3% and *T. peruviana* 0.15% concentrations. The plots treated with *A. annua* 0.5% concentration had the least reduction in the population of beetles with a mean of 4.33 beetles per plot. Plots treated with water recorded the highest population of beetles when compared to leaf extracts. Plots treated with Albaz 10 EC significantly ($p<0.0001$) reduced the number of beetles when compared to leaf extracts.

During the long rains there were significance differences ($p<0.0001$) in the population of beetles between the treatments. Among the leaf extracts the plots treated with *A. annua* 1% concentration had the highest reduction in the population of beetles with a mean of 1.42 beetles per plot. These was followed by *T. peruviana* 0.3% and *T. peruviana* 0.15% concentrations (Table 10). Plots treated with *A. annua* 0.5% concentration had the least reduction in the population of beetles with a mean of 2.92 beetles per plot. Plots treated with water recorded the highest population of beetles when compared to leaf extracts. Plots treated with Albaz 10 EC significantly ($p<0.0001$) reduced the number of beetles when compared to leaf extracts.

The population of beetles was higher during the short rain season as compared to long rains season (Table 10). Plots treated with *A. annua* 0.5% and *T. peruviana* 0.15% concentrations had higher population of beetles in short and long rain seasons. Plots treated with *A. annua* 1% concentration had less beetles as compared to plots treated with *A. annua* 0.5% concentration during both seasons. Plots treated with *T. peruviana* 0.3% concentration had less beetles as compared to plots treated with *T. peruviana* 0.15% concentration in both seasons. Water had the highest population of beetles as compared to leaf extracts for both seasons. Albaz 10 EC had the least population of beetles as compared to leaf extracts for both seasons. There were significant differences in populationof beetles among all the treatments in both short rain and long rain seasons. (df = 47; F= 16.08; p< 0.0001) (Table 10).

Table 10: Mean (±SE) number of beetles per plot on *S. scabrum* treated with leaf extract of *A. annua* and *T. peruviana* during short and long rain seasons.

	Before spraying	After spraying			
Short rains season					
Treatments	**P/T(Day0)**	**(Day2)**	**(Day16)**	**(Day31)**	**Grand mean**
A.annua 0.5%	5.00±0.58a	3.00±0.58b	4.33±0.88b	5.00±0.58a	4.33±0.38ab
A.annua 1%	3.00±0.58c	0.33±0.33d	0.33±0.33f	0.00±0.00f	0.92±0.40ef
T.peruviana 0.15%	4.67±0.88b	2.33±0.33c	2.67±0.33c	4.33±0.88b	3.50±0.47bc
T.peruviana 0.3%	2.00±0.58c	0.00±0.00e	0.33±0.33f	0.00±0.00f	0.58±0.29f
Albaz 10 EC	5.33±0.88a	0.00±0.33e	0.00±0.33g	0.00±0.00f	1.33±0.72def
Water	3.67±0.88c	5.67±0.33a	6.67±0.66a	7.67±0.88a	5.92±0.54a
Long rains season					
A.annua 0.5%	6.33±0.88a	2.33±0.33c	1.00±0.00e	2.00±0.58d	2.92±0.66bcde
A.annua 1%	3.00±0.58c	1.00±0.58d	0.67±0.33f	1.00±0.00e	1.42±0.31def
T.peruviana 0.15%	2.67±0.33d	1.33±0.00d	1.00±0.00e	1.00±0.00e	1.50±0.23bcd
T.peruviana 0.3%	3.00±0.58c	1.00±0.88c	0.67±0.33f	2.00±0.00d	1.67±0.36cde
Albaz 10 EC	2.33±0.88e	0.00±0.00e	0.00±0.00g	0.00±0.00f	0.58±0.36f
Water	3.67±0.33c	3.00±0.00b	2.33±0.33d	2.33±0.33c	3.00±0.17bcd

Test values (df = 47; F= 16.08; P< 0.0001)

Means with same letters within same column are not significantly different at (p≤ 0.05)**,** the means are compared within columns for all seasons.

4.4.3 Effect of leaf extracts of *A. annua* and *T. peruviana* on black ant population.

During the short rains there were significance differences ($p<0.0001$) in the population of black ants between the treatments. Among the leaf extracts the plots treated with *A. annua* 0.5% concentration had the highest population of black ants with a mean of 15.61 black ants per plot. These was followed by *T. peruviana* 0.15% and *T. peruviana* 0.3% concentrations (Table 11). Plots treated with *A. annua* 1% concentration had the least population of black ants with a mean of 5.80 black ants per plot. Plots treated with water recorded the highest population of black ants when compared to leaf extracts. Plots treated with Albaz 10 EC lowest population of black ants when compared to leaf extracts.

During the long rains there were significance differences ($p<0.0001$) in the population of black ants between the treatments. Among the leaf extracts plots treated with *A. annua* 0.5% concentration had the highest population of black ants with a mean of 12.11 black ants per plot. These was followed by *T. peruviana* 0.15% and *T. peruviana* 0.3% concentrations (Table 11). Plots treated with *A. annua* 1% concentration had the least population of black ants with a mean of 4.83 black ants per plot. Plots treated with water recorded the highest population of black ants when compared to leaf extracts. Plots treated with Albaz 10 EC lowest population of black ants when compared to leaf extracts.

The population of black ants was higher during the short rain season as compared to long rains season (Table 11). Plots treated with *A. annua* 0.5% concentration and *Thevetia peruviana* 0.15% had higher population of black ants in short and long rain seasons. Plots treated with *A. annua* 1% concentration had less black ants as compared to plots treated with *A. annua* 0.5% concentration during both seasons and plots treated with *T. peruviana* 0.3% concentration had less black ants as compared to plots treated with *T. peruviana* 0.15% concentration during both seasons. Water had the highest population of black ants as compared to leaf extracts for both seasons. Albaz 10 EC had the least population of black ants as compared to leaf extracts for both seasons. There were significant differences in population of black ants among all the treatments in both short and long rain seasons (df = 47; F= 82.95; p< 0.0001) (Table 11).

Table 11: Mean (±SE) number of black ants per plot on *S. scabrum* treated with leaf extracts of *A. annua* and *T. peruviana* during short and long rain seasons.

	Before spraying	After spraying			
Short rains season					
Treatments	**P/T(Day0)**	**(Day2)**	**(Day16)**	**(Day31)**	**Grand mean**
A.annua 0.5%	15.33±0.33a	17.00±0.60b	14.22±0.78b	15.89±0.84b	15.61±0.36bc
A.annua 1%	13.11±0.33a	3.00±0.37f	4.0±0.44f	3.11±0.35h	5.80±0.74ef
T.peruviana 0.15%	12.89±0.66a	15.11±1.10b	11.57±0.85c	12.33±0.82c	12.97±0.48cd
T.peruviana 0.3%	10.00±0.47c	6.33±0.71d	6.11±0.61e	5.2±0.40f	6.91±0.41e
Albaz 10 EC	10.22±0.32b	2.00±0.47f	1.4±0.38h	1.11±0.39i	3.69±0.67ef
Water	13.2±0.84a	29.11±0.82a	28.44±0.65a	28.89±0.73a	24.91±1.19a
Long rains season					
A.annua 0.5%	12.55±0.62a	13.33±0.83b	11.44±0.78c	11.11±0.9d	12.11±0430d
A.annua 1%	11.44±0.67b	3.89±0.84f	1.78±0.53g	2.2±0.32h	4.83±0.72ef
T.peruviana 0.15%	14.22±0.88a	11.89±0.98c	9.00±0.90d	9.56±0.33e	11.16±0.48d
T.peruviana 0.3%	12.11±1.07a	5.89±0.93e	3.67±0.69f	4.00±0.37g	6.42±0.76e
Albaz 10 EC	10.56±0.50c	0.78±0.36g	0.11±0.11i	0.67±0.24j	3.02±0.75f
Water	15.89±0.75a	25.11±0.90a	15.33±0.89b	13.89±0.58b	17.55±1.00b

Test values (df = 47; F= 82.95; $p < 0.0001$)

Means with same letters within same column are not significantly different at ($p \leq 0.05$), means within similar column are compared for all seasons.

CHAPTER FIVE

DISCUSSION

5.1. Effect of leaf extracts of *A. annua* and *T. peruviana* on aphid population.

Solanum scabrum has a high demand in Kenya due to its nutritional and medicinal value. One of the major challenges facing its production is the attack by aphids which have mainly been controlled using synthetic insecticides which have detrimental effects. The present study assessed the effect of botanical insecticides from leaf extracts of *A. annua* and *T. peruviana* to control *A. fabae*.

Results showed that the leaf extracts of *A. annua* 1% was was second best to Albaz 10 EC, the recommended synthetic insecticide in reduction of aphid population density. These results agree with findings reported by Mwalilino *et al*., (2016), who found that the efficacy of *A. annua* was similar to actellic super in controlling maize weevil and larger grain borer in stored maize grains although actellic super dust was superior. The findings of this study indicated that *A. annua* 1% reduced the population density of aphids significantly when compared to that of *A. annua* 0.5% concentration due to possibly high concentration. This observation agrees with findings of Anshul *et al.*, (2013), who reported that *A. annua* has strong isomeric flavonoids which reduced larval weight and inhibited growth of larva of African pod borer (*Helicoverpa amigera* Hubner). The use of *A. annua* 1% in the present study agree with findings of Dancewicz and Gabrys, (2008), on reduction of green peach aphids in potatoes using a concentration of *Artemisia abisinthium* 1%. Leaf extracts of *A. annua* have strong insecticidal activity against corn bug/ Sunn pest, *Eurygaster integriceps* in wheat (Zibaee and Bandani, 2010). Studies done by Khosravi *et al*., (2010), indicate that *A. annua* has chemical compounds such as flavonoids, tannins and sterols that have deterrence effect against larvae of lesser mulberry pyralid (*Glyphodes pyloalis* Walker). Studies conducted by Hanseul, (2016), indicate that ethanol extract of *A. annua* possess repellent activities against drosophila fruit flies. Studies done by Ramzi *et al*., (2018), indicate that *A. annua* contains essential oils that have toxicity, deterrence and physiological effects on the third nymphal stage of tea mealy bug *Pseudococcus viburni* Sigornet.

In the present study *A. annua* 0.5% had a low reduction in aphid population because it had low concentration hence quick decomposition of plant extract because they were not persistent enough and may need more frequent applications than synthetic insecticides to make them effective in aphid control as reported by Oparaeke, (2007). Studies by Forouzan, *et al*., (2012), indicate that essential oil of *Artemisia annua* had insecticidal activity against adult of three most important storage pests namely, *Tribolium castaneum* Herbst., *Sitophilus granarius* L. and *Callosobruchus maculatus* F. The present study used *Artemisia annua* because it is a medicinal plant which has been used in treatment of malaria, cancer, leishmaniasis and trypanosomiasis as reported by Abad *et al*., (2012) and Sen *et al*., (2008). Essential oil of *A. annua* reduced adult emergence, longevity of male and female insects, fecundity and fertility of females of Indian meal moth *Plodia interpunctella* Hubner. in laboratory condition as indicated by Zamani *et al*., (2011).

Leaf extracts of *T. peruviana* 0.3% reduced the population density of *A. fabae* significantly when compared to *T. peruviana* 0.15% due to high concentration. This observation is in agreement with the studies done by Birgucu *et al*., (2015), where *T. peruviana* was most effective in the control of *Aphis gossypii* Glover and *Bemisia tabaci* Genn as it had antifeedant effect on the pests. Similar results have been reported by Sathish *et al.*, (2015); Ramamurthy, (2015), that *T. peruviana* has phytochemicals such as alkaloids, tannins, steroidal glycosides, phenols, chlorogenic acid, terpenoids and flavonoids that reduced mosquito larva and common housefly larva. The results on *T. peruviana* also concurs with findings reported by Theurkar, (2014); Suresh, (2013), where *T. peruviana* has been found to be toxic to scarab beetle (*Holotrichia serata* Fab), (*Aedes aegypti* and *Anopheles stephensi)* mosquito larvae, cow pea bruchid *(Callosobruchus maculatus)* in stored beans probably due to insect growth inhibition. *Thevetia peruviana* 0.15% had a lower reduction in the population density of *A. fabae* due to low concentration hence biodegraded fast. *Thevetia peruviana* 0.3% recorded a decrease in *A. fabae* population density at different spraying regimes than *T. peruviana* 0.15%. This could be attributed to quick decomposition *T. peruviana* 0.15% concentration hence it was not persistent enough to control aphids throughout the season. For this treatment to be effective, more frequent applications than synthetic insecticides as suggested by Oparaeke, (2007). Results by Mboussi *et al*., (2018), show that leaf extracts of *T. peruviana* and *Azadirachta indica* have insecticidal, anti-feeding and repellent effects to cocoa mirids *Sahlbergella singularis* Haglund. The present study tested *T. peruviana* because it is a medicinal plant with a wide array of pharmacological properties. It has been used traditionally in treatment of amenorrhoea, malarial fever, jaundice, hemorrhoids, constipation, headaches, skin disorders (Ahmad *et al*., 2017). The tested of leaf extracts of *A. annua* and *T. peruviana* to control *A. fabae* is the first time being reported on *S. scabrum.*

Aphids were effectively controlled by synthetic insecticide Albaz 10 EC in both short and long rain seasons as compared to the leaf extracts. These results are similar to those reported by Suganthy and Sakthivel, (2012), where maximum reduction of aphids was observed in synthetic insecticide profenophos on *S. nigrum*. Synthetic insecticides Thiamethoxam, Imidaclopride and Acetamiprid have been effective in controlling aphids in wheat (Zeb *et al*., 2016). Although Albaz 10 EC was the best in reduction of aphids its use is not recommended for *S. scabrum* since the vegetable is plucked regularly and might lead to poisoning of human beings as it takes a longer period of time to disintergrate (Mia *et al*., 2014; Amaoko *et al*., 2012). The harmful effects of insecticides to human beings include: potential risk to human and life form particularly health effects like immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities and cancer (Aktar *et al.,* 2009).

Water recorded the highest aphid population throughout the period although immediately after spraying, there was a very slight reduction in aphid population due to washing of the aphid by water. These findings agree with Roland, (2014), who observed that negative control water has least reduction of aphids in cow pea. Short rains season recorded higher aphid population as compared to long rains season. It is possible that the heavy rains experienced during long rains, could have reduced the reproductive success and survival of *A. fabae* on *S. scabrum*. These results are similar to those reported by Hasan *et al.,* (2009), where aphid populations declined due to influence of rainfall.

Leaf extracts *A. annua* 1% and *T. peruviana* 0.3% recorded relatively low number of leaves damaged because they were effective in reducing aphid populations. These result concur with finding of Mochiah *et al*., (2011), where fruit damage by fruit borers was low when botanicals of neem, papaya leaves and garlic were used to control pests in okra and eggplant vegetables. Leaf extracts of *A. annua* 0.5% and *T. peruviana* 0.15% recorded high number of damaged leaves as they were not effective in controlling aphids. This results differ from those by (Dadang *et al*., (2009), where botanical insecticide formulations from *Piper retrofractum* (Piperaceae) and *Annona squamosa* (Annonaceae) had the least leaf damage caused by cabbage webworm, *Crocidolomia pavonana* F. and the diamondback moth *Plutella xylostella* than synthetic insecticide deltamethrin. Albaz 10 EC recorded least number of damaged leaves due to high ability to control aphids. These result agree with findings of Suganthy and Sakthivel, (2012), where no leaf miner damage was observed on *S. nigrum* plants treated with synthetic insecticide profenophos as compared to neem botanicals. Water recorded the highest number of damaged leaves since it had the highest population of aphids which damaged the leaves. This is in agreement with Suganthy and Sakthivel, (2012), where untreated control had the highest leaf miner damage in *S. nigrum* plants. Similar results were observed by Mochiah *et al*., (2011), where fruit damage by fruit borers was the highest in control as compared to botanicals of neem, papaya leaves and garlic in okra and eggplant vegetables. Leaf damage was higher during short rains as compared to long rains season due to high population of aphids experienced during the short rains.

5.2 . Effect of leaf extracts of *A. annua* and *T. peruviana* on growth and yield parameters of *S. scabrum.*

The highest plant height and leaf width were in *A. annua* 1%concentration. This could be attributed to best protection of *S. scabrum* from aphid infestation hence good growth. This results are similar to those reported by Kumar *et al*., (2017), where yield of oats increased when *A. annua* was used as a botanical insecticide to control army worm. Similar results were reported by Degri and Zakaria, (2015), where cabbage height was taller in when treated with leaf botanicals of garlic, neem seed and bitter melon which were used to control the diamond black moth (*Plutella xylostella* L.) when compared to untreated plots which had the shortest plants. Studies by Ahmad *et al*., (2017), show that synergistic biopesticide of neem oil had the highest shoot length and compared to synthetic insecticide bifenthrin in control of aphids and leaf hoppers in potatoes. *A. annua* 0.5% and *T. peruviana* 0.15% had a lower plant height and leaf width due to high aphid population which led to poor growth. Albaz 10 EC recorded the highest plant height and leaf width because it offered the best protection against aphids which led to good growth. This result disagrees with findings of Baidoo *et al.*, (2017), who observed that there were no significant differences in plant height when *Lantana camara* L. leaves and root extract, mektin synthetic insecticide were used to control aphids, flea beetle and white flies in okra plant. Water recorded the lowest plant height and leaf width due high populations of aphids on the plants which affected their growth. Similar results were observed by Mochiah *et al*., (2011), where the highest plant height was in plots treated with neem, papaya leaves and garlic botanicals to control pests in okra and eggplant as compared to control which had the lowest plant height.

Leaf extracts of *A. annua* 1% concentration had the highest number of plants that had flowered, formed fruits and had ripened fruits when compared to other leaf extracts. This was attributed to the due to low aphid population which resulted in good growth of plants. These findings agree with those reported by Ibekwe *et al*., (2014), where the biopesticides from neem, African black pepper, castor oil, *Jatropha curcas* seeds recorded higher mean number of fruits per plot when used to control cutworms, grasshoppers, fruit borers and leaf hoppers in garden egg vegetable (*Solanum gilo*). Albaz 10 EC recorded the highest number of plant that had flowered, formed fruits and had ripened fruits when compared to all the leaf extracts. This was attributed to low aphid population which resulted in good growth of plants. This result agrees with findings of Nderitu *et al*., (2008), who reported that higher yield of okra pods was observed in plots treated with imidacloprid synthetic insecticide as compared to neem based insecticide in managing aphids. Water recorded the lowest number of plants that had flowered, formed fruits and ripened fruits. This was attributed to high populations of aphids on the plants which prevented it from producing to its potential. This agree with findings of Dehariya *et al*., (2015), where untreated control plants had the lowest yield of healthy fruit in brinjal compared to botanicals of neem, karanj oil and eucalyptus oil used in control of aphids and jassid in brinjal. Similar findings have been reported by Degri *et al*., (2013), who found out that leaf extracts of neem, castor bean and siam weed used to control pod sucking bug had higher number of pods compared to control which had the least number of pods.

Leaf extracts *A. annua* 1% recorded the highest fresh and dry weight of leaves, stems and seeds due to good growth caused by low aphid population. The results concur with findings by Khosravi *et al*., (2010), which indicated that *A. annua* has antifeedant property on lesser mulberry pyralid thus effective in reduction of aphid populations increasing yield. Leaf extracts of *T. peruviana* 0.15% and *A. annua* 0.5% had the lowest fresh and dry weight of leaves, stems and seeds due to poor growth caused by high aphid population. Similar results have been reported by Dadang *et al*., (2011), where *Piper rectrofractum* Trel. and *Annona squamosal* L. plant extracts are effective in reducing the larval population of cabbage web worm *Crosidolomia pavonana* Fabricious. and a diamond black moth *Plutella xylostella* L. in cabbage and increasing the cabbage yield. The results are different from those reported by Ahmad *et al*., (2017), where potato plants treated with synergistic biopesticide of neem had the highest weight of potato plant than control and synthetic insecticide bifenthrin in control of aphids and leaf hoppers in potatoes. Albaz 10 EC recorded highest fresh and dry weight of leaves, stems and seeds. This is because Albaz 10 EC was found to be the best treatment for management of aphids hence led to maximum yield. This observation agrees with results of Suganthy and Sakthivel, (2012), where highest leaf yield of *S. nigrum* was from synthetic insecticide treated plots. This results are different from those reported by Baidoo *et al.*, (2017), where harvested fruit of okra were not significantly affected by treatments of *Lantana camara* L. leaves and root extract, mektin synthetic insecticide, which were used to control aphids, flea beetle and white flies in okra plant. This is because no significant differences were observed among fruit weights. Water recorded the lowest fresh and dry weight of leaves, stems and seeds due to poor growth caused by high aphid population. This observation agrees with finding of Mochiah *et al*., (2011), where fruit yield from okra and eggplant were higher in plants treated with neem, papaya leaves and garlic botanicals to control pests in as compared to control. This was probably due to reduced fruit damage. The findings of this study indicate that the *S. scabrum* plants treated with Albaz 10 EC had the highest yield for both short and long rains seasons as compared to those treated with the leaf extracts. Similar results were observed by Dehariya *et al*., (2015), where synthetic insecticide triazophos 40 EC recorded highest healthy fruits yield compared to botanicals of neem, karanj oil and eucalyptus oil in brinjal. Similar findings have been reported by Alao *et al.,* (2011), where synthetic insecticides are more effective as compared to botanical insecticides when applied at the same field condition. Synthetic insecticide Uppercot 500 EC recorded the highest grain yield of cow pea when compared to aqueous leaf extracts of neem, castor bean and siam weed used to control pod sucking bug (Degri *et al*., 2013). The long rains season had a slightly higher yield of fresh and dry leaves, stems and seeds as compared short rains season. This was attributed to low aphid population and the rains experienced during long rains season which led to good growth.

5.3. Effect of leaf extracts of *A. annua* and *T. peruviana* on non-target organisms.

Non-target organisms that were identified during trials included honey bees, bumble bees, scarab beetle, lady bird beetle and black ants. Leaf extracts of *A. annua* 0.5% and *T. peruviana* 0.15% concentrations recorded the highest number of bees that landed on the *S. scabrum* plants. This is attributed to the low concentration hence did not repel the pollinators. This finding agrees with Dalal, (2017) and Pashte and Patil, (2017), who reported that lower mortality rate and longer life span of forage honey bee workers was associated with Azadirachitin when compared to imidacloprid and methoxyfenozide synthetic insecticide under laboratory conditions. Leaf extracts of *A. annua* 1% and *T. peruviana* 0.3% recorded lower numbers of bees that landed on the *S. scabrum* plants. This is attributed to the high concentration that repelled the pollinators immediately after spraying. This indicates that use of botanical insecticides should be avoided during flowering stage when plants are visited by bees. This observation agrees with finding of Xavier *et al.*, (2015), where garlic and neem oil extract were found to be toxic to larvae and adult honey bees. Water treatment recorded highest number of bees since water did not affect the pollinators in any way. This result agrees with findings of Xavier *et al.*, (2015), who observed that adult worker bees *Apis millifera* subjected to the diet exposed to botanicals of citronella oil, eucalyptus oil, garlic extract, neem oil, or rotenone suffered higher mortality rates ranging from 42% to 60% compared with the uncontaminated food control. Albaz 10 EC recorded the lowest number of bees since it repelled the pollinators. This observation agrees with finding of Yang, (2008), who reported that honey bees (*Apis millifera*) have abnormal foraging when the honey subjected to the pesticide imidacloprid and don't return to site the same way as untreated bees. Similar results were reported by Krischik, (2014), who observed that bees lost navigation and foraging skills when subjected to sub lethal doses of neonicotinyl insecticide. Result by Pashte and Patil, (2017), indicate that high residual toxicity of honey bees was observed in sunflower treated with insecticides imidacloprid, flipronil, and indoxacarb, dimethoate and cypermenthrin) as compared to botanical insecticide (azadirachtin) which was the least toxic.

The highest number of beetles was in plots treated with leaf extracts *A. annua* 0.5% and *T. peruviana* 0.15%. This was attributed to the high aphid population since they are predators of aphids. These results agree with earlier observation of Shiberu *et al*, (2013), who stated that *A. annua* at 10 grams per litre did not affect the lady bird beetles on the experimental plots when *A. annua* was used to control onion thrips in onions. This finding are similar to those reported by Mollah *et al*., (2013), where insecticides of fresh neem oil and stored neem oil were found safe for the predaceous lady bird beetle as they obtained low percentage mortality as compared to synthetic insecticide Esfenvalerate 5 EC, Cypermethrin, Deltramethrin 2.5 EC, Fenvelarate 20 EC, Curtap 50 SP which had high percent mortality in bean field. Similar findings were reported by Choudhary *et al.*, (2017), that neem based insecticides were found less toxic to Coccinellids (lady bird beetle) and rove beetles in rice fields.

Leaf extracts of *A. annua* 1% and *T. peruviana* 0.3% recorded low number of beetles that were found on the *S. scabrum* plants because of low aphid population. This finding are similar to those reported by Tunca *et al.*, (2012), that very high mortalities of parasitoid *Venturia canescens* were revealed with use of pyrethrum. Similar findings were reported by Tunca *et al*., (2014), that when larvae of *Ephestia kuehniella* parasitoid hosts were treated with Azadirachtin, very few adult parasitoids emerged which indicated a strong detrimental effect on the parasitoid. Similar findings were reported by Bonsignore and Vacante, (2012), that rotenone and neem reduced the numbers of adult anthocorid *Orius laevigatus*, a predator of flower thrips, *Frankliniella occidentalis*.

Water treatment recorded highest number of beetles that were found on the plots. This was attributed to the highest aphid population. This result agrees with earlier observation by Gemmeda and Ayalew, (2015), who stated that the lowest and highest number of lady bird beetle which was pea aphid predator was recorded from standard insecticide dimethoate and water control respectively while botanical treated plots were intermediate on field pea plots. Albaz 10 EC recorded the lowest number of beetles that were found since it effectively controlled aphids. These results are similar to those reported by Suganthy and Sakthivel, (2012), where maximum reduction in predatory coccinelid was observed in chemical treated plots and botanical insecticide conserved the coccinelids in *S. nigrum*. Synthetic insecticides lambda-cyhalothrin and bestox effectively controlled red pumpkin beetle as compared to the botanical pesticides of neem extract and parthenium extract in cucumber under field conditions (Zahid *et al*., 2017). Synthetic insecticide amitraz was found to be harmful to on the parasitoid wasp, *Encarsia formosa* used to control the whitefly, *Trialeurodes vaporariorum* (Chitgar and Ghadamyari, 2012). Results by Araya *et al*., (2010), indicate that mortality of *Aphidius ervi*, an important parasitoid of the pea aphid, (*Acyrthosiphon pisum*) was found after applying insecticides dimethoate, spinosad and imidacloprid.

The findings of the present study suggest that *A. annua* 0.5% and *T. peruviana* 0.15% were safer to beneficial insects of *S. scabrum* as compared to Albaz 10 EC, *A. annua* 1% and *T. peruviana* 0.3% although they were not effective in controlling aphids. The present study found out that the population of beetles was high during short rains season compared to long rains. This was because the aphid population was higher during short rain as compared to long rains season and beetles were predators of aphids. The study suggests that botanical insecticides can be used together with IPM to control aphids and increase vegetable yields since low concentrations were not effective in controlling aphids but more beetles were found on plots *A. annua* 0.5% and *T. peruviana* 0.15% which agree with finding of Shailendra, (2012).

Leaf extracts *A. annua* 0.5% and *T. peruviana* 0.15% recorded highest number of black ants that were found on the *S. scabrum* plants. This is attributed to higher aphid population which attracted more black ants as they fed on honey dew produced by aphids. This finding is in agreement with result of Silva *et al*., (2016), who reported that botanical insecticides citronella oil and eucalyptus oil have been found to be less harmful to the predatory ant *Paratrechina species* on pumpkin. Similar findings have been reported by Peris and Kipto, (2017), that mexican marigold leaf extract was found to be the most effective due to its friendliness to the parasitic wasp (*Aphidius ervi* Haliday.) when compared to plant extracts of garlic, ginger and sodom apple in kales.

A. annua 1% and *T. peruviana* 0.3% recorded low number of black ants that were found on the *S. scabrum* plants because of low aphid population which attracted less ants. This finding is in agreement with result of Azad *et al*., (2012), who reported that extracts of dried leaves of khuksa (*Ficus hispida* L.), neem (*Azadiracta indica*) and seeds of Mahogany (*Swietenia mahagoni* Jacq.) were found to be effective in control of ants in brinjal field. Similar findings have been reported by Peris and Kipto, (2017), that garlic extract was found to be lethal to the parasitic wasp (*Aphidius ervi* Haliday.) in kales.

Water treatment recorded highest number of black ants that were found since water had the highest aphid population which attracted more black ants as they fed on honey dew produced by aphids. Albaz 10 EC recorded the lowest number of black ants that were found since it effectively controlled aphids. These results are similar to those reported by Aljedani, (2017), where high mortality rate for forager honeybee workers (*Apis mellifera*

Jemenatica.), was observed when toxicity of synthetic insecticides Imidacloprid and Methoxyfenozide was tested and compared to Azadirachtin.

In the present study, high population of black ants was observed in plots that had high population of aphids e.g. water, *A. annua* 0.5% and *T. peruviana* 0.15% concentrations because ants co-exist mutually with aphids. This concurs with studies done by Crystal *et al*., (2008), where aphids form mutualistic association with black ants in a way that ants feed on honey dew secreted by aphids while in turn provide for aphids against natural enemies as well as cleaning aphid environment. The population of black ants was high during short rains season since the aphid population was higher as compared to long rains season which had a lower aphid population hence low black ants.

5.4. Conclusions

Based on the present study of efficacy of leaf extracts of *A. annua* and *T. peruviana* against *A. fabae* and non-target organisms on *S. scabrum*, the following conclusions are drawn:

1. Among the botanical insecticides *A. annua* 1% and *T. peruviana* 0.3% concentrations recorded significant reduction in *A. fabae* population density.
2. Treatments of leaf extracts *A. annua* 1% and *T. peruviana* 0.3% concentrations gave the highest yield (seeds, stems and leaves) of *S. scabrum.*
3. Non-target organisms (bees, beetles and black ants) were more repelled from *S. scabrum* by application of *A. annua* 1% and *T. peruviana* 0.3% oncentrations and less repelled by *A. annua* 0.5% and *T. peruviana* 0.15% concentrations.

5.5. Recommendations

1. Leaf extracts *A. annua* 1% and *T. peruviana* 0.3% concentrations could serve as a valuable alternative in management of *A. fabae* on *S. scabrum* to reduce the side effects of using synthetic insecticides.
2. Further research is needed to determine LC_{50} and LC_{90} using different concentrations of *A. annua* and *T. peruviana* in order to effectively control *A. fabae* and increase yield of *S. scabrum.*
3. There is need for further research on integrated use of leaf extracts of *A. annua* 0.5% and *T. peruviana* 0.15% concentrations together with other IPM practices so as to increase yields while preserving non-target organisms such as bees, beetles and black ants.

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APPENDICES

APPENDIX 1. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on population of *A. fabae* infesting *S. scabrum*.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1136.197[a]	179	6.347	100.630	.000
Intercept	3471.159	1	3471.159	55030.031	.000
TM	1136.197	179	6.347	100.630	.000
Error	329.012	5216	.063		
Total	4938.460	5396			
Corrected Total	1465.209	5395			

APPENDIX 2. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on leaf damage.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	13520.083[a]	11	1229.098	287.322	.000
Intercept	40602.250	1	40602.250	9491.435	.000
TR	13520.083	11	1229.098	287.322	.000
Error	102.667	24	4.278		
Total	54225.000	36			
Corrected Total	13622.750	35			

APPENDIX 3. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on plant height.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	778642.787[a]	83	9381.238	254.386	.000
Intercept	16343966.679	1	16343966.679	443190.104	.000
TM	778642.787	83	9381.238	254.386	.000
Error	43368.533	1176	36.878		
Total	17165978.000	1260			
Corrected Total	822011.321	1259			

APPENDIX 4. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on leaf width.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	372.241[a]	83	4.485	196.825	.000
Intercept	22940.075	1	22940.075	1006766.486	.000
TM	372.241	83	4.485	196.825	.000
Error	21.054	924	.023		
Total	23333.370	1008			
Corrected Total	393.295	1007			

APPENDIX 5. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on flowering.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	13867.435[a]	35	396.212	334.304	.000
Intercept	49708.231	1	49708.231	41941.320	.000
TM	13867.435	35	396.212	334.304	.000
Error	85.333	72	1.185		
Total	63661.000	108			
Corrected Total	13952.769	107			

APPENDIX 6. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on fruit formation.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8552.741[a]	35	244.364	184.555	.000
Intercept	40677.926	1	40677.926	30721.790	.000
TM	8552.741	35	244.364	184.555	.000
Error	95.333	72	1.324		
Total	49326.000	108			
Corrected Total	8648.074	107			

APPENDIX 7. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on fruit ripening.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6147.583[a]	35	175.645	96.784	.000
Intercept	22446.750	1	22446.750	12368.617	.000
TM	6147.583	35	175.645	96.784	.000
Error	130.667	72	1.815		
Total	28725.000	108			
Corrected Total	6278.250	107			

APPENDIX 8. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on dry leaves

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.816[a]	11	.074	52.201	.000
Intercept	9.402	1	9.402	6618.301	.000
SN	.000	0	.	.	.
TR	.801	10	.080	56.385	.000
SN * TR	.000	0	.	.	.
Error	.034	24	.001		
Total	10.252	36			
Corrected Total	.850	35			

APPENDIX 9. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on fresh leaves.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2.125[a]	11	.193	102.595	.000
Intercept	22.872	1	22.872	12149.067	.000
SN	.000	0	.	.	.
TR	2.036	10	.204	108.153	.000
SN * TR	.000	0	.	.	.
Error	.045	24	.002		
Total	25.042	36			
Corrected Total	2.170	35			

APPENDIX 10. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on dry stems.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	15.111[a]	11	1.374	80.120	.000
Intercept	196.934	1	196.934	11485.849	.000
SN	.000	0	.	.	.
TR	14.466	10	1.447	84.368	.000
SN * TR	.000	0	.	.	.
Error	.412	24	.017		
Total	212.457	36			
Corrected Total	15.522	35			

APPENDIX 11. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on fresh stems.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	235.176[a]	11	21.380	117.745	.000
Intercept	3055.694	1	3055.694	16828.762	.000
SN	.000	0	.	.	.
TR	229.190	10	22.919	126.223	.000
SN * TR	.000	0	.	.	.
Error	4.358	24	.182		
Total	3295.228	36			
Corrected Total	239.534	35			

APPENDIX 12. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on dry seeds.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4.073[a]	11	.370	68.494	.000
Intercept	55.304	1	55.304	10230.958	.000
TR	3.783	10	.378	69.983	.000
SN	.000	0	.	.	.
TR * SN	.000	0	.	.	.
Error	.130	24	.005		
Total	59.506	36			
Corrected Total	4.202	35			

APPENDIX 13. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on fresh seeds.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	753.339[a]	11	68.485	76.956	.000
Intercept	12243.791	1	12243.791	13758.132	.000
SN	.000	0	.	.	.
TR	737.710	10	73.771	82.895	.000
SN * TR	.000	0	.	.	.
Error	21.358	24	.890		
Total	13018.489	36			
Corrected Total	774.697	35			

APPENDIX 14. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on bees.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2774.000[a]	47	59.021	18.278	.000
Intercept	13924.000	1	13924.000	4311.948	.000
TM	2774.000	47	59.021	18.278	.000
Error	310.000	96	3.229		
Total	17008.000	144			
Corrected Total	3084.000	143			

APPENDIX 15. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on beetles.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	587.889[a]	47	12.508	16.082	.000
Intercept	765.444	1	765.444	984.143	.000
TM	587.889	47	12.508	16.082	.000
Error	74.667	96	.778		
Total	1428.000	144			
Corrected Total	662.556	143			

APPENDIX 16. Analysis of variance on effect of leaf extracts of *A. annua* and *T. peruviana* on black ants.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	22784.942[a]	47	484.786	82.950	.000
Intercept	46895.836	1	46895.836	8024.161	.000
TM	22784.942	47	484.786	82.950	.000
Error	2244.222	384	5.844		
Total	71925.000	432			
Corrected Total	25029.164	431			