EVALUATION OF BOTANICAL PESTICIDES AND COLOURED STICKY INSECT TRAPS FOR MANAGEMENT OF INSECT PESTS (THRIPS, WHITEFLIES AND APHIDS) IN FRENCH BEANS (*PHASEOLUS VULGARIS* L.)

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A Thesis Submitted In Partial Fulfillment for the Requirement for the Award of Master of Science Degree in Crop Protection of the University of Nairobi, Department of Plant Science and Crop Protection

2015

DECLARATION

I declare that this is my original work and has not been presented for award of a degree in any other University.

Signed……………………………………………..Date……………………………..
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I dedicate this work to my family particularly my husband, my children and the entire extended family who gave me unwavering support throughout my study. May the Lord God Almighty bless them and guide them in all their endeavours.

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ABBREVIATIONS AND ACRONYMS

CAN	Calcium Ammonium Nitrate
CIAT	Centro Internacional de Agricultura Tropical
CTDT	Community Technology Development Trust
DAP	Diammonium phosphate
HCDA	Horticultural Crops Development Authority
ICIPE	International Centre of Insect Physiology and Ecology.
SNV	Netherlands Development Organization
RCBD	Randomized Complete Block Design
WFT	Western flower thrips

ABSTRACT

EVALUATION OF BOTANICAL PESTICIDES AND COLOURED STICKY INSECT TRAPS FOR THE MANAGEMENT OF INSECT PESTS (THRIPS, WHITEFLIES AND APHIDS) IN FRENCH BEANS (*PHASEOLUS VULGARIS* L.)

French bean, *Phaseolus vulgaris* L. is an important crop in Kenya mainly grown by small holder farmers in various parts of the country. However, farmers face many challenges among them pests and diseases.

The objective of the study was to evaluate the effectiveness of the botanical pesticides Tithonia *(Tithonia diversifolia)*, Tephrosia *(Tephrosia vogelii)*, Tagetes (*Tagetes minuta*) and Spider plant (*Gynandropsis gynandra*) extracts were used and coloured sticky traps, blue, yellow and clear to control insect pests of French bean: thrips (*Megalurothrips sjostedti* Trybom, *Frankliniella occidentalis* Pergade, *Frankliniella schultzei* Trybom, bean aphid (*Aphis fabae* Scopoli)) and whiteflies (*Bemisia tabaci*). The experiment was laid out in a randomized complete block design (RCBD) replicated three times. The treatment application was done once a week to control thrips, whiteflies and aphids and the experiments were carried out in relay for three crop cycles.

The botanical pesticides were prepared from dried powdered leaves of Tithonia, Tephrosia, Tagetes and Spider plant which were infused in hot water for twelve hours and then sieved using muslin cloth. The extracts were sprayed on the French beans on a weekly basis. All the plant extracts were compared with a synthetic pyrethroid (Decis) and a commercial pesticide derived from neem product (Nimbecidine). In another experiment sticky colored traps blue, yellow and clear were used for controlling aphids, thrips and whiteflies . The traps were mounted in the in the middle of the plots 60 cm above the ground just before flowering. The traps were placed

weekly and assessment done for four weeks. The yields of French beans were recorded for each planting.

Data was collected on a weekly basis where thrips population was assessed from 5 flowers per plant on 5 plants randomly selected in the middle of each plot. The aphids and white flies were assessed in the same manner but from 3 leaves and 3 plants.

All the plant extracts were effective in controlling the insect pests. Tephrosia was more effective than the other extracts ($p<0.05$). However, there was no significant difference between by Tephrosia and Tithonia treatments in reducing pest numbers. The two botanical pesticides Tithonia *(Tithonia diversifolia)* and Tephrosia *(Tephrosia vogelii)* activity on aphids, thrips and whiteflies was comparable to that of commercial pesticides (Decis and Nimbecidine) in reducing pest population densities and damage caused by the target insect pests. The blue and yellow traps were significantly ($p<0.05$) more effective than the clear traps in reducing target pests. The chemical (Decis) treatment was superior and significantly different from the traps ($p<0.05$), as was expected.

The study demonstrated that botanical pesticides and sticky colored traps have a role to play in the management of insect pests (aphids, whiteflies and thrips) in French beans and can be used in an integrated pest management strategy to reduce pesticide use in small scale farmers' fields. Botanical pesticides can be a sustainable alternative to synthetic pesticides for controlling pests and diseases. Coloured sticky insect traps are usually used to monitor pests but can also be used to mass trap insects and reduce the rate of increase of pests.

CHAPTER ONE

INTRODUCTION

1.1 Production and consumption of French beans

Snap bean (*Phaseolus vulgaris* L.), also widely known as French bean, is an important crop in the socio-economic systems of East and Central Africa. It is a crop with great potential for addressing food insecurity, improving incomes and alleviating poverty in the region (Kabata and Anyango, 1996). It is grown in many areas of Kenya and its immature pods which are consumed as fresh vegetables or processed and canned. The edible fresh pods contribute to human nutrition by providing ascorbic acid, proteins, fibre, and minerals particularly iron, which is recommended especially to expectant and lactating mothers (CIAT, 1988; Njeru, 1989).

The crop ranks highly among the export horticultural crops in Kenya. Other ECA countries with increasing production of snap bean are Uganda, Tanzania and Rwanda. Snap bean production is dominated by rural small-scale farmers (Wambua, 2004). The main challenges in snap production include: (a) lack of high yielding, pest and disease resistance and premium market value varieties; (b) high costs of pesticides; (c) low soil fertility and limited moisture; (d) high post-harvest losses; and (e) market constraints including stringent requirements in the international markets (Anon, 2000; Kasina, 2003; Monda *et al.*, 2003).

French beans are a major export crop in Kenya whose local consumption is gradually being adopted (Mishek, 2011). The crop is grown on small scale with staggered planting due to intensive labour requirements. It is cultivated both for fresh consumption and processing either canning or freezing.

The varieties of French beans which are grown in Kenya are determined by market preference and these include Monel, Gloria, Claudia, Morgan, Amy coby, Espada, Maasai, Samantha, Paulista, Slender green and Nerina. Farmers prefer high yielding varieties with straight long, round and fleshy pods and with a long picking duration. With irrigation, all year round production is possible but the main export planting is October to May and crop takes 45-50 days from planting to first picking. (Farmers Pride International Company LTD – Mkulima online, 2014).

1.2 Importance of French beans in horticultural industry

French beans are grown in many areas of Kenya for the immature pods which are consumed as fresh vegetables or processed and canned..The major French bean growing areas in Kenya are Embu, Meru, Nyeri, Kirinyaga, Kiambu, Nairobi, Machakos, Makueni, Kericho, Nanyuki, Muranga, Naivasha, Trans-Nzoia, Vihiga, Bungoma and Kericho. The production is done throughout the year mainly under irrigation and it takes six to eight weeks from planting to harvesting allowing quick returns on investment. The year round production of French beans is hindered by accumulation of pests and diseases which are a major constraint. The range of pests that attack French beans in order of importance are bean flies *(Ophiomya spp*), flower thrips (*Megalurothrips sjostedti* Tribom *and Frankliniella occidentalis* Pergade), bean aphid (*Aphis fabae* Scopoli), red spider mites (*Tetranychus spp),* African bollworm *(Helicoverpa armigera* Hurbner), legume pod borer (*Maruca testularis* Geyer) and whiteflies, (*Bemisia tabaci*) (Lohr and Michalik, 1995). The severity of the pests attack depends on location and planting (Seif, *et al.*, 2001).

About 80% of French beans in Kenya are produced by small scale farmers (Nderitu, *et al.,* 2008). They mainly grow French beans for the export as a source of income for the family. According to SNV Netherlands Development Organization (2012), the sector employs 45,000 to 60,000 people. Sixty percent of the workers are women engaged in commercial farms and they dominate post harvest handling of French beans; sorting, grading and in quality control. Farmers are always under pressure to meet standards on product quality, food safety, traceability, occupation health and safety of workers especially those set by the European Union which is the main market for French beans from Kenya (Standard media July 29th 2014; Kenya Economic Survey 2013). Table 1.1 shows the production of French beans.

Table 1.1: Production of French beans in Kenya

Year	Production (Ha)	Production in (MT)
2007	7,733	67,330
2008	4,616	92,095
2009	3,336	46,496
2010	4,840	55,841
2012	4,128	44,000

Source:HCDA

1.3 Problem statement

Small holder farmers produce low yields of French beans mainly due to challenges of pests, diseases and poor agronomic practices. Pests and diseases are mainly controlled using chemical pesticides some of which have been detected as residues in farm produce during marketing. Furthermore some of the chemicals used to control pests and diseases are pollutants of the environment and are expensive. The chemical residues make the produce unmarketable hence leading to loss of income for farmers. Resistance to the currently available synthetic insecticides is another serious concern. For example, available information indicates that higher densities of thrips especially *Frankliniella occidentalis* and *Megalurothrips sjostedti* were recorded in farms with more frequent application of synthetic pyrethroids, indicating a high degree of resistance to pyrethroids (ICIPE, 2011). There is need to evaluate other ways of managing pests and diseases such as use of botanical pesticides and coloured sticky traps which can reduce the cost of production, increase yields per unit area, enhance the family income and promote a clean environment.

1.4 Justification of the study

French bean is an important crop for small holder farmers for income generation and employment. Production constraints have been mainly bean pests, diseases and poor agronomical practices. Residues in produce, pest resistance development and environmental pollution caused by overuse of pesticides are matters of concern for both scientists and the consumers. There is need to search for selective and biodegradable pesticides to solve problems of pests on farms and long term toxicity to non-targeted insects, mammals and environment. Pesticides derived from plant extracts can be alternatives to synthetic pesticides for controlling pests and diseases hence can reduce negative impacts to human health and environment. The plant extracts are locally available and can be a cheap alternative to the small holder farmers. Botanical pesticides may be the key to organic, renewable and cost effective pest management strategy using readily available materials. Similarly, colured traps for mass trapping may also be an alternative to pesticide use.

The use of botanical pesticides and coloured sticky insect traps is another way of producing French beans free of chemical residues. The results will contribute to the knowledge on clean environment and safe production of crops in the country. Furthermore, the results will also provide information for farmers and policy makers on integrated pest management other than use of synthetic chemicals. This information will encourage the farmers to use readily available plant materials and sticky traps in the control of pests to improve productivity of in Kenya.

1.5 Objectives

1.5.1 Overall Objective

The goal of this study was to improve French bean production by evaluating techniques that can be used in an integrated pest management strategy for sustainable French bean production.

1.5.2 Specific Objectives

1. To determine the effect of botanicals, namely Tagetes (*Tagetes minuta)*, Spider plant (*Gynandropsis gynandra*), Tithonia (*Tithonia diversifolia*) and Tephrosia (*Tephrosia vogelii*) water extracts, on flower thrips, whiteflies and aphids affecting French beans.
2. To assess the effect of different coloured sticky traps in the management of thrips, whiteflies and aphids on French bean.

1.6 Hypotheses

i) Botanical pesticides can be used to control insect pests in French beans.

ii) Coloured sticky insect traps have no effect in reducing pest populations in French beans.

CHAPTER TWO

LITERATURE REVIEW

2.1. French bean production and constraints in Kenya

French beans (*Phaseolus vulgaris*) are known to grow from low lands of the warm tropics to the cold high altitude mountains and hot desert. However, most common varieties grown in the tropics perform well with relative narrow ecological zone ranging from 0-1000 m above sea level (Tindall, 1983). In Kenya; French beans are known to grow well within the midland to lower highland ecological zones. They perform better at an altitude between 1500 m and 2100 m above sea level, at temperatures between 14-22^{0}C with moderate rainfall of 900-1200 mm. However, most of the crop is grown under irrigation (Anon, 2000). French beans can grow in a wide range of soils from sandy loam to clay but will grow best on friable, medium loam soils, well drained and with a lot of organic matter (Anon, 2000). They need optimum pH levels of 6.5-7.5 but can tolerate a low pH of 4.5-5.5 (Anon, 2000). The crop takes 45-50 days from planting to first picking. Farm yard manure is recommended in poor soils at a rate of 10 tons/ha applied in planting furrows. Two hundred kg per ha of DAP fertilizer is applied in the furrows and mixed well before planting. At three leaf stage top dressing is carried out with 100 kg of CAN and a second application follows at the onset of flowering. Foliar feed should be applied fortnightly from the fourth week to mid podding stage (Kasina, 2003).

Excessive nitrogen promotes growth of leaves instead of pods. Regular watering is essential for the promotion of high yields, uniformity and high quality. The crop is sensitive to water stress at flowering.Waterlogging should also be avoided. Application of 35 mm of water per week at planting to 10 days after germination and 50 mm thereafter to flowering stage is recommended for good growth of French beans. Timely weed control is absolutely essential. The following preemergence herbicides are recommended for French beans in Kenya (Farmers Pride International Company LTD – Mkulima online, 2014). These are Lasso 4 EC(Alachlor)-3 litres in 400 litres of water per hectare and Stomp (Pendimethalin)-2.5 Litres in 400 litres of water per hectare

Effective control of insect pests' infestation can be achieved through use of conventional insecticides. However, conventional pesticides are expensive; they result in ecological health hazard and cause insect resurgence and can also lead to the development of resistance to the pesticides and destruction of natural antagonists. Botanicals have been reported to have insecticidal properties (Sohail, *et al.*, 2012; Adebayo 2003; Adebayo and Gbolade, 1994). Sustainable pest management is a prerequisite to farming in developing countries of Africa with economic risks and uncertainties and harsh climatic conditions (Schwarb, *et al*., 1995). There is renewed interest in the application of botanical pesticides for crop protection. Scientists have continued to do research on indigenous plant materials which have positive activity in reducing insect pests which attack crops (Roy, *et al.*, 2005). Botanical pesticides are biodegradable (Devlin and Zettel, 1999) and their use in crop protection is a practical sustainable alternative to synthetic chemicals used to protect crops. They maintain biological diversity of predators and reduce environmental contamination and human health hazards (Grange and Ahmed, 1988). Research on active ingredients, pesticide preparations, application rates and environmental impact of botanical pesticides are a prerequisite for sustainable agriculture (Buss and Park-Brown 2002). Italo, *et al.*, 2009, Jazzar and Hammand, 2003 have reported the insecticidal effects of leaves and fruits of *Melia azedarach* L. on various insects.

Colored sticky traps that reflect certain wavelengths of yellow, blue, white and red are most often used to attract and catch insect pests such as winged aphids, whiteflies, thrips, leafminers, fungus gnats, and shoreflies eg. *Scatella stagnalis* (Fallen) Ephydridae, DIPTERA (Rodriguez-Saona, *et al.*, 2012; Taha, *et al.*, 2012). Blue traps are said to be better at capturing western flower thrips and shore flies. However, it is suggested that yellow traps be used in a monitoring program that include whiteflies and fungus gnats. Traps can also be used to control some pests or at least slow the rate of increase of pests such as whiteflies (Pasian and Lindquist, 2009).

2.2 Insect pests and diseases of French beans

Arthropod pests are the major constraints contributing to high yield loss, while high cost of inputs (certified seeds, labour and fertilizers) make farmers produce in small areas ranging from 0.25 – 2 acres. Continuous production of the crop throughout the year coupled by poor pests control strategies encourages pests and diseases build up (Makokha, *et al.*, 2001). The crop is attacked by a host of pests and diseases which include the bean fly (*Ophiomya spp*), flower thrips (*Megalurothrips sjostedti* Trybom), (*Frankliniella occidentalis* Pergade), *(Frankliniella schultzei* Trybom), bean aphid (*Aphis fabae* Scopoli), Red spider mites (*Tetranychus spp),* African boll worm (*Helicoverpa armigera* Hurbner), Legume borer (*Maruca testularis* Geyer) and whiteflies (*Bemisia tabaci*). Damage due to thrips is reported to be as high as 70% in French beans in Kenya and Uganda (Lohr and Machalik, 1995, ICIPE, 2011).

2.2.1. Thrips

Thrips inhabit flowers, shoots and tender leaves (Tamo *et al.*, 1993). They feed on flowers causing abscission of flower buds and curling of pods that lead to low yields. The silvery lesions made on the pods render the product unfit for export (Kibata and Anyango, 1996).

2.2.1.1 Frankliniella occidentalis Pergande

Frankliniella occidentalis is known to be a native of Pacific states of North America (Kasina, 2003) and has spread to colonize almost the entire world. The pest is identified by the number of setae on the pronotum, the number of pairs of setae between the compound eyes and ocelli, and the presence of two complete rows of setae on the wings of *Frankliniella* spp (Plate 2.1).

Plate 2.1.Western flower thrips *(Frankliniella occidentalis)*
http:/nfrec.ifas.ufas.ufl.edu/programs/tomato_spotted_wilt_management.shtml

2.2.1.2. Frankliniella schultzei Trybom

Frankliniella schultzei Trybom is known as commom blossom thrip (plate. 2.2). It is found in the tropics and sub- tropics (Viebergen and Mantel, 1991). In Australia, it was known as *Frankliniella lycopersici* Steele. It is found in both the dark and pale forms; the dark form is found in south Sudan to Cape Town while the pale form is found in Egypt, Sudan, Uganda and Kenya (Mound, 2004; Sakimura, 1969).

Plate 2.2. Commom blossom thrip (*Frankliniella schultzei)*
www.ozthrips.org/terebrantia/thripidae/thripinae/frankliniella schultzei/

2.2.1.3. Megalurothrips sjostedti Trybom

Megalurothrips sjostedti Trybom is from Africa, in the Ethiopian, Niger and the Cape regions including the Cape Islands (Palmer, 1987). For many years, the pest was known as *Taeniothrips sjostedti* until after Bhatti (1969) did a series of studies, which led to substantial changes of generic relationships in the sub-family, Thripinae (Plate 2.3). The pest is found throughout Sub-Sahara Africa where it has been documented in Ethiopia, Niger and Kenya, (Taylor, 1974; Tamo *et al.*,1993; Kyamanywa *et al.*, 1993a; Kyamanywa *et al.*, 1993b and Mensah, 1988). *Megalurothrips sjostedti* is considered an African thrip and has been reported as a pest in East Africa (Faure, 1960). *Megalurothrips sjostedti* differs from *Frankliniella* spp. by having a pronotum with one pair of long setae at the anterior margin while the latter has two pairs.

Plate 2.3. African bean flower thrips (*Megalurothrips sjostedti*)
www.infonet-biovision.org/default/ct/120/crops

2.2.2 Whiteflies (Bemisia tabaci)

Whiteflies belong to the order Hemiptera; sub-order Homoptera and family Aleyrodidae (Fig 2.5). There are more than 1500 species. (Lohr and Michalik, 1995).They typically feed on the underside of the plant leaves. The life cycle of whiteflies is given in Plate 2.4. The genus *Bemisia* is important in transmission of crop diseases particularly the bean dwarf mosaic and bean golden mosaic diseases. The severity of the pest infestation depends on location and planting (Seif *et al.*, 2001).

Plate 2.4. White flies *(Bemisia tabaci)*

http:/entnemdept.ufl.edu/creaturers/veg/leaf/silverleaf_whitefly.htm

2.2.3 Aphids (*Aphis fabae)*

Black bean aphid *(Aphis fabae*) belongs to the family Aphididae (Plate 2.5). It is a major pest of legume which attacks early and can greatly affect the yields of the beans. Aphids are tiny and are insects that suck sap from the plants. They develop rapidly in warm and dry weather and high populations can build up quickly. A part from sucking plant sap, aphids transmit virus causing plant diseases in many crops (Raccah and Ferere, 2009).

Plate 2.5. Black bean aphid *(Aphis fabae*)
www.agroatlas.ru/pests/Aphis fabae_en.htm

2.3. Pest management Methods

Major pest and diseases in growing of French beans includes fungal diseases, insect attacks and nematodes. Control is mainly by application of recommended pesticides, crop rotation, and use of certified seeds, field hygiene and crop rotation (Mishek, 2011; Nderitu, *et al.* 2001, 2007, 2008).

2.3.1. Cultural Practices

Cultural practice is the purposeful manipulation of the crop environment to reduce the rate of pest increase and damage. Cultural practices are used to control thrips on legume crops in various parts of the world. Intercropping of legumes such as cowpeas with groundnuts and other crops is reported as one of the effective cultural methods for controlling thrips of legume crops (Emeasor and Ezueh, 1977; Kyamanywa and Kuo, 1996). The timing of intercropping is very important in thrips management. Intercropping cowpeas and maize crop significantly reduce the insect damage (Ezueh and Taylor, 1984). Flooding fields with irrigation has been used to destroy a large proportion of pupal population stage of thrips in the soil (Pathak and Khan, 1994). Pesticide Action Network (2005) has listed many cultural practices used to control pests in French beans. These cultural practices include increasing seeding/seedling rate, mulching, planting flowering grasses around field margins and planting tobacco as a trap. Pests that are controlled include aphids, whiteflies, and bean flies; nematodes and diseases such as anthracnose, bacterial leaf blight and rust. Natural enemies such as spider and ladybird beetles can also control aphid and whiteflies populations. Other governments and organizations have articulated the role of cultural practices in an integrated pest management (Queensland Government, 2013; CTDT, 2008).

2.3.2 Biological control

Biological control is the use of living organisms to manipulate insect populations.The use of inundative biological control in the protected growing conditions with the predatory mites (*Neoseiulus cumeris* and *Amblyseius barkeri*) or predatory bugs (*Orius* species) is a routine practice in Europe and the United States of America (Lenteren, 2012; Lenteren, 2003). In Kenya, studies by Gitonga (1999) showed that a predator *Orius species* and a parastoid *Ceranisus menes* had low predation and parasitism hence the need for augmentation. Example of entomo-pathogenic fungi used in biological control methods include *Beauveria spp*, *Trichoderma spp.*, and *Metarhizium spp*. Isolates of pathogenic fungi have been available for many years in Europe for control of thrips and other glasshouse pests (Helyer, *et al.*, 1995). A lot of research work has also been carried out in Kenya especially at International Centre of Insect Physiology and Ecology (ICIPE) on *Beauveria* spp, and *Metarhizium* spp. Omukoko, *et al.*, (2011) found that the ten isolates of *Beauveria bassiana* tested were pathogenic to adult banana weevil with isolate

ICIPE 273 and M313 being the most active. Ouna, (2010) and Ouna, *et al*., (2010) reported that out of the 24 isolates of *Metarhizium anisopliae* and *Beauveria bassiana* screened for pathogenicity against *Bactrocera invadens* (mango fruit fly), 7 isolates and *M. anisopliae var. acridium* (ICIPE 21), induced significantly high mortalities. The results reported by Mburu, *et al.*, (2009) showed that termite's response to *Metarhizium anisopliae* or *Beauveria bassiana* is directly related to the potential harm these fungi can inflict on the insect and that the virulent strains are more likely to be recognized from some distance and avoided. Karanja, *et al.*, (2010) reported that pathological entomopathogens *Metarhizium anisopliae* and *Beauveria bassiana* were potential biological agents as the isolates of these fungi caused infection and death to white coffee stem borer in Kenya.

2.3.3 Use of Traps in pest control

Concerns about the potentially negative impacts of broad spectrum insecticides on environmental quality, food security and natural enemies have lead to research aimed at minimizing the use of insecticides for pest management (Grzywacz, *et al.*, 2014). Use of traps is one of the interventions of pest pest management (Wallis and Shaw, 2008). Insect traps are useful tools for monitoring insect populations to determine the need for control or the timing of control practices (Covaci *et al*., 2012). In some instances, attractants and traps can be used together to control insect populations directly by mass trapping or mating disruption (Thomson, *et al.*, 2004). Mass trapping is most likely to be effective when the density of the target pest is low and immigration into the trapped area is minimal, as is the case in restricted environments (e.g. greenhouses) (www.infonet.org). Insect traps consist of a visual (colour, shapes and light) and/or chemical (scent/pheromone) attractant to attract the target insect, plus a device to capture the insect once it arrives. Most insect traps either use glue to immobilize insects or have funnel structures to prevent them from escaping (Kasina, *et al.*, 2009; Hoddle, *et al.*, 2002). Traps are used for one of the two reasons: One trapping and secondly monitoring of insect pests. Colored sticky traps, with or without pheromones are often used to attract various insect pests depending on the colour. Colours, including blue, yellow, white, red, green, pink and orange traps, are used to attract different insect pests. Although some colored traps have minimal attraction on certain insect pests, others may trap non-target/beneficial insects (Barrett, 1992; Clare, *et al.*, 2000, Wallis and Shaw 2008). Sticky yellow traps have been tested severally (Atakan and Canhilal, 2004). According to Kaas (2005), insects are differentially attracted to coloured surfaces, particularly yellow which is notorious among house painters as a general insect attractant. This feature has been exploited among entomologists for collection of Coleoptera, Cicadellidae, aphids, Hymenoptera and Thysanoptera (Kaas, 2005).

Literature indicates that different sticky coloured traps are used for different pests. Field experiments conducted to determine the attractive action of different colors to *Tuta absoluta* moths (Taha, *et al.*, 2012) showed that the red sticky traps caught the greatest number of moths, while the yellow sticky traps caught the fewest number of moths. Other field experiments conducted to determine adult attraction of the blunt-nosed leafhopper, *Limotettix vaccinii* (Van Duzee), and the sharp-nosed leafhopper, *Scaphytopius magdalensis* (Provancher), to colored sticky traps indicated that green was the most attractive color to blunt-nosed leafhoppers, followed by red and yellow; whereas yellow was the most attractive to sharp-nosed leafhoppers, followed by green and red (Rodriguez-Saona *et al.*, 2012). The response of *Ceratothripoides claratris*, a pest on tomato, to colors was also evaluated in a pesticide free tomato field (Ranamukhaarachchi and Wickramarachchi, 2007). Many colors were tested but blue and white trapped more *C. claratris* compared to the rest. In another field study conducted to evaluate various colour sticky traps and light traps in sugarcane fields for the insect vectors of sugarcane white leaf phytoplasma, the leafhoppers *Matsumuratettix hiroglyphicus* (Matsumura) and *Yamatotettix flavovittatus* (Thein *et al.*, 2011), a higher number of the putative vectors, *Matsumuratettix hiroglyphicus* and *Yamatotettix flavovittatus* were trapped on blue and yellow than in other sticky traps. Hassan and Mohammed (2004) while evaluating the insects trapping efficiency of various colored traps to monitor thrips *Thrips tabaci* (Lindeman) and the leafminer *Liriomyze trifolii* (Burgess), they demonstrated that significantly higher mean number of insect pests trapped on fluorescent yellow traps compared to other coloured traps.

2.3.4 Chemical methods

Chemical control is the use of chemical insecticides to kill, deter or influence pests for control purposes. Use of conventional insecticides for pest management is the most frequently used method to suppress insect pests of French beans in Kenya (Wambua, 2004; Pest Control Products Board, 2014). Some of the commonly used insecticides to control thrips, aphids and whiteflies include synthetic pyrethrins, carbamates, neonicotinoids and benzourea based insecticides (Kasina, 2003; Misheck, 2011, Pest Control Products Board, 2014). In Kenya, pesticides use for the control of thrips on French beans has been evaluated and recommendations made (Kibata and Onyango, 1996, Muriuki, 1988, Wambua, 2004). The introduction of maximum residue levels in export produce by the European Union posed and still poses a challenge in the horticulture industry (Lohr, 1996). Although use of chemical pesticides is the most common method of pest management, the chemicals are expensive for small scale farmers, thereby increasing cost of production and reducing the farmers' income (Mishek, 2011).

2.3.5 Use of botanical pesticides in insect pest control

Effective control of insect pests' infestation can be achieved through use of conventional insecticides. However, conventional pesticides are expensive, result in ecological pollution, health hazards and cause pest resurgence by destroying the natural enemies (Isman, 2008). Botanicals have been reported to have insecticidal properties but their efficacy in controlling pests on various crops remains largely unknown. However, there are reports on some pesticidal activities of some plants. Adebayo and Olaifa (2004) and Oparaeke, *et al*. (2005) investigated a mixture of Neem and Eucalyptus leaf extracts with leaf extract of other plant species efficacy in the management of two major post flowering insect pests (Maruca pod borers and *Clavigralla tomentosicollis* Stal.) of cowpea. The extract mixtures caused great reduction in pod damage per plant and ensured higher grain yield compared with the unsprayed plots (Oparaeke *et al.,* 2005).
The complementary roles played by individual plant species used for the extracts mixtures in reducing pests numbers and increasing grain yields on sprayed plots suggested the future direction of new formulations of biopesticides in the management of field pests of crops on farms owned by resource limited farmers in low input agriculture characterizing the developing countries (Oparaeke *et al.,* 2005). Sustainable pest management is a prerequisite to farming in developing countries of Africa with economic risks and uncertainties and harsh climatic conditions. There is renewed interest in the application of botanical pesticides for crop protection. Research on indigenous plant materials to protect insect infestation on crops has been of interest to researchers (Roy *et al.,* 2005).

Botanical pesticides are biodegradable (Devlin and Zeltel, 1999) and their use in crop protection is a practical sustainable alternative. They maintain biological diversity of predators and reduce environmental contamination and human health hazards (Grange and Ahmed, 1988). Research on active ingredients, pesticide preparations, application rates and environmental impact of botanical pesticides are a prerequisite for sustainable agriculture (Buss and Park-Brown, 2002).

Evaluation of various botanical pesticides used in controlling insect pests has been done and has shown reduced pest populations (Henn and Weinzierl, 1989). Use of botanicals is prefered in organic food production, both in the field and in controlled environments (Isman, 2008). Recent studies in Africa, suggest that extracts of locally available plants can be effective as crop protectants, either used alone or in mixtures with conventional insecticides at reduced rates (Kareru *et al.,* 2013; Khater, 2012). The studies suggest that indigenous knowledge and traditional practice can make valuable contributions to domestic food production. Further more, botanical insecticides have long been considered as an attractive alternative to synthetic chemical insecticides in pest management. This is because they pose little threat to environment and humans. They are also suited for use in organic food production in industrialized countries and they play a much greater role in crop production and post-harvest management of food in developing coutries (Isman, 2006 and 2008).

Generally botanical extracts act quickly, degrade rapidly and with few exceptions have low mammalian toxicity. The most recent US Environmental Protection Agency Registration Standard considered rotenone, the active ingredient of tephrosia to be non toxic by inhalation rather than by ingestion (Neal,2013). However, standardization of some of these pesticides has been commercialized for insect control for example azadirachtin (Henn and Weinzierl, 1989). Azadirachtin is used as an insecticide and fungicide. It acts as a repellent, anti-feedant and growth regulator (Henn and Weinzier, 1989). *Tephrosia vogelii* Hook. f.) *Tithonia diversifolia*

(Hemsl.) Gray, *Tagetes minuta* L. and *Gynandropsis gynandra* (L.) Brig. are some of the plants which have been used by small scale farmers for pest control in French beans production.

2.4 *Tephrosia vogelii* Hook. f. (Papilionaceae, Fabaceae)

This is a woody perennial with leaflets 13-29 and bluish-green in colour (Plate 2.6). The veins are prominent with silver hairs: flowers white or pale yellow in dense, terminal, shortly stalked psedo-racemes; standard white-silky, about 22 mm long; pod 13 x1.5 mm, densely golden-hairy. It is distributed in many parts of Kenya in waste grounds and well known as fish poison by the indigenous people (Agnew and Agnew, 1994). *Tephrosia vogelii* has been extensively used as a natural control of pests on snap beans, cowpea and pigeon peas among others (Adebayo and Olaifa, 2004). In a study to evaluate the effectiveness of botanical pesticides for the control of insect pests in cowpea, *T. vogelii* was the most active and was ranked equal to the synthetic Decis in reducing the population density and damage (Adebayo *et al.,* 2007). Lao et al., (2011) evaluated the natural toxicant from *Tephrosia vogelii* and *Petiveria alliacea* and their mixture against *Megalurothrips sjostedti* and *Apion varium* on cowpeas. The findings showed that the two insect pests were effectively controlled by the botanical insecticides compared to the untreated plants. *Tephrosia vogelii* is toxic to insects and has repellent effects on maize weevils (Ogendo, *et al.,* 2003, 2004). It is effective against *Macrotermes bellicosus*, an emerging pest of Cocoa (Oyedokum *et al.*, 2011). In another recent experiment by Mudzingua *et al.*, (2013) three plants, *T. vogelii, Allium sativum and Solanum incanum* were tested against aphids (*Brevicoryne brassicae* L.) in rape seed (*Brassica napus* L.). *Tephrosia vogelii* extract was the second most active after dimethoate (Mudzingua *et al.,* 2013).

The efficacy of *T. vogelii* on insects feeding on pigeon pea in Kenya has been assessed. In one such experiment, different concentrations of leaf water extracts were sprayed to the pigeon peas.

Tephrosia extract like dimethoate showed significant reduction in seed damage compared to the control treatment. It was suggested that farmers be encouraged to grow the plant for easy accessibility of the leaves (Minja, *et al.,* 2002). According to Njiru, (2006) a combination of rotenone, one of the major ingredients of *T. vogelii,* with pyrethrins is a safe insecticidal formulation to human and environment. *Tephrosia vogelii* water extract has also been tested for its activity against several termites, aphids and red spider mites with 20% w/v giving mortality of more than 90% to the pests (McDavid and Lesseps, 1995). In another experiment, the results indicated that *T. vogelii* in hexane extract and its mixture with *Piper cubeba* extract had potential as an alternative to conventional insecticides for the control of crucifer pests (Nugroho, *et al.*, 2009). *T. vogelii* extract has also has been considered as a biorational insecticide by Namungu, (2003). These are insecticides which are active against pest populations, but relatively innocuous to non-target organisms and therefore, non-disruptive to biological control. An insecticide can be "innocuous" by having low or no direct toxicity, or by having systemic or rapid translaminar activity or short field residual, thereby minimizing exposure of natural enemies to the insecticide (Schuster and Stansly, 2012).

The major ingredients in *T. vogelii* are rotenone, dequelin, alpha-toxicarol, tephrosin, sarcolobin and 5-methoxyisolonchocarpin which are responsible for the insecticidal and antifeedant activity (Carlson and Tallent, 1970; Belmain, *et al.*, 2012; Wanga, 2003). Although these compounds are highly toxic to numerous insects, Tephrosia extract is relatively non toxic to most mammals with short residual time (Adebayo and Olaifa, 2007; Fukami *et al.*, 1970; Barnes and Freyre, 1966). The biocidal effect of fresh water extract is said to be more effective in the presence of soap (Bandason and Mchingula, 2013).

Plate 2.6. Tephrosia vogelii
Source: FN Mwangi 2012

2.5. *Tithonia diversifolia* (Hemsl.) Gray (Compositae, Asteraceae)

This is a common plant introduced from Central America (Plate 2.7). The plant is used as a hedge plant in Kenya. It is a soft shrub with simple to 3-lobed mostly opposite leaves; heads large, orange yellow on an expanded stalk (Agnew and Agnew, 1994).

The powder and ethanol extract of *Tithonia diversifolia* leaves have been tested for their efficacy mortality, oviposition and adult emergence of cowpea seed bruchid, (*Callosobruchus maculatus).* The results indicated that *T. diversifolia* could be a potential candidate for bio-insecticide preparations because of anti-ovipositional, ovicidal and knockdown properties of its products (Adedire and Akinneye, 2004). The nematicidal effect of *T. diversifolia* among other plants has been tested against *Meloidogyne incognita* and its extract has been shown to be as effective as the nematicide carbofuran in management of root-knot nematode (Akpheokhai,*et al*., 2012). Moreno (1991) studied the possible utilization of wild sunflower (*Tithonia diversifolia* A. Gray) leaf extract as an insecticide against selected vegetable insect pests. The water extract of *Tithonia diversifolia* was found to be the best for control of *Periplanata americana* over organic extracts (Ambama, 2013). Toxicity studies demonstrate that it can be considered as a safe, biodegradable and renewable source of the botanical pesticide (Maud, *et al.*, 2011).

Plate. 2. 7. *Tithonia diversifolia*
Source: FN Mwangi 2012

2.6 *Tagetes minuta* L. (Compositae, Asteraceae)

This is an erect strong-smelling annual, often very robust but variable in habit; the leaves are pinnate with elliptic toothed leaflets, heads creamy yellow, in terminal corymbs; phyllaries 10 cm long (Plate 2.8). The plant is abundant and a troublesome weed in upland arable land and was introduced from America. It is widely distributed in many parts of Kenya (Agnew and

Agnew, 1994). Tagetes has been used as a pesticide especially in repelling insects traditionally (Opender, *et al.,* 2008*).* Tagetes has also been used as an intercrop with vegetable crops like onions to control pests (Waiganjo, *et al.,* 2007). A patent for a product for killing subsurface and surface soil pathogens including nematodes, wire worms, cut worms, worms, insects, fungi and plant and soil surface pests comprising an extract derived from the plant *Tagetes minuta* exists in USA since 1997 (patent no. US5662915 A, 1997). According to the patent the extract is a natural product, i.e. derived from the plant *Tagetes minuta.* It does not pose a threat to the environment and is no danger to man. The insecticidal and fungicidal activity of floral, foliar and root extracts and *Tagetes minuta* essential oil have also been extensively studied. The studies have highlighted the effectiveness of the plant as a pesticide (Weaver, *et al.,* 1994; Sadia, *et al.,* 2013; Koul, *et al;* 2008; Padin, *et al.* 2013).

Fig.2.8. Tagetes minuta
Source: FN Mwangi 2014

2.7 *Gynandropsis gynandra -Cleomes gynandra* (L.) Brig. (Cruciferaceae, Brassicaceae)

Gynandropsis gynandra (syn. *Cleome gynandra* L.) is a herb used as a local bitter vegetable (Chisaga**,** Spider flower, Cat's whiskers). It is a glandular or almost hairless annual with 3-7 obovate to elliptic leaflets ; petal white, pale pink or lilac measuring 10-20 mm long. In some areas it was considered as a weed distributed along roadsides and on dry bush land that grow in soils with high organic matter (Agnew and Agnew, 1994). In Kenya it has become a common leafy vegetable utilized mainly in Western Kenya, Rift Valley, Nyanza and main towns where metropolitan populations exist. The leaves are bitter and are said to be high in calcium and has medicinal value (Plate 2.9).

It has been used as an intercrop to control pests in vegetables (Gachu, *et al*., 2012). Intercropping French bean with spider plant, for example, significantly reduces the population of spider mites on the beans. Besides the direct effect on thrips population associated with spider plant, it was also recorded to be a host for *Orius* spp. a natural enemy of thrips (Waiganjo *et al.*, 2007). *Gynadropsis gynandra* has also been recorded to have insecticidal, anti-feedant and repellent characteristics. The ethanol extract is insecticidal to painted bug (*Bagrada cruciferatum* Kirk.) and diamond back moth (*Plutella xylostella* L.). It also has anti- feedant activity against tobacco caterpillar (*Spodoptera litura* F.) while the seed extract has insecticidal effects against brinjal aphids (*Aphis gossypii* Glov.) (Cheya and Mnzawa, 1997).

Companion planting of *Cleome gynandra* of Kenyan origin, in beds of cut-flower roses reduced significantly red spider mite (*Tetranychus urticae* Koch) infestation without any detrimental effect on productivity or flower quality. The potential benefits of such companion planting for growers of field roses and those involved in some domestic markets have been enumerated (Nyalala and Grout, 2007).

Fig. 2.9. Spider plant, *Gynandropsis gynandra*
Source: FN Mwangi 2014

CHAPTER THREE

EFFECT OF BOTANICAL PESTICIDES ON FRENCH BEAN INSECT PESTS (APHIDS, THRIPS AND WHITEFLIES)

3.1 Abstract

French bean *Phaseolus vulgaris* L. is an important crop in Kenya mainly grown by small holder farmers in various parts of the country. Approximately 50,000 small holder families are directly or indirectly involved in its cultivation, producing about 80% of the crop in the country. However, its production is faced by many challenges which include pest and diseases, high cost irrigation systems, seeds and chemicals.The objective of the study was to evaluate the effectiveness of the botanical pesticides Tithonia *(Tithonia diversifolia),* Tephrosia *(Tephrosia vogelii),* Tagetes (*Tagetes minuta*) and spider plant (*Gynandropsis gynandra*) in the controlling insect pests (thrips, aphids and whiteflies) in French bean field.

The botanical pesticides were extracted using water to give 10% w/v based on powder and were sprayed on the French beans on a weekly basis. Data collected from plant extracts were compared with a synthetic pyrethroid (Decis) and a commercial pesticide derived from neem product (Nimbecidine). The experimental design was a Randomized Complete Block Design" (RCBD) with seven treatments assigned randomly per block and replicated three times.

Data was collected on a weekly basis where and the population was assessed from 5 flowers per plant on 5 plants randomly selected in the middle of each plot while aphids and white flies were assessed in the same manner but from 3 leaves and 3 plants.

The botanical extracts had a significant reduction of pests compared to the control

Tephrosia botanical extract was the most effective followed by Tithonia. The two, Tephrosia and Tithonia, were not different in their effect compared to commercial pesticides (Decis and

Nimbecidine) in reducing insect (aphids, thrips and whiteflies) population densities. The botanical extracts can be used as an alternative to chemical control to reduce pest population sustainable production of French beans.

3.2 INTRODUCTION

3.2.1 Pest management in French beans

Arthropod pests are the major constraints contributing to high yield loss, while high cost of inputs (certified seeds, labour and fertilizers) make farmers produce French beans in small areas ranging from 0.25 – 2 acres (Nderitu *et al.*, 2008; Makokha *et al.*, 2001). Continuous production of the crop throughout the year coupled by poor pests control strategies encourages pests and diseases to build up (Makokha *et al.*, 2001). The French bean is attacked by several pests and diseases which include bean fly (*Ophiomya spp*), flower thrips (*Megalurothrips sjostedti* Trybom), (*Frankliniella occidentalis* Pergade), *(Frankliniella schultzei* Trybom), bean aphid (*Aphis fabae* Scopoli), red spider mites (*Tetranychus spp)*, African boll worm (*Helicoverpa armigera* Hurbner), legume borer (*Maruca testularis* Geyer) and white flies (*Bemisia tabaci*). It is estimated that damage due to thrips could be as high as 70% in French beans in Kenya and Uganda (Lohr and Machalik, 1995, ICIPE, 2011).

The pests are mainly controlled by use of chemicals. Some farmers control the pests by drenching twice within the two weeks after emergence while other farmers spray up to four times during the first four weeks and many insecticides are also used to control thrips in order to maintain the high quality demanded by the export market (Misheck, 2011; PCPB, 2014). Routine spraying every one or two weeks ending up in spraying 8 to 15 times per French bean season is common (Nderitu,*et al.*, 2001). High use of pesticides has also been found to intestify spider mites infestation (Seif *et al.*, 2001). However, conventional pesticides are expensive, result in ecological pollution, health hazard, cause insect pest populations to increase and lead to the development of resistance to the pesticides and destruction of natural antagonist (Isman, 2008). Botanical insecticides could lead to reduction of the undesirable effects of chemical insecticides in pest management in French beans.

Although botanical extracts have insecticidal properties, their efficacy in controlling of pests in various crops remains largely unknown (Adebayo and Gbolade, 1994). Sustainable pest management is a prerequisite to farming in developing countries of Africa with economic risks and uncertainties and harsh climatic conditions (Schwarb *et al.,* 1995). There is renewed interest in application of botanical pesticides for crop protection. Scientists are working to protect insect infestation by indigenous plant materials (*Roy et al.,*2005). Botanical pesticides are biodegradable (Devlin and Zeltel, 1999) and their use in crop protection is a practical sustainable alternative. They maintain biological diversity of predators and reduce environmental contamination and human health hazards (Grange and Ahmed, 1988). Research on active ingredients, pesticide preparations, application rates and environmental impact of botanical pesticides are a prerequisite for sustainable agriculture (Buss and Park-Brown, 2002). This will provide standards for botanical pesticides use.

The objective of the present study was to determine the effect of botanicals, namely Tagetes (*Tagetes minuta)*, Spider plant (*C.gynandra*), Tithonia (*Tithonia diversifolia*) and Tephrosia (*Tephrosia vogelii*) water extracts, on flower thrips, whiteflies and aphids affecting French beans.

3.3 Materials and methods

3.3.1. Experimental site

The study was carried out at the College of Agriculture and Veterinary Science (CAVS) Kabete, Field Station Farm, University of Nairobi between November 2012 and July 2013. The site is about 1800 m above sea level. The soils are well drained, deep, reddish brown to dark red (nitosols) developed from Limuru trachite, (Michieka, 1977). The area receives an annual rainfall of about 1000 mm and experiences average temperatures of 23^{0}C (Wambua, 2004).

3.3.2 Crop establishment

The experiment was laid out in a randomized complete block design (RCBD) in plots of 3 m by 2.7 m replicated three times (Fig. 3.1). The plots were separated by 0.5 m and blocks separated by 1 m. The variety of French bean planted was the Slender Green chosen because of its availability in the market at the time when the experiment was done. The spacing of the crop was 50 cm, between rows and 10 cm between plants. The treatment application was done once in a week to control thrips, whiteflies and aphids. The experiments were carried out in relay for three crop cycles from November 2012 to July 2013.

T2	T4	T7	T1	T5	T6	T3
T4	T1	T5	T3	T2	T7	T6
T6	T2	T3	T7	T4	T1	T5

Fig. 3.1 Layout of the treatments in the field

T= Treatment, T1-tithonia, T2-tagetes, T3-tephrosia, T4-spider plant, T5-nimbecidine, T6-decis and T7-control.

Di-ammonium phosphate (DAP) fertilizer was applied during planting at the rate of 133kg per hectare. A similar amount of calcium ammonium nitrate (CAN) was used for top dressing at 35 days after crop emergence. Weeding was done twice during the growing period, first two weeks after emergency and three weeks after the first weeding Fig. 3.1 shows a plot of French beans after the 2^{nd} weeding while Fig. 3.2 shows the French beans with pods.

3.3.3 Preparation of extracts, decis and nimbecidine

Plant materials (leaves) of the selected botanical pesticides were collected from various regions in Kenya where they were found abundantly. These included Tephrosia (*Tephrosia vogelii*) from Nakuru, Tithonia (*Tithonia diversifolia*) from Kirinyaga, Spider plant (*Cleome gynandra*) from Kisii and Tagetes (*Tagetes minuta*) from Nairobi. The materials were dried under the shade for two weeks and then ground and packaged in polythene bags. The botanical pesticides were made from dried leaves ground into powder. Briefly, about one l litre of water was heated to boiling, removed from heat and 100 g of accurately weighed material put into the hot water for each plant. The powder was infused (left in boiled water) in water for twelve hours and then filtered with muslin cloth. The extracts were then made to volume (1 litre) using cold water to give 10% w/v based on the powder and sprayed on the French beans on weekly basis. Previous work had shown that 10% and 20% w/v of *Tephrosia vogelii* water extract was highly effective to certain insects (McDavid and Lesseps, 1994; Adebayo *et al*., 2007). Decis 2.5 EC (25 g/L deltamethrin emulsifiable concentrate) diluted at 20 ml/15L and Nimbecidine(0.03% azadirachtin emulsifiable concentrate) at 0.5 ml/L were also sprayed. Water spray was used as the control.

3.3.4 Data collection and analysis

Before application, pre-treatment assessment of thrips, white flies and aphids were carried out. The aphids and white flies were recorded from three leaves per plant randomly selected in the middle of each plot and from three plants. Thrips population was assessed from 5 flowers per plant on 5 plants and preserved in 50% alcohol in separate bottles for flower maceration, identification and counting of thrips. The flower thrips (*Megalurothrips sjostedti*), (*Frankliniella occidentalis*), *(Frankliniella schultzei* Trybom), were all recorded as thrips. The bean aphid (*Aphis fabae*), and whiteflies (*Bemisia tabaci*) were also recorded. Treatment and assessment of pest population was done weekly for a period of four weeks. The yield of French beans was recorded for each treatment in each plot for every planting. Data analysis was carried out by using GenStat Release 14.2 software.

Plate 3.1 Plot of French beans after the second weeding.
Source: FN Mwangi 2012

Plate 3.2 Plot of French beans with pods.
Source: FN Mwangi 2013

3.4 RESULTS

3.4.1. Effect of botanicals on aphids population in planting one (Nov 2012 –Feb 2013)

In planting one, the effect of Decis on aphids was significantly different from all other treatments and the control ($p<0.05$). The control plots had the highest mean of aphids (11) while Decis had the least (2) aphid (Table 3.1). The mean number of aphids for tephrosia (3) was comparable to that of Nimbecidine. The effect of spider plant and tagetes on aphids was not different from each other.

Table 3.1 Mean number of aphids recorded on French bean in planting one

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	1.7	3.0	3.7	7.1	3.9bc
Tephrosia	1.1	2.1	3.0	5.2	2.9bc
Tagetes	4.3	7.4	9.9	12.9	8.6ab
Spider plant	5.0	8.2	11.7	15.3	10.1ab
Nimbecidine	1.2	2.0	3.8	4.3	2.8bc
Decis	1.1	1.7	2.3	3.3	2.1c
Control	6.8	8.4	12.2	16.8	11.1a
P value	<0.001				
Lsd	1.5				
Cv	5.7%				

Means with the same letters are not significantly different at p<0.05

3.4.2 Effect of botanicals on thrips population in planting one (Nov 2012-Feb 2013)

Tithonia and tephrosia extracts were able to reduce thrips populations significantly compared to the control. In planting one, thrips were least recorded in the plots treated with Decis (6.7). (Table 3.2). Tithonia, tephrosia extracts produced the same effects on thrips.

Table 3.2 Mean number of thrips recorded on French bean in planting one

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	3.7	5.3	11.8	12.3	8.3b
Tephrosia	1.7	4.3	13.3	13.2	8.2ab
Tagetes	5.1	9.4	17.1	19.1	12.7ab
Spider plant	6.6	8.4	17.3	22.6	13.7ab
Nimbecidine	3.9	4.2	12.4	12.4	8.3ab
Decis	3.0	4.1	9.2	10.6	6.7b
Control	8.8	10.3	18	22.9	15.0a
P value	<0.001				
Lsd	1.4				
Cv	4.5%				

Means with the same letters are not significantly different at p<0.05

3.4.3 Effect of botanicals on whiteflies population in planting one (Nov 2012-Feb 2013)

There was no significant difference of the mean number of whiteflies found in plots treated with spider plant, tagetes and the control (Table 3.3). Decis plots had the least mean number of whiteflies (6) followed by nimbecidine (7), tephrosia (8) and tithonia (9). The mean number of whiteflies for tephrosia and nimbecidine were not significantly different.

Table 3.3 Mean number of whiteflies recorded on French bean in planting one

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	6.9	8. 3	8.7	11.4	8.6b
Tephrosia	6.9	6.6	7.4	9.2	7.5bc
Tagetes	13.8	15	17.2	20.2	16.6a
Spider plant	13.3	15	22.2	24.8	18.8a
Nimbecidine	5.6	6.3	7.3	8.0	6.9bc
Decis	5.0	5.0	5.7	7.0	5.6c
Control	14.4	18.3	21.6	24.9	19.8a
P value	<0.001				
Lsd	5.4				
Cv	6.2 %				

Means with the same letters are not significantly different at p<0.05

3.4.4. Effect of botanicals on aphids population in planting two (March-June 2013)

In planting two, the most effective treatments were Decis, nimbecidine, tephrosia and tithonia respectively. These were not significantly different from each other but they were significantly different form those treated with tagetes, spider plant and the control ($p<0.05$) (Table 3.4).

Table 3.4 Mean number of aphids recorded on French bean in planting two

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	3.0	5.7	4.3	8.3	5.3b
Tephrosia	2.3	5.0	5.7	6.3	4.8b
Tagetes	6.0	10	13.3	13.3	10.7a
Spider plant	6.7	9.0	15.5	15.7	11.7a
Nimbecidine	2.7	4.0	5.7	6.3	4.7b
Decis	1.7	3.7	4.7	6.7	4.1b
Control	8.0	9.7	17.3	17.3	13.1a
P value	<0.001				
Lsd	1.2				
Cv	2.3%				

Means with the same letters are not significantly different at p<0.05

3.4.5 Effect of botanicals on thrips population in planting two (March –June 2013)

Decis reduction on thrips populations was significantly different from that of other treatments used. Decis had the least number of thrips while the control had the highest. The effect of tithonia and tephrosia on thrips was comparable (Table 3.5).

Table 3.5 Mean number of thrips recorded on French bean in planting two

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	3.0	5.7	14.3	16.7	9.2abc
Tephrosia	2.3	5.0	14.0	16.3	9.4abc
Tagetes	6.0	10.0	17.3	20.3	13.0ab
Spider plant	6.0	8.0	19.3	22.7	14.0ab
Nimbecidine	2.7	4.0	11.0	16.3	8.5bc
Decis	1.7	3.0	7.3	14	6.5c
Control	8	9.7	18	22.2	14.5a
P value	<0.001				
Lsd	1.2				
Cv	4.2%				

Means with the same letters are not significantly different at p<0.05

3.4.6 Effect of botanicals on whiteflies population in planting two (March –June 2013)

The plant extracts (tithonia and tephrosia) significantly p< 0.05 reduced whitefly populations compared to the control in season 2. Decis had the least mean of whitefly populations compared to the control which had the highest. Again tithonia, tephrosia and nimbecidine effect on whiteflies was not significantly different from that of Decis.There was no significant difference between the mean populations of control, tagetes and spider plant (Table 3.6). Tithonia, tephrosia, nimbecidine and decis mean populations significantly differed with those of spider plant, tagetes and the control. Decis and tephrosia were the most effective.

Table 3.6 Mean number of whiteflies recorded on French bean in planting two

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	0	1.3	2	4.7	2.0b
Tephrosia	0	0	2	3	1.2b
Tagetes	1.3	2.3	5.7	8	4.2a
Spider plant	2.0	2.3	6.7	9	5.0a
Nimbecidine	0	0.3	2.3	1.7	1.1b
Decis	0	0	1	1	0.5b
Control	2.3	4.7	6	10	5.8a
P value	<0.001				
Lsd	0.72				
Cv %	1.9				

Means with the same letters are not significantly different at p<0.05

3.4.7 Effect of botanicals on aphids population in planting three (April - July 2013)

The number of aphids recorded in planting 3 is shown (Table 3.7). Tagetes and spider plant extracts were the least active treatments showing high mean numbers of aphids. Tephrosia (1) and tithonia (2) extracts were very active as compared to tagetes and the spider plant.

Table 3.7 Mean number of aphids recorded on French bean in planting three

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	0.7	1.0	2.0	6.0	2.4c
Tephrosia	0.3	0.3	0.3	3.7	1.2c
Tagetes	5.7	8.3	11.3	17.3	10.7b
Spider plant	7.0	11.7	14.3	22.7	13.9ab
Nimbecidine	0	0.3	2.3	2.3	1.2c
Decis	1.3	0.3	1.7	1.7	1.0c
Control	9.3	11.0	14.0	24.3	14.7a
P value	<0.001				
Lsd	1.0				
Cv	4.5%				

Means with the same letters are not significantly different at p<0.05

3.4.8 Effect of botanicals on thrips population in planting three (April - July 2013)

Plots treated with tephrosia extract had the least number of thrips (8) compared to the other extracts. Its effect was comparable to Decis and nimbecidine (Table 3.8). Spider plant (15) and Tagetes (14) had low insecticidal activity and were comparable to control (15).

Table 3.8 Mean number of thrips recorded on French bean in planting three

Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	3.0	5.0	13.3	16.3	9.4bc
Tephrosia	1.0	3.0	12.0	15.3	7.8c
Tagetes	5.7	8.3	17.7	22.7	13.6ab
Spider plant	7.7	10.0	17.3	25.0	14.8ab
Nimbecidine	3.0	4.0	11.3	16.7	8.6c
Decis	3.0	4.0	10.3	15.3	8.2c
Control	9.3	11.0	18.3	22.0	15.2a
P value	<0.001				
Lsd	1.2				
Cv	3.1%				

Means with the same letters are not significantly different at p<0.05

3.4.9 Effect of botanicals on whiteflies population in planting three (April - July 2012)

Table 3.9 shows that tithonia, tephrosia, nimbecidine effects on pests were significantly different from tagetes and spider plant (p<0.05). While the control and tagetes had a mean of 15 and 10 whiteflies respectively. Plots treated with Decis had a mean of only one insect. The effect of Decis, nimbecidine, tephrosia and tithonia were not significantly different from each other (p<0.05).

Table 3.9 Mean number of whiteflies recorded on French bean in planting three

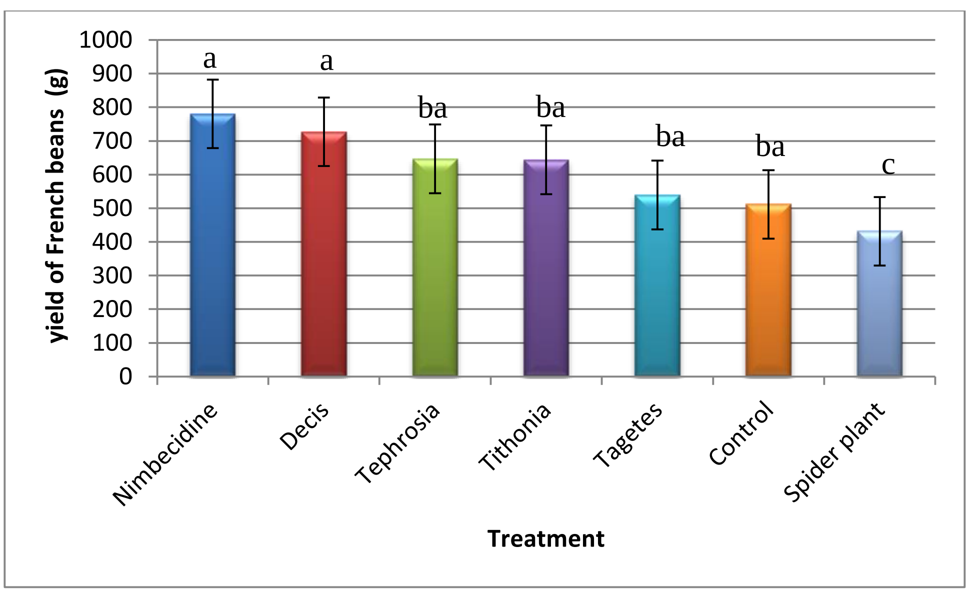
Sampling	1	2	3	4	Overall mean
Treatment					
Tithonia	1.0	2.3	4.7	7.0	3.8c
Tephrosia	0.3	1.0	2.3	5.0	2.2c
Tagetes	5.7	9.3	12.3	13.7	10.2b
Spider plant	7.0	11.0	17.0	25	15.0a
Nimbecidine	0	0.7	3.7	3.3	1.9c
Decis	0	0.3	1.3	3.0	1.2c
Control	9.3	11.0	19.7	21.7	14.9a
P value	<0.001				
Lsd	1.4				
Cv	6.2%				

Means with the same letters are not significantly different at p<0.05

3.4.10 Yield of French beans in planting one

There was a general increase of yields of French beans among the plant extract treatments.

Nimbecidine had the highest yield compared to the rest of the treatments (Fig. 3.2).

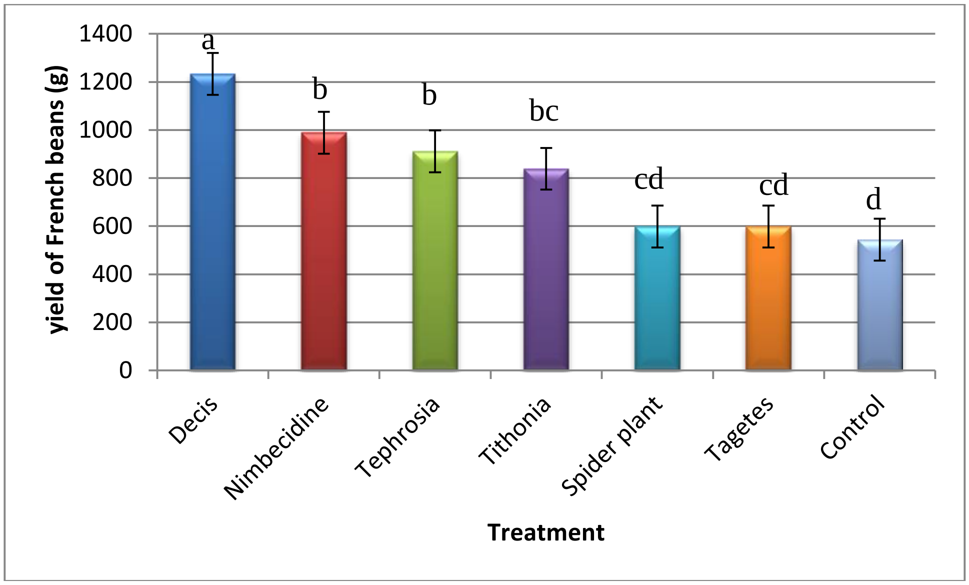


Means with the same letters are not significantly different at p<0.05

Fig 3.2 Yield of French beans in planting one

3.4. 11 Yield of French beans in planting two

Decis treated French beans had a significant higher yield in planting two compared to other treatments and the control ($p<0.05$). Nimebicidine did not show any significant difference in yield compared to tephrosia (Fig. 3.3). Nimbecidine and tephrosia French bean yields did not significantly differ from each.

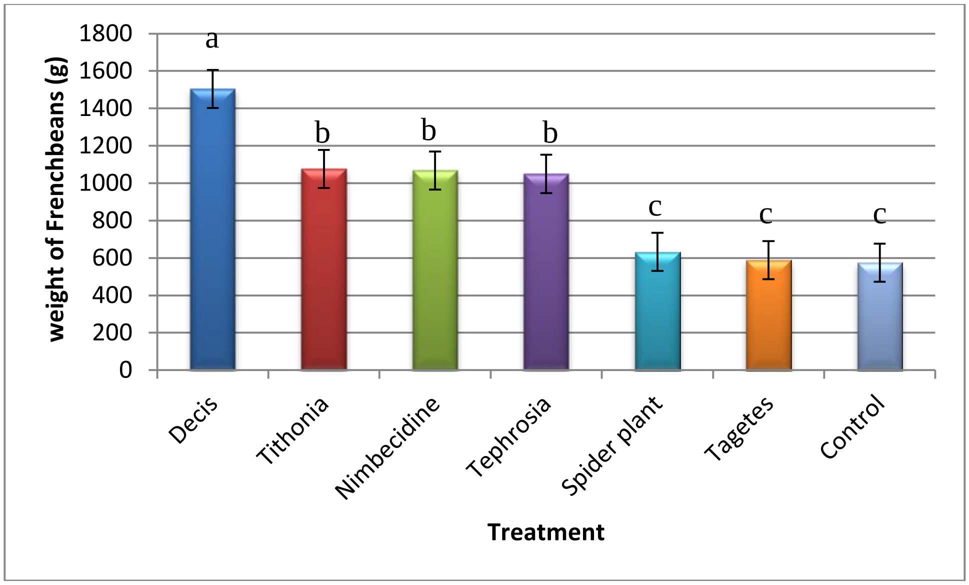


Means with the same letters are not significantly different at $p<0.05$

Fig 3.3 Yield of French beans in planting two

3.4.12 Yield of French beans in planting three

In planting three, Decis had significantly higher French bean yield compared to other treatments and the control ($p<0.05$). Nimbecidine, Tithonia and Tephrosia did not show any significant differences in French bean yield (Fig. 3.4). Spider plant, tagetes and the control were comparable in the yield of French beans and were significantly different from that of Decis and the rest of the treatments.



Means with the same letters are not significantly different at p<0.05

Fig 3.4 Yield of French beans in planting three

3.5 Discussion

Pesticide application (both synthetic and botanical) has been shown to control insect infestations and increase yield of French bean in the present work. The results show that use of botanical pesticides could effectively manage thrips, whiteflies and aphids. Spraying Tephrosia *vogelli* and *Tithonia diversifolia* water extracts controlled the pest populations in French beans compared with the synthetic pesticide Decis and Neem derived product (Nimbecidine). Application of botanical pesticides, *Tephrosia vogelii* and *Tithonia diversifolia* proved to be more effective against the investigated insect pests (aphids, thrips and whitefies). The major ingredients in *T. vogelii* are rotenone, dequelin, alpha-toxicarol, tephrosin, sarcolobin and 5-methoxyisolonchocarpin which may have been responsible for the insecticidal and antifeedant activity (Carlson and Tallent, 1970; Belmain, *et al.*, 2012). These are the compounds responsible for the activity of tephrosia extract.. A number of compounds including sesquiterpenoids and sesquiterpene lactones such as tagitinin, tirotundin, tithofolinolide, 3α-acetoxydiversifolol, 3βacetoxy-8β-isobutyryloxyreynosin and their derivatives have been isolated from *Tithonia diversifolia* (Lee, *et al.,* 2011; Gu, *et al.,* 2002; Garcia and Guillermo, 2006; Zhou, *et al.,* 2000; Baruah, *et al.,* 1979). Some of these compounds could be responsible for the insecticidal activity of tithonia extract. Commercial pesticide (Decis, as synthetic pyrethroid, deltamethrin) and nimbecidine (derived from neem oil) performed best as expected. Tephrosia and tithonia extracts were as effective as Decis and nimbecidine, while *Tagetes minuta* and *Gynadropsis gynadra* (*Cleome gynadra*) demonstrated very low insecticidal activity on the pests and were similar with the control.

This study indicates that tithonia extract was very effective and in some instances was sometimes as effective as Decis and *nimbecidine* insecticides. The effect of tithonia water extract on thrips and whiteflies on French beans is reported here for the first time. The powder and ethanol extracts of *Tithonia diversifolia* leaves have been shown to have anti-ovipositional, ovicidal and knock down properties on cowpea seed bruchid (Adedire and Akinneye, 2004). Its extract is said to be as effective as the nematicide carbofuran in the management of root-knot nematode (Akpheokhai, *et al*., 2012). Moreno (1991), considered high concentation of tithonia water extract to be potentially useful in blocking rapid reproduction of aphids at 59,38 and 19.5% kill when sprayed with 100,75 and 50% water extract, respectively). Water extract of *Tithonia diversifolia* has been shown to be the best for the control of *Periplanata americana* over organic extracts (Ambama, 2013). The present study showed that 10% w/v of tithonia and tephrosia extracts had a significant effect on French beans in yields and thrips number on the flowers compared with the other plants extracts and the control. This study has given a comprehensive report on pesticidal effect of water extract of Tephrosia on the three tested insects (Aphids, Thrips and Whiteflies) in French beans. Work done by Alao, *et al.,* (2011) reported that application of *Tephrosia vogelii* and *Petiveria alliacea* was effective against *Riptortus dentipes, Megalurothrips sjostedti* and *Megalurothrips vitrata* in cowpea. The study conducted by (Adebayo, *et al.,* 2007) at the research farm in Nigeria using *T. vogelii* and *P. alliacea* to control insect pests *(Maruca testularis)* on cowpeas showed the potential of these plants in controlling pests. Another study by (Lao, *et al.,* 2011) evaluating the natural toxicants from *Tephrosia vogelii* and *Petiveria alliacea* on *Megalurothrips sjostedti* and *Apion varium* of cowpea (*Vigna unguiculata* (L) Walp) showed that the two insect pests were effectively controlled by the botanical insecticides compared with untreated plants. Also, the plant extracts at 20% and 10% v/v significantly protected cowpea pods and grains from the insect damage. However, higher grain yield was obtained from the plant treated with 20% v/v compared to those treated with 10%, 5% v/v and untreated plants. combination of the two plant extracts at 20% v/v had the same efficacy with synthetic insecticide (Decis) (Lao, *et al.,* 2011). Results obtained from the present study confirm that tephrosia water extract can be used in the control of insects in French beans.

The low insecticidal activity of tagetes may be attributed to the fact that the pesticidal activity of the plant resides in its essential oil which could have evaporated during the hot water extraction or due to the fact that the activity may be due to non-polar compounds which cannot be extracted with water (Dinesh, *et al.,* 2014, Perich, *et al.,* 1995; Phoofolo, *et al.,* 2013; López, *et al.,* 2011; Singh *et al.,* 2003; Weaver, *et al.,* 1994; Maradufu, *et al.,* 1978). It was not clear why the spider plant did not have any effect on insects. There is a possibility that it could be due to the extraction method used (Cheya and Mnzawa, 1997). This is because it has been used as an intercrop to repel insects such as aphids on cabbages, Kales and roses (Waiganjo, *et al.,* 2007).

Tephrosia vogelii is widely spread in Kenya and grows well in areas where French beans are cultivated so this plant can readily be grown by farmers for use as a pesticide. However, the plant is quickly being uprooted in the new fishing area as the leaves paralyse the fish if sprinkled into the fish ponds (Neil, 2013; Akpa, 2010). *Tithonia diversifolia* is planted as hedges in many homes and therefore does not present the same challenge as Tephrosia.

This is the first comprehensive report on the effect of water extract of tephrosia on the three tested insects (Aphids, Thrips and Whiteflies) in French beans. However, work done earlier on French beans (string bean) had shown that high concentrations of *Tithonia diversifolia* leaf water extract solution resulted in high mortality on aphids and reduced root damage caused by *Aphis sp.*,*Crocidomia binotalis, Ophiomyia (Melanogramxya) phaseoli* and a borer species (Moreno 1991). While the Aphids species was not specified, there is no report on pesticidal activity of *Tithonia diversifolia* on *Megalurothrips sjostedti*, *Frankliniella occidentalis* and *Bemisia tabaci* on French beans.

CHAPTER FOUR

EFFECT OF COLOURED STICKY TRAPS IN MANAGEMENT OF FLOWER THRIPS, WHITEFLIES AND APHIDS AFFECTING FRENCH BEANS

4.1 Abstract

A field experiment was conducted to evaluate the effect of different coloured sticky traps on the monitoring and management of selected insect pests of French beans. The experiment was laid out in a Randomized Control Block Design and was set up at Kabete Campus, University of Nairobi experimental farm. Different colour sticky traps (Blue, Yellow and clear) were used as treatments, decis and water were used as control. Thrips population was assessed from 5 flowers per plant on 5 plants randomly selected in the middle of each plot. The aphids and white flies were assessed in the same manner but from 3 leaves and 3 plants. Data was analysed. The target insect species were Western flower thrips *(Frankliniella occidentalis)*, commom blossom thrip (*Frankliniella schultzei)*, African bean flower thrips (*Megalurothrips sjostedti)* and whiteflies *(Bemisia tabaci)*, Black bean aphid *(Aphis fabae*); the most common pests on French beans. Data was analysed to assess the effect of colour on the target pests

The plots where the blue sticky color traps had been mounted had less of thrips than the plots with yellow traps. Plots treated with Decis had almostvery few thrips in the flowers. Although the total number of aphids recorded did not have any significant difference over the three plantings for yellow and blue traps, there was a signicant difference for thrips and whiteflies at $p < 0.05$.

Plots with yellow and blue sticky traps did not show any significant difference in yield of French beans. The plots treated with Decis had the highest yields of at least about 1.4 higher than yellow

or blue traps mounted plots. These results imply that the farmer may apply reduced rates of Decis thereby resulting in fewer negative effects on human health and reduced cost of production.

4.2 INTRODUCTION

It is estimated that over 50,000 small holder families are directly or indirectly involved in French bean cultivation in Kenya. About 80% of French beans in Kenya are produced by small scale farmers (Nderitu *et al.*, 2008). They are mainly grown for the export market as a source of income for the family. According to SNV Netherlands Development Organization study, French bean production employs 45,000 to 60,000 people (2012). Sixty percent of the workers are women engaged in commercial farms and they dominate post harvest handling of French beans; sorting, grading and in quality control. Farmers are always under pressure to meet standards on environment, food safety, quality and traceability, occupation health and safety of workers especially those set by the European Union which is the main market for French beans from Kenya (Ogola, 2013; Goro, 2013).

Use of coloured sticky insect traps is another way of contributing to increased production of French beans free of chemical residues. The information will encourage the farmers to use readily available plant materials in the control of pests to improve productivity of French beans in Kenya. In general yellow sticky traps are recommended for monitoring and reducing adult leaf miners, moths, leafhoppers, whiteflies, aphids (winged forms) thrips and fungus gnats, among other insect pests (Hoddle, *et al.*, 2002). Thrips are also attracted to white and blue colour. As the yellow colour attracts many insect species, including beneficial insects, yellow sticky traps should be used only where necessary. Adult thrips can be monitored and in some cases be reduced by mass trapping with coloured (blue, yellow or white) sticky traps in greenhouses. Red sticky traps have been found to to be more effective on *Tuta absoluta* moths (47%) compared with other trap colours (Taha, *et al.*, 2012). Rodriguez-Saona, *et al.*, (2012) found that green coloured traps had the most attractive activity to blunt-nosed leafhoppers while yellow traps were most attractive to sharp-nosed leafhoppers. Pasian and Lindquist (2009) recommended yellow coloured traps for monitoring western flower thrips, whiteflies and fungus gnats.

Western flower thrips (WFT), *Franklinella occidentalis* (Pergande) is considered the most destructive insect pest of greenhouse-grown crops due to direct feeding damage to plant parts such as foliage and flowers, and indirect damage by vectoring the tospoviruses; impatiens necrotic spot and tomato spotted wilt virus (Cloyd, 2009). Furthermore, western flower thrips is difficult to manage in greenhouse production systems due to a number of factors including broad range of ornamental plants fed upon, high female reproductive capacity, rapid life cycle (egg to adult), residence in cryptic habitats such as unopened terminal buds that protect them from exposure to contact insecticides, and resistance to various insecticide chemical classes (Cloyd, 2009). As such, the management of WFT requires a holistic or complex approach, including the concurrent implementation of scouting, cultural, physical, insecticidal, and biological strategies. Greenhouse producers utilize sanitation and biological control practices to avoid solely relying on insecticides. The advent of resistance among WFT populations worldwide has led to a general interest among greenhouse producers in adopting the use of biological control as a long-term strategy to deal with WFT, and still produce and sell quality produce (Bielza, *et al.,* 2007). The main technique used to scout for WFT adults is to place either blue or yellow sticky cards above the crop canopy, although there is still disagreement on which color is the most attractive to WFT (Cloyd, 2009).

Tests on sticky traps on thrips populations have revealed differential attraction, and published results are not consistent. In some tests where sticky yellow and white traps were used, it was reported that there were more *Frankliniella occidentalis* on white than on yellow traps (Kaas, 2005). Other reports comparing blue, white and yellow traps indicated higher catches for yellow than for other colors (Kaas, 2005). In general blue sticky traps have been used for thrips monitoring and yellow for whitefly, aphid and other insects. According to Kaas (2005) blue sticky traps are significantly more attractive to thrips than yellow.

In Kenya some studies on sticky colored traps has been reported. A study by Muvea, (2011) with French beans, blue sticky traps caught 2– 3.5 times as many thrips as yellow traps, and 22 – 29 times more than white traps. Furthermore, blue traps were most attractive to *Megalurothrips sjostedti* (Trybom), *Ceratothripoides brunneus* (Bagnall) and *Frankliniella schultzei* (Trybom). *Hydatothrips adolfifriderici* (Karny) were only attracted to yellow traps. Muvea (2011) also indicated that blue and yellow traps were equally attractive to *Frankliniella occidentalis* (Pergande) in tomato *(*Muvea, 2011). In another report based on the survey of *Frankliniella schultzei*, *F. occidentalis* (French bean, capsicum and cucurbits), *Thrips tabaci* (onions and crucifers), *Ceratothripoides brunneus* (tomato) and *Megalurothrips sjostedti* (French bean, cowpea, common bean), it was recorded that most of the thrip species were attracted to blue-coloured sticky traps than the yellow sticky traps (ICIPE, 2011). Kasina, *et al.,* (2009), studied the spatial distribution of flower thrips, *Frankliniella occidentalis* (Pergande) and *Megalurothrips sjostedti* Trybom, on French beans (*Phaseolus vulgaris* L.) in Kenya. The build up and population dynamics were monitored using sticky blue colour traps and sampling of leaves and flowers in two plantings. The study showed that a combination of monitoring with sticky traps and proper sampling would contribute to sustainable thrips management.

Blue sticky traps with and without pheromone capsules have also been used to monitor and control *Frankliniella occidentalis* (Elimem *et al.*, 2014). However, the pheromone enhances the effect of blue sticky traps in catching thrips species such as *F. occidentalis* and T*hrips tabaci* (Mateus, *et al.,* 2012). According to Zepa-coradini, *et al.*, (2010) yellow sticky traps attract a large number of *Frankliniella occidentalis* adults and can be used directly in controlling or monitoring this pest population. In an experiment to monitor western flower thrips (*Frankliniella occidentalis)*, population in a greenhouse with tomato crop, blue and yellow traps had the highest attractiveness compared to other colors (white, red and clear). Among the colors used in this study, blue proved to be the most effective (Covac, *et al.,* 2012). Yellow, white, and blue sticky cards when tested in an avocado orchard for their attractiveness to *Scirtothrips perseae, Frankliniella occidentalis* and *Franklinothrips orizabensis*, yellow cards were most attractive to *Scirtothrips perseae* and white cards captured mostly *Franklinothrips orizabensis* and *Frankliniella occidentalis* (Hoddle, *et al.*, 2002). Experiments conducted by Yudin, (1987) to determine color preference of thrips, aphids and leafminers in lettuce farms in Hawaii indicated that white traps significantly caught more thrips than 14 other colors tested. *Frankliniella occidentalis* (Pergande) was the predominant thrips species trapped. More adult and larval thrips were associated with plants with tomato spotted wilt disease than with healthy plants during later weeks of lettuce growth. The mean number of aphids and leafminers trapped did not indicate any conclusive preference of these insects for a particular color.

In a study mounted by Oseto (1999) flower thrips, *Frankliniella tritici*, were attracted to white sticky traps while aphids, *Aphis spiraecola*, were attracted to yellow traps. A study to determine the effectiveness of sticky trap designs with different colours for trapping alate whitefly, *Bemisia tabaci* using yellow, blue, green, red, white and black, yellow was the most attractive colour to these whiteflies and therefore had the highest number of whiteflies caught compared to the other colours (Idris, *et al.*, 2012). The sweet potato whitefly, *Bemisia tabaci* densities in the greenhouse with yellow sticky traps were significantly lower than the greenhouse without traps. In the field, the yellow traps did not have a significant impact on the population dynamics of adult and immature potato whiteflies (Yaobin, *et al.* 2012). The objective of the present study was to assess the effect of different colored sticky traps to management of thrips, whiteflies and aphids on French bean.

4.3 MATERIALS AND METHODS

4.3.1 The Experimental site

The study was carried out at the College of Agriculture and Veterinary Science Kabete, Field Station Farm, University of Nairobi between November 2012 and July 2013 (First planting: November 2012- February 2013, second planting: March –June 2013 and third planting: April – July 2013). The site is about 1800 m above sea level. The soils are well drained, deep, reddish brown to dark red (Nitosols) developed from Limuru Trachite (Michieka, (1977). Kabete area receives an annual rainfall of about 1000 mm and experiences average temperatures of 23^{0}C (Wambua, 2004).

4.3.2 Experimental layout

Commercial certified seed of French beans (Slender Green variety) was planted between November 2012 and July 2013. Demarcation into blocks and making of trenches were done manually (Fig 4.1). The crop was rain-fed and irrigation was done to supplement when necessary. The experimental layout was RCBD with four replicates. Different coloured traps were used as treatments. These were blue, yellow and clear. The traps were placed in the middle of the plots 60 cm above the ground arranged in a triangular design at 0.5 m apart four weeks after planting.

T4	T2	T1	T5	T3
T2	T3	T4	T1	T5
T5	T1	T3	T2	T4

Fig. 4.1 Layout of the trap treatments in the field

T= Treatment, T1-Decis, T2-Clear, T3-Control, T4-Yellow and T5-Blue.
Di-ammonium phosphate (DAP) fertilizer was applied during planting at the rate of 133 kg per hectare. Weeding was done twice during the growing period, first two weeks after emergence.

Plate. 4.1. Plot of French beans with Colored Traps
Source :FN Mwangi 2013

Plate 4.2 Mounted colored yellow trap
Source :FN Mwangi 2013

Plate 4.3. Blue colored trap with pests stuck on it.
Source :FN Mwangi 2012

Randomized Complete Block Design (RCBD) was used with four replicates. The traps were mouted 0.5 m from each other and 60 cm from the ground.

Assessment of the colored traps was undertaken during the period of November 2012 to July 2013.

4.3.3 Data collection and analysis

Before mounting the coloured traps, assessments of thrips, whiteflies and aphids were carried out. The aphids and whiteflies were recorded on three leaves per plant randomly selected in the middle of each plot from three plants. Thrips population was assessed in the same manner from 5 flowers per plant on 5 plants randomly selected in a plot; the flowers were preserved in 50% alcohol in separate bottles for flower maceration, identification and counting of thrips. The flower thrips (*Megalurothrips sjostedti*), (*Frankliniella occidentalis*), *(Frankliniella schultzei* Trybom), were all recorded as thrips. The bean aphid (*Aphis fabae*), and whiteflies (*Bemisia* *tabaci*) were recorded separately. Pest population data was done weekly for a period of four weeks and the traps were replaced weekly with new ones (Figs. 4.1 – 4.3). The yields of French beans were recorded for each planting. Data analysis was carried out by using GenStat Release 14.2 software.

4.4 RESULTS

4.4.1 Effect of coloured traps on aphids in planting one (Nov. 2012- Feb 2013)

Decis treated plots had significantly lower aphid populations recorded compared to other treatments and the control ($p<0.05$). Plots with mounted yellow and blue sticky colors did not show a significant difference in mean number of aphids in the plots. The control plots had the highest aphid infestation (13) while Decis plots had no aphids. In the plots where blue and yellow traps were mounted 3 and 5 aphids were recorded, respectively (Table 4.1).

Table 4.1 Mean number of aphids recorded on French bean in planting one

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	2.8	2.3	3.8	4.7	3.4c
Yellow	7.1	2.1	4.3	5.7	4.8c
Clear	11.8	6.4	7.3	7.8	8.3b
Control	10.4	11.7	14.8	15.8	13.2a
Decis	0	0	0	0	0.0d
P value	<0.001				
Lsd	2.5				
Cv	10.1%				

Means with the same letters are not significantly different at $p<0.05$

4.4.2 Effect of coloured traps on thrips on planting one (Nov. 2012- Feb 2013)

Decis treated plots had significantly lower number of thrips compared to the other treatments and the control ($p<0.05$). Plots with yellow colored traps had lower number of thrips compared to other coloured traps (Table 4.2).

Table 4.2 Mean number of thrips recorded on French bean in planting one

Sampling	1	2	3	4	Overall mean
<u>Treatment</u>					
Blue	78	62.2	69.4	153.1	90.7d
Yellow	84.4	66.3	78.6	88.9	79.6c
Clear	96.8	81.6	90.3	115.3	96.0b
Control	167.2	187.1	222.0	333.3	227.2a
Decis	0.1	1.0	1.2	0.6	0.7e
P value	<0.001				
Lsd	23.7				
Cv	10.9%				

Means with the same letters are not significantly different at p<0.05

4.4.3 Effect of coloured traps on whiteflies in planting one (Nov. 2012- Feb 2013)

In planting one there was only one whitefly recorded in the plots treated with Decis (Table 4.3). Although 18 thrips were recorded in the plots having blue coloured traps, plots with yellow traps had a mean of 50 whiteflies while Decis had a mean of 1 whitefly. The control had the highest mean number of whiteflies (120) and was significantly $p < 0.05$ different from the coloured traps. Clear traps had the 2nd highest mean of whiteflies (80) and was different from all other traps including Decis and the control.

Table 4.3 Mean number of whiteflies recorded on French bean in planting one

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	18.7	14.4	14.0	24.0	17.9cd
Yellow	40.2	53.4	40.8	68.0	50.6c
Clear	53.8	43.7	54.3	94.1	61.5b
Control	109.3	88.7	90.7	192.2	120.2a
Decis	0.4	0	3.4	0.4	1.1d
P value	<0.001				
Lsd	12.5				
Cv	3%				

Means with the same letters are not significantly different at p<0.05

4.4.4 Effect of coloured traps on aphids in planting two (March 2013- June 2013)

The Decis treated plots had significantly lower aphid population in planting two compared to the coloured traps and the control(p<0.05) (Table 4.4). There was no significant difference between blue and yellow traps regarding the aphids recorded.The control plots had the most mean number of aphids (13). Plots treated with Decis had no aphids.

Table 4.4 Mean number of aphids recorded on French bean in planting two

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	2.7	2.3	4.0	4.7	3.4c
Yellow	4.3	1.7	4.7	5.7	4.1c
Clear	7.3	8.7	10.3	10.3	9.2b
Control	10.0	11.7	15.3	16.3	13.3a
Decis	0	0	0	0	0.0d
P value	<0.001				
Lsd	0.962				
Cv	3.6%				

Means with the same letters are not significantly different at p<0.05

4.4.5 Effect of coloured traps on thrips in planting two (March 2013- June 2013)

The plots mounted with blue sticky traps had significantly lower mean number of thrips (58) compared to the yellow traps (83) in planting two ($p<0.05$). The control had the most mean number thrips (204) while the Decis plots had only one thrip.

Table 4.5 Mean number of thrips recorded on French bean in planting two

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	74.0	46.3	52.3	60.7	58.3d
Yellow	100.0	71.0	78.7	81.7	82.8c
Clear	125.3	107.0	115.7	120.0	117.0b
Control	163.0	189.7	221.0	224.0	204.4a
Decis	0	0.3	1.0	0.3	0.5e
P value	<0.001				
Lsd	0.962				
Cv	3.6%				

Means with the same letters are not significantly different at p<0.05

4.4.6 Effect of colured traps on whiteflies in planting two (March 2013- June 2013)

The control plots had the most mean number of whiteflies (121) in planting two (Table 4.6). The mean number of whiteflies in plots with blue colored traps (21) and yellow traps (39) were significantly different close. Decis had the least mean number of whiteflies (1) in planting two.

Table 4.6 Mean number of whiteflies recorded on French bean in planting two

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	20.0	16.0	23.0	23.0	20.5cd
Yellow	39.3	46.3	31.7	40.3	39.4c
Clear	56.7	70.3	87.0	117.7	82.9b
Control	113.3	88.7	90.7	191.0	120.9a
Decis	0.7	0	3.7	0	1.1d
P value	<0.001				
Lsd	19.58				
Cv	7.0%				

Means with the same letters are not significantly different at p<0.05

4.4.7 Effect of coloured traps on aphids in planting three (April 2013- July 2013)

In planting three, aphid populations in the control plots (13) were comparable with those in the clear sticky traps plots (14 aphids). Although the plots treated with Decis had no thrips, there was no significant difference between aphid population in Decis and those with blue colored sticky traps. (Table 4.7).

Table 4.7 Mean number of aphids recorded on French bean in planting three

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	2.7	2.3	4.0	4.7	3.4b
Yellow	14.0	3.0	4.7	5.7	6.8ab
Clear	27.3	8.7	9.3	9.7	13.8a
Control	10.3	11.7	13.7	14.7	12.7a
Decis	0	0	0	0	0.0b
P value	<0.001				
Lsd	6.92				
Cv	26.2%				

Means with the same letters are not significantly different at p<0.05

4.4.8 Effect of coloured traps on thrips in planting three (April 2013- July 2013)

In planting three, coloured and clear traps had a significant effect on thrip populations compared to the control. The mean thrip population recorded in the decis plots was different compared to the blue, yellow and clear traps (p<0.05). The coloured traps mean numbers were all different from each other (Table 4.8).

Table 4.8 Mean number of thrips recorded on French bean in planting three

Sampling	1	2	3	4	Overall mean
Treatment					
Blue	80.3	53.3	48.7	48.0	62.6d
Yellow	103.7	71.0	77.0	89.0	85.2c
Clear	126.7	92.0	101.3	118.0	109.5b
Control	168.0	182.0	221.0	236.7	201.9a
Decis	0.8	1.3	1.3	0.7	0.8e
P value	<0.001				
Lsd	16.83				
Cv	13.7%				

Means with the same letters are not significantly different at p<0.05

4.4.9 Effects of coloured traps on whiteflies in planting three (April 2013- July 2013)

In planting three, there were significant differences in the mean whiteflies populations recorded in control the plots (120) compared to that in clear sticky traps (77) (p<0.05). Whitefly mean numbers recorded in plots with blue coloured traps were higher than those recorded in yellow traps (Table 4.9). Similarly, the mean whiteflies population in the blue coloured trap plots was not different from the Decis plot. However, there was a difference between yellow trap on whitefly mean population and Decis plots whitefly population.

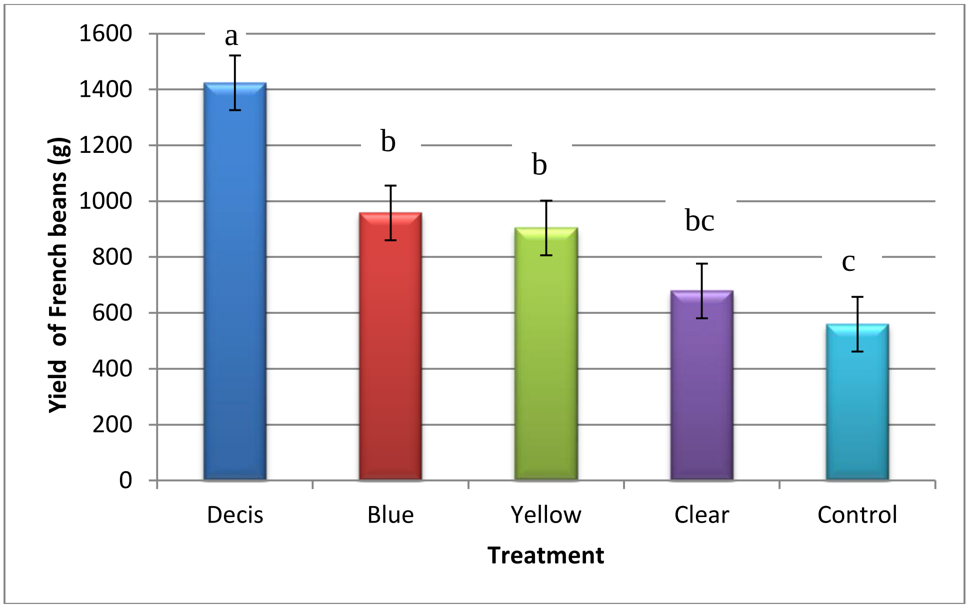
Table 4.9 Mean number of whiteflies recorded on French bean in planting three

Sampling	1	2	3	4	Overall mean
<u>Treatment</u>					
Blue	18.0	18.0	11.7	23.0	17.7cd
Yellow	40.7	50.3	25.3	39.7	39.0c
Clear	57.3	55.7	69.3	126.0	77.1b
Control	107.3	88.7	90.7	194.7	120.3a
Decis	0.3	0	3.3	0.7	1.1d
P value	<0.001				
Lsd	19.7				
Cv	0.4%				

Means with the same letters are not significantly different at p<0.05

4.4.10 Yield of French beans in planting one

Fig. 4.2 shows that there was significant difference in yield for the plots treated with Decis compared to coloured traps and the control in planting one ($p<0.05$) and there was no significant difference between blue, yellow and clear traps in yield. In this planting the Decis treated plots yielded an average of 1424 g (1,758 kg/ha) while blue and yellow yielded 958 g (1,183 kg/ha) and 904 g (1,116 kg/ha), respectively. Control had the least mean yield of 559.1 g (690 kg/ha).

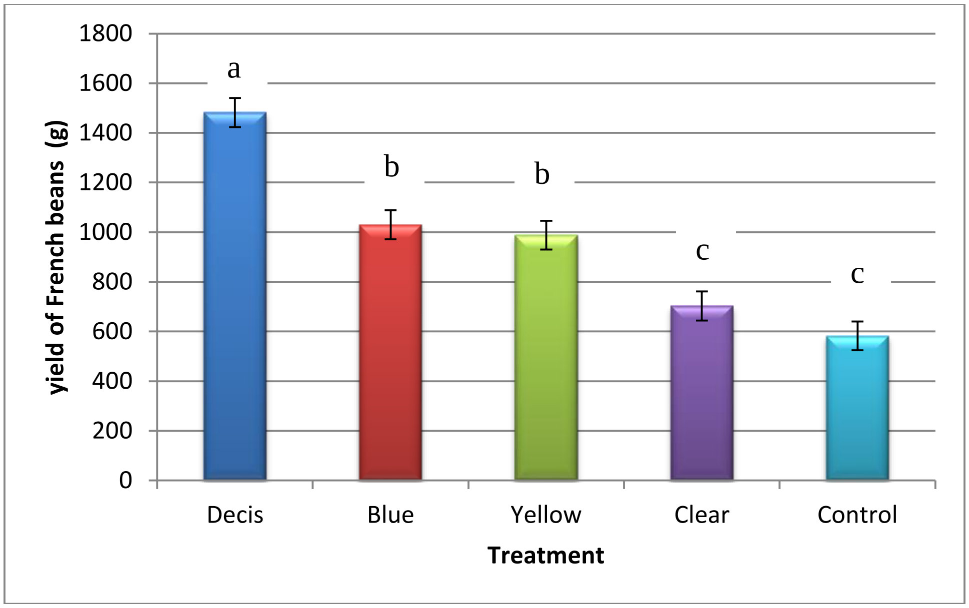


Means with the same letters are not significantly different at p<0.05

Fig. 4.2 Yield of French beans in planting one

4.4.11 Yield of French beans in planting two

In planting two Decis plots yielded an average of 1482 g (1,830 kg/ha) while blue and yellow treatments produced 1030 g (1,272 kg/ha) and 988 g (1,220 kg/ha) respectively (Fg. 4.14). There was no significant difference in the yields of French beans between the plots with blue and yellow traps and there was no significant difference in yields between plots with clear traps and the control. Control had the least yield of 600 g. (740 kg/ha).

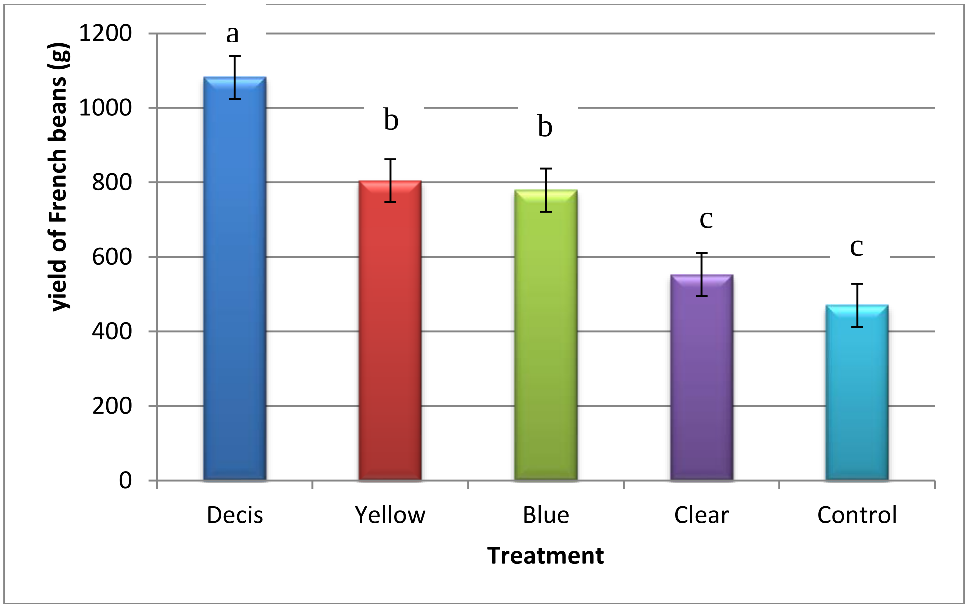


Means with the same letters are not significantly different at $p<0.05$

Fig. 4.3 Yield of French beans in planting two

4.4.12 Yield of French beans in planting three

A similar picture on yields which was recorded in planting two was also observed in planting three (fig.4.4). In planting three, Decis plots yielded an average of 1082 g (1,335 kg/ha) while blue and yellow produced 779 g (962 kg/ha) and 804 g. (993 kg/ha) respectively. There was no significant difference in yield between plots with blue and yellow traps. There was also no significant difference in yield between plots with clear traps and the control. Control had the least mean yield of 460 g. (568 kg/ha).



Means with the same letters are not significantly different at p<0.05

Fig. 4.4 Yield of French beans in planting three

4.5 Discussion

The results obtained in this study showed that colored sticky traps were able to reduce the number of whiteflies, aphids and thrips on the leaves or flowers of French beans. In all plantings, the insect populations in plots mounted with blue traps were lower than those recorded in plots with yellow traps. The results confirm the reported finding by other researchers that blue sticky traps are more effective on thrips (Muvea, 2011; Covaci *et al.*, 2012; ICIPE, 2011; Harbi *et al.*, 2013; Elimem *et al.*, 2014). Hoddle *et al*. (2002) reported that white sticky traps were more attractive to *Frankliniella occidentalis* than yellow or blue traps. Other results report that yellow sticky traps are better in monitoring and controlling of *Frankliniella occidentalis (*Zepa-Coradini *et et al.*, 2010). Different hues of colours, possibility of trap materials, reflectance and other factors next to colour as recorded by the human eye could be playing some part in the effect which coloured sticky traps exhibit (Kaas, 2005). In this study, rsults have demonstrated that clear traps had slightly low insect populations compared to control the plots. Currently, thrips rank as primary pests of French beans in Kenya. *Frankliniella occidentalis* and *Megalurothrips sjostedti* being the main thrips species causing 40-60% yield losses at farm level. While *M. sjostedti* is said to be manageable using insecticides to uneconomical levels, *F. occidentalis* has shown great challenges arising from resistance to most insecticides currently being used by local farmers (Kasina *et al.,* 2006: Nderitu *et al.,* 2007). Hence blue, yellow and clear traps will be useful in lowering this species population levels.

This study has also demonstrated that the presence of yellow or blue sticky traps in the field resulted to the reduction of thrips, aphids and whiteflies. The plots in which these coloured traps had been mounted produced significantly different higher yields of French beans compared with the control or clear traps. Coloured sticky traps are usually used to monitor pests either in green houses or in the field (Lua, *et al.,*2012; Covaci *et al.,* 2012; Thein *et al.,* 2011; Yaobin *et al.;* 2012). Most researchers therefore concentrate on the trapped pests on the coloured sticky traps rather than the impact on population dynamics of the pests. This study indicates that, for the control of pests, it would also be useful to monitor those pests that are on the plants.

From the results obtained in this study, it is demonstrated that there was a positive effect of blue and yellow traps in reducing the number of whiteflies *(Bemisia tabaci)* and Black bean aphid *(Aphis fabae*) and that blue traps were slightly better than other traps. Further, it showed that the coloured traps could be used in the field for whiteflies. Yellow has been reported as the most attractive colour to alate aphids since it had the highest number of alates caught compared to the other colours (yellow, blue, green, red, white and black) (Idris, *et al.,* 2012). In a study by Yaobin, *et al.,* (2012), the impact of yellow sticky traps on the population dynamics of the sweet potato whitefly, *Bemisia tabaci* was determined in the greenhouse and field. In contrast to the present study they reported that yellow sticky traps can be used as an effective method for the control of whiteflies in the greenhouse but not in the field.

In the present study, there was not much difference in aphids, *Aphis fabae,* present in the plots with blue or yellow traps. Doring and Chittka (2007), have done a review on behavioral responses of aphids to stimuli of different colors. They have stated that there is scanty data on spectral sensitivity to explain aphid behaviour crisply in mechanistic terms. In a report by Straw *et al.,* (2011) in which a series of field trials were used to assess the practicability of using sticky traps to monitor populations of green spruce aphid, *Elatobium abietinum* (Walker), in plantations of Sitka spruce, significantly more alate aphids were caught on the red sticky traps than on traps of any other color except for green. Light yellow and green coloured sticky traps have also been shown to have a significant attractiveness to tea aphid, *Toxoptera aurantii* (Baoyu *et al.*, 2012). The yield of French beans for each of the three plantings indicated that both blue and yellow sticky traps had similar and higher effect on the insects compared to clear and the control.

CHAPTER 5

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

The present study reports an alternative pest management system for French beans. It provides an easy method of preparation of either Tithonia or Tephrosia extract and spraying to French beans. Tithonia and Tephrosia emerged as an alternative to chemical pesticides already in use in crop production. Although the effects of these two extracts were compareable, Tithonia seemed more specific to thrips. Tagetes and spider plant did not have much insecticidal effect on the insects. The low effect of Tagetes could be attributed to the method of preparation of the test materials. If the extract of Tagetes was prepared by distillation of its essential oil or cold organic extraction, the results may have been different as the insecticidal activity resides in its essential oil which is volatile (Maradufu, *et al.* 1978). Tithonia and Tephrosia are either available in the French bean growing areas or can easily be cultivated by the farmers as hedges or live fences. The current problem is that our horticultural produce (especially French beans) has raised a red flag in European countries due to pesticide residues present in the produce. Kenya therefore needs to relook at biopesticides (Ogola, 2013; Goro, 2013).

Natural insecticides are low in cost, locally available, easy to prepare, safe for the environment and non target organisms, and insect resistance is not common. The use of plant extracts in French bean production is a significant contribution to knowledge particularly because small holder farmers are the major food producers in Kenya and the world over. This study provides scientific basis for using a more rational approach to integrated pest management in developing countries where farmers cannot afford high cost of procuring synthetic insecticides. It also provides possible natural alternative techniques that could complement synthetic pesticides.

Blue and yellow sticky traps were also found to be effective alternatives to chemical insecticides and could be used in integrated the Pest Management programmes.

This study demonstrated that the presence of yellow or blue sticky traps in the field resulted in the reduction of thrips, aphids and whiteflies. The plots in which these coloured traps had been mounted produced significantly different higher yields of French beans compared with the control or clear traps. Coloured sticky traps are usually used to monitor pests either in green houses or in the field (Covaci *et al.,* 2012; Thein *et al.,* 2011; Yaobin *et al.;* 2012). Most researchers therefore concentrate on the trapped pests on the coloured sticky traps rather than the impact on population dynamics of the pests. This study indicated that, for the control of pests, it also would be useful to monitor those pests that are on the plants.

5.2 ConclusionsZ

- Botanical pesticides at the rate 165 litres of 10% w/v per acre sprayed weekly can be used to manage pests on French beans and they have the ability to reduce aphid, thrip and whitefly populations. The most effective extracts were Tephrosia and Tithonia.
- Yellow and blue coloured sticky traps were able to reduce insect populations at the rate of 500 traps per acre.

5.3 Recommendations

- Further studies of the conditions and the optimum concentrations, to improve on quality for use of *Tithonia vogelii* and *Tephrosia diversifolia* in French beans should be studied.

- Since the blue and yellow colored sticky traps had useful activity on the tested pests, follow up could be carried out to determine if there would be improved effects if used together with Tithonia and Tephrosia extracts.
- There are no studies of combined extracts of Tithonia and Tephrosia extracts in French beans and therefore it would be necessary to combine the two and observe the effects.
- The cost of production of French beans when Tithonia and Tephrosia extracts and coloured traps are used should also be studied.

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