Evaluation of Various French bean Cultivars for their Susceptibility to Thrips and the Effect of Nitrogen Fertilizer and Natural Enemies on Population Dynamics of Thrips

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A thesis submitted in partial fulfillment for the Degree of Masters of Science in Zoology of Jomo Kenyatta University of Agriculture and Technology

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

This work is dedicated to my family, Dad and Mum, my sisters and brothers.

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LIST OF ABBREVIATIONS

WFT	Western Flower Thrips
MASL	Meters Above Sea Level
HCDA	Horticultural Crop Development Association
IPM	Integrated Pest Management
JICA	Japan International Co-operation Agency
JKUAT	Jomo Kenyatta University of Agriculture and Technology
MOA	Ministry of Agriculture
TSWV	Tomato Spotted Wilt Virus

ABSTRACT

Western flower thrips; *Frankliniella occidentalis* (Pergande) and *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae) are among the most important pests of French beans, (*Phaseolus vulgaris)* in Kenya. Attack by thrips leads to flower malformation, distortion, and discoloration while in severe infestations, flower buds do not open and may abort prematurely, hence, the need for urgent and effective alternative intervention strategies. The study was aimed at evaluating various French bean cultivars for their susceptibility to thrips and the effect of nitrogen fertilizer and natural enemies on population dynamics of thrips and hence come up with innovative integrated pest management (IPM) strategies for management of thrips in French beans. This was done through a study of changes in the population of flower thrips based on different French bean cultivars: Paulista, Army Star, Julia, Samantha and Alexandra, grown under varied top dressing nitrogenous fertilizer regimes. This was done between August 2007 and January 2008 in, JKUAT farm and KARI Mwea. The experiment was laid in a Randomized Block Design with two treatments and four replications. Ten flowers and leaves were sampled at random from each of the experimental plots and taken to the laboratory for counting of thrips and Natural enemies. There was significant difference in the mean number of both *F. occidentalis* and *M. sjostedti* population among the six French bean cultivars. Results from this study demonstrated that some French bean cultivars were more resistant to flower thrips. Julia had the highest overall mean while Paulista had the least number of thrips. This suggests that the most susceptible variety among the six

cultivars was Julia and Paulista was the least susceptible both species of thrips viz: *F. occidentalis and M. sjostedti*. Assessment of Trichome densities per square cm for each cultivar showed that Paulista had a higher density while Julia had a lower density. This could be a reason for thrips resistance in Paulista. This study concluded that resistance to thrips is cultivar dependant in French bean c. Further studies are, however, recommended on assessment of yield effect by quantification of damage on the pods, since a particular cultivar could have high thrips count but less pod damage, an indication that the cultivar might be thrips tolerant though susceptible. An evaluation of trichome on these cultivars is also recommended to identify the types and their phytochemical components and their effect on thrips. *Orius* spp. were the only natural enemies encountered, and had no effect on population of thrips. Increasing the level of nitrogen fertilizer on French beans did not affect the abundance of thrips in each of the varieties and therefore, the different fertilizer levels had no effect on the overall number of thrips.

CHAPTER 1

1.0 GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 Status of French beans production in Kenya

Horticulture is one of the fastest growing industry in Kenya having overtaken tourism, tea and coffee as the major foreign exchange earner in 2004 (HCDA, 2005). Export of cut flowers contributed more than half of the income generated (about 19 millions US dollars), with vegetables and fruits earning the country 140 million US dollars in export in 2004 (HCDA, 2005). Among the vegetable crops, French beans or snap beans (*Phaseolus vulgaris* L.) have dominated horticultural fresh produce exported mostly to European destinations (HCDA, 2003). French bean farming is largely a small scale operation in which about 50,000 families are involved in production and a further 500000 deriving livelihood directly from the export of French beans (Michalik *et al.,* 2001).

French beans are grown in a wide variety of agroecological zones in Kenya. The main growing areas include: Meru, Embu, Kirinyaga, Nyeri, Muranga, Maragua and Kiambu. Other areas include Machakos, Makueni, Naivasha, Bungoma, Vihiga, Trans Nzoia and Kericho (Gitonga, 1999). Popular cultivars of French beans grown in Kenya include: Samantha, Loby, Gloria, Paulista, Nerisa, Amy, and Vernadon (MoA and JICA, 2002). Although French bean is an important export crop, export figures indicate that there has been a noticeable decline (HCDA, 2005) due to among other factors, difficulties in the protection of the crop against insect pests and diseases. The most important insect pests are bean flies, bean flower thrips, aphids, and red spider mites and various root diseases (Seif *et al.*, 2001).

Comment [A1]: Chek scientific names

1.2 Economic importance of flower thrips

The importance of flower thrips has largely been due to the expansion of world trade in fresh horticultural produce and changes in production and marketing systems (Loomans *et al.,* 1995). Thrips species attacking beans are *Megalurothrips sjostedti* Trybom and the Western Flower Thrips (WFT) *Frankliniella occidentalis* Pergande, an invasive species native of USA and first recorded in Kenya in 1986 (Seif *et al.,* 2001). Attack by thrips leads to malformation, distortion, and discoloration of flowers while in severe infestations, flower buds do not open and may abort prematurely (Gitonga, 1999). In addition to the direct feeding damage, extensive losses occur when thrips transmits vectors Tomato Spotted Wilt Virus (Manson and Heinz, 2002). Western flower thrips adults that have fed on diseased tissue as larvae may infect tomatoes with tomato spotted wilt virus It is a serious disease in several economically important crops worldwide including French beans (Maris *et al.*, 2003).

The yield loss attributed to damage by flower thrips in French beans is in the range of 60% (Michalik *et al.*, 2001). In many species, thrips feed within buds and furled leaves or in other enclosed parts of the plant. Their damage is often observed before the thrips are seen. Discolored or distorted plant tissue or black specks of frass around stippled leaf surfaces are sign that thrips are or were present (Helyer *et al.,* 1995).

1.3 Rationale for an IPM strategy for the control of flower thrips in French bean farms in Kenya

Thrips are characterised by polyphagy, agility, a short generation time and tendency towards parthenogenesis (Mound, 1997), advantageous characteristics for exploiting the transient optimal conditions of a growing crop. Thrips are very difficult to control because of their biology and behavior and prefer to feed within flowers and buds, which protect them from insecticides and natural enemies (Chau *et al.,* 2005). They further pose problems when attempting to manage populations with conventional methods such as chemical insecticides (de Kogel *et al.*, 1997). Populations of thrips may continue to increase despite frequent applications of toxic insecticides (Funderburk *et al*., 2000) and due to development of resistance to these insecticides (Immaraju *et al.*, 1992). Residues further threaten the export market, especially since the introduction of new regulations by the European Union for maximum residual levels in January 1994 and currently the EurepGAP restrictions.

In view of the high losses of marketable produce caused by the thrips, development of resistance to most conventional insecticide as well as to be in line with the EurepGAP regulations, an IPM system is required. An IPM strategy would combine various tactics including the use of pesticides with biological control in which naturally occurring organisms and processes are exploited to counteract pest and disease attack (Sonya and Grant, 2007). Other tactics that could be used to manage thrips include use of pest resistant or tolerant cultivars and use of optimal fertilizer application rates that would reduce the problem of thrips infestation. Use of resistant varieties can decrease the amount of chemicals needed for pest control. Work done by de Kogel *et al.*(1997) for screening of Chrysanthemum for resistance to *F. occidentalis* indicated that there was a large genetic variation in thrips resistance among the cultivars screened.

Studies carried out on the effect of flower nitrogen status on populations of WFT on tomatoes showed that there was increased thrips population on hosts that received higher rates of nitrogen fertilizer (Brodbeck *et al.,* 1995, 1996 and 2001). Thrips population build-up was significantly restricted in thrips-resistant pepper cultivars (Maris *et al*., 2003, 2004). Such information for French beans is lacking in Kenya and it may be critical for understanding thrips problems on French beans as well as giving possible IPM strategies nin their control. Population dynamics of flower thrips and the factors that influence their abundance in French bean fields in Kenya are not well understood. Host plants vary in their suitability for thrips, not just between species but also between cultivars (Gitonga, 1999).

Leaf hairiness is well known as a factor conferring crop resistance to a pest, either because dense hairs prevent access to the leaf surface for feeding and oviposition or because the hairs or trichomes trap or injure the insects as shown in studies using tomatoes (Kumar *et al.*, 1995). The surface of plants forms a framework within which many insects live. A plant surface covered with hair might prevent insects from moving, whereas a slippery surface might make the insects lose their grip and fall off the plant (Malakar and Tingey, 2000; Simon *et al.,* 2003)).

Several studies have also shown that plant characteristics such as leaf structure and trichome density influence the natural enemies of herbivorous insects (Hare, 1992, 2002; Krings *et al.,* 2003; Bjorkman and Ahrne, 2005). For example, the walking speed of *Encarsia Formosa* Gahan females, a parasitoid of whitefly, is three times greater on hairless cucumber than on hairy varieties (Boethel and Eikenbary, 1986). Non-glandular trichome may form physical obstacles that hinder insects from moving on the plant or from feeding, whereas glandular trichomes may release various forms of chemical repellent (Krings *et al.,* 2003). There was a need to investigate the effects of the density of trichomes found on various French bean cultivars with a view of isolating those cultivars that could suppressthe populations of flower thrips as part of an effective IPM strategy.

1.4 The nutrition Flower thrips

Several lines of research suggest the importance of dietary nitrogen to *F. occidentalis*. Pollen has comparatively high concentrations of nitrogen and feeding preference for this tissue is often cited as a means of obtaining a higher protein diet (Kirk, 1997). Artificial diet studies have shown that addition of pollen increases rates of growth, development, and fecundity for *F. occidentalis* (Trichilo and Leigh, 1988).

Chemical fertilizers are used extensively to ensure production of high quality crops (Chau and Heinz, 2006). These fertilizers provide essential nutrients for plant growth but also inadvertently elevate the nutritional quality and attractiveness of plants to phytophagous insects (Chau *et al.,* 2005). Brodbeck *et al*. (2002) showed that population growth of *F. occidentalis* on tomato was well correlated with the number of flowers, which is consistent with the hypothesis that total flower nitrogen is important to *F. occidentalis*..

A wide diversity of feeding habits occur even within a particular species of thrips, and may also be evident at the insect/host plant level; a given thrips species may respond differently to chemical changes in one host plant than to similar changes in another host.

Increased soil nitrogen has also been shown to increase population of thrips (Vos and Frinking, 1997; Schuch *et al*., 1998) Frankliniella *occidentalis* populations have been shown to consistently respond positively to increasing soil nitrogen. However it has been documented that other thrips species commonly found feeding on *Lycopersicon. Esculentum* L. do not respond to varying soil nitrogen (Stavisky *et al.,* 2002). Studies by Waring and Cobb (1992) showed that population growth rate and development time of phytophagous insects are influenced not only by plant nutrient levels but also by nutrient ratio especially soluble amino acids. However, excessive application to fertilizer can be detrimental not only aphids and thrips (Chau *et al*., 2004) but also to their host plants (Schuch *et al.*, 1998; Scheirs and De Bruyn, 2004). Given that topdressing with nitrogenous fertilizers is a standard practice in French bean production in Kenya, the importance of nitrogen in the diet of flower thrips is a gap that this study aims to resolve with a view to coming up with recommendations fitting into an effective IPM strategy.

1.5.0 Control of thrips

1.5.1 Chemical control

Control of flower thrips by French bean farmers in Kenya has mostly depended on regular application of chemical pesticides, especially the synthetic pyrethroids. Some of the pesticides used in thrips control include: Fipronil, Methiocarb, Spinosad and Lambdacyhalothrin (Michalik. *et al.,* 2001). Thrips are difficult to control because pesticides do not reach their feeding places deep in the flowers or buds (Ekesi and Maniania, 2000; 2003; Michalik *et al*., 2001). Additionally, there is development of resistance to major classes of insecticides (Dagli and Tunc, 2007**)**, pest resurgence and environmental damage as well as adverse effects on non-target organisms (Michalik *et al.,* 2001). There is an increasing public demand to develop alternative control measures, as the use of most of the potentially effective pesticides is no longer allowed in an increasing number of countries, due to residual levels, pest resurgent and consequently ndevelopment of resistance (Maris *et al*., 2003). There is, therefore, an increased tendency to turn to other biopesticides which are seen to be more efficient in terms of residual levels and their efficacy in thrips control (Waturu, 1998; Sila, 2004; Waturu *et al.,* 2005).

1.5.2 Biological Control

The effectiveness of biological control agent could be enhanced by manipulating the amount of fertilizer to slow pest development, (Chau *et al*., 2005), which may also minimize insecticide usage. If fertilizer level can be manipulated to slow pest population growth, this tactic may be used in biological control (Berndt *et al*., 2004), host plant resistance (Bergh and Le Blanc, 1997; de Kogel *et al.,* 1997; Maris *et al*., 2004), and other cultural practices (Schuch *et al*., 1998; Stavisky *et al*., 2002) for effective control of important pests such as thrips

Some of the reported natural enemies of thrips include: *Orius* spp (Anthocordae: Hemiptera.), *Aeothrips fasciatus* L (Thysanoptera.), *Amblyseius cucumeris* Oudemans (Acarina) and *Ceranisus menes* Walker (Hymenoptera.) (Loomans *et al*, 1995; Gitonga, 1999; Gitonga *et al*., 2002 a, b). However, the natural enemy complex in French bean farming systems has not been fully understood. *Orius albidipennis* Reuter and *Cerenisus menes* have been recorded in Kenya (Gitonga, 1999) but there is need to broaden the studies regarding their spatial temporal variation, survival and host range of natural enemies in order to identify candidates for mass rearing and release as part of an IPM strategy in French bean production.

1.6 Statement of the problem

Horticulture is one of the fastest growing industries in Kenya having overtaken tourism, tea and coffee as the major foreign exchange earner in Kenya in 2004. Although French bean is an important export crop, export figures indicate that there has been a noticeable decline (HCDA, 2005) due to among other factors, difficulties in the protection of the crop against insect pests and diseases. The most important insect pests are bean flies, bean flower thrips, aphids, pod borers and red spider mites and various root diseases (Seif *et al.,* 2001).

Thrips pest are very difficult to control because of their biology and behavior and prefers to feed within flowers and buds, which protect them from insecticides and natural enemies (Chau *et al.,* 2005). Populations of thrips may continue to increase despite frequent applications of toxic insecticides (Funderburk *et al*., 2000) due to development of resistance (Immaraju *et al.*, 1992) and development of resistance to insecticides, their cost not withstanding,

An IPM strategy would combine various tactics including use of pesticides with biological control in which naturally occurring organisms and processes are exploited to counteract pest and disease attack. Other IPM tactics that may be used to manage thrips include use of pest resistant or tolerant cultivars and use of optimal fertilizer application rates that would not escalate the problem of thrips infestation. Use of resistant varieties can decrease the amount of chemicals needed for pest control. Several lines of research suggest the importance of dietary nitrogen to *F. occidentalis*. Given that topdressing with nitrogenous fertilizers is a standard practice in French bean production in Kenya, the importance of nitrogen in the diet of flower thrips is a gap that this study aims to resolve with a view to coming up with recommendations fitting into an effective IPM strategy.

1.7 Justification of the study

French beans are a major vegetable export crop in Kenya associated with small-scale farmers. Most of the yield ends up in EU market, which has imposed stringent regulations for EurepGAP certification on imports. This sector is threatened in that farmers rely heavily on pesticides for the control of a myriad of pests attacking French beans, chiefly thrips. Effective alternatives are therefore urgently needed.

An IPM strategy requires a thorough understanding of the population dynamics of both the pest thrips and their natural enemies both on the crop and their alternate hosts in a variety of agroecological zones. Moreover, some of the agricultural practices may be contributing directly to the thrips problem, viz use of N-fertilizers that may enhance thrips populations. Different French beans cultivars may have different levels of thrips attack susceptibility but this is yet to be ascertained. There is therefore a need to establish whether there exists a correlation between the amounts of fertilizes (N- fertilizer in this case) used and hence the optimal levels that can be used by farmers without increasing the risk of thrips attack on the different French bean cultivars.

1.8 Hypotheses:

1. The susceptibility of French beans to thrips is not cultivar-dependent;

2. The build up of thrips is not influenced by the extent of nitrogen fertilizer use;

3. The natural enemies of thrips are not found in close association with thrips.

1.9.0 Objectives

1.9.1 General objective

To evaluate various French bean cultivars for their susceptibility to thrips and the effect of nitrogen fertilizer and natural enemies on population dynamics of thrips

1.9.2 Specific objectives

1. To determine French bean cultivar variability for resistance to flower thrips infestation
2. To determine the effects of application of different rates of, Calcium Ammonium Nitrate (CAN), on the population of flower thrips.
3. To identify the natural enemies of French beans flower thrips in experimental fields and relate their numbers with change in the number of flower thrips.

CHAPTER 2

2.0 GENERAL MATERIALS AND METHODS

2.1 Field sites

Field studies were conducted at two localities to represent high and low intensity production systems. One station was at KARI- Mwea in Kirinyaga District of Central Province. This station is at (0° 36´ S 37°25´ E). The altitude is 1200 m above sea level. The area receives an average rainfall of about 900 mm per year. The soils are moderately fertile and are well-drained, very deep and red brown to dark brown (arido-humic with humic andosols). The centre is about 120 Km North East of Nairobi (Jaetzold and Schmidt, 1983). The other station was Jomo Kenyatta University of Agriculture and Technology (JKUAT) farm, (01° 01´ S 37´ 06´ S), the altitude is 1600m ASL. The area receives an average rainfall of 950mm and is about 35 km from Nairobi, in Thika District, central province (Jaetzold and Schmidt, 1983)

2.2 Experimental Design.

A randomized block design was used in each site. A plot measuring 18x32 m was demarcated and divided into four sections to accommodate four replicates in each of the experimental sites during the two planting seasons. Each replicate was sub-divided into four blocks to allow for three treatments of different fertilizer regimes and one without fertilizer, which served as a control. Each of the blocks was then divided into six plots each measuring 3x2m where each of the six French bean cultivars used in the experiment were planted. All the plots were surrounded by a walking path of 1m width.

2.3 Planting of Beans

Field studies were conducted in two planting seasons; season one between August - November 2007 and season two between November 2007- January 2008 at the two localities. Certified seed of French bean cultivars (Army, Julia, Samantha, Alexandra, Star and Paulista), were sown in each experimental sites in both planting seasons. The French beans were sown at a spacing of 60cm between the rows and 10cm within the row and there was one seed per hole. All other standard agronomic practices like weed control and irrigation were carried out.

2.4 French bean Cultivars and Fertilizer Treatments

Calcium Ammonium Nitrate fertilizer was applied at three different rates; 100kg/ha, 200kg/ha and 300kg/ha which was applied twice during each growing season. The first application was done 20 days after sowing (d.a.s.) and the second application was done 60 d.a.s. The treatments were allocated to blocks and plots at random. The second treatment was the Cultivars, where six varieties of French beans were used namely Amy, Paulista, Alexandra, Samantha, Star and Julia. They were assigned at random to each block for the two sites in each planting seasons.

2.5 Sampling and data collection

Soil samples were initially taken from each of the experimental sites and taken to the JKUAT Horticulture laboratories for testing and analysis to determine the percentage nitrogen content in the soil. During sample collection, four auger holes drilled to a depth of 20cm were made in the each of the four blocks and mixed thoroughly in 2kg sample polythene bags to obtain one composite sample in each of the blocks. The sampling was done following a zigzag pattern in each block.

Sampling of flowers commenced 40 days after sowing, where ten leaves and ten flowers were randomly picked from each of the experimental plots in each site. The flower samples were kept in 60% ethanol in separate bottles for each plot in the field and taken to the laboratory for counting of thrips and natural enemies. The leave samples were kept in separate self adhesive polythene for each plot. The thrips and the natural enemies were extracted by dissecting the flowers and then immersing them in ethanol three times then filtered through Whatman filter paper No. 1, 90mm. Adult thrips were counted and identified to species level using keys described by Palmer *et al.* (1990), under a dissecting microscope while any other insect was put in 70% ethanol in 10ml vials and taken to Kenya Agricultural Research Institute (KARI) Mwea Entomology laboratory for identification of natural enemies present throughout the study period. Sampling was done once a week between 06.00am-7.00am to reduce diurnal variation in sampling.

Five plants were selected randomly and the number of leaves, flowers and plant height for each sampled plant estimated. Five plants were chosen from each plot, and one well developed leaf was chosen randomly from each of the five plants starting when the crop was four weeks old and taken to the laboratory to determine the trichome density. The number of hairs per square cm was counted under dissecting microscope. In addition, ten randomly taken samples of flowers from each plot in the two sites were kept in vials containing 60% ethanol and taken to the laboratory to determine the flower nitrogen content. This was done 45 and 70 days after sowing. To determine the quantity of nitrogen in the flowers, *Kjeldahl method* for Nitrogen determination was used (Benton, 1991). The samples were oven dried at 70^{o}C then digested in a digestion mixture, (Sulphuric acid + Hydrogen peroxide + Selenium powder + Lithium Sulphate), for two hours in a digestion chamber. The digested samples were then distilled to recover Nitrogen and titrated to quantify the percent nitrogen in the sample.

2.6 Data Analysis

Individual counts of *F. occidentalis* and *M. sjostedti* per variety and fertilizer levels were analyzed by SAS software (SAS, 2006). Pooled data were subjected to a two way ANOVA. Where there were interactions between factors, analysis was carried out on individual factors. Where factors were significantly different, means were separated using Tukeys Studentized Test (P=0.05).

CHAPTER 3

3.0 RESISTANCE OF FRENCH BEAN CULTIVARS TO ATTACK BY FLOWER THRIPS

3.1 Introduction

The development and use of resistant cultivars to control thrips populations and plant diseases is a promising avenue that may provide an economic and efficient solution to pest problems and can be exploited as an IPM strategy for many pests. Genetic resistance to damage from WFT feeding has been investigated in tomatoes (Kumar *et al*., 1995), cucumber (Soria and Mollema, 1995) sweet pepper (Fery and Schalk, 1991), Cucumber (de Kogel *et al.,* 1997) and pepper (Maris *et al.,* 2003). While potentially a useful factor in IPM programs to manage WFT, use of resistant cultivars alone has not resolved the problem, and variations between cultivars in their other qualities are important influences on production decisions (Soria and Mollema, 1995). Use of resistant varieties can decrease the amount of chemicals needed for pest control. Work done during screening *Chrysanthemum* for resistance to *F. occidentalis* indicated that there was large genetic variation in thrips resistance among the cultivars screened (Schuch *et al.,* 1998).

The surface of plants forms a framework within which many insects live. A plant surface covered with hair might prevent insects from moving, whereas a slippery surface might make the insects lose their grip and fall off the plant. Trichomes are a feature of plant surfaces, which, in some cases provide resistance to pests and are found on many plant families (Malakar and Tingey, 2000). Studies have also shown that plant characteristics such as leaf structure and trichome density influence the natural enemies of herbivorous insects. For instance the walking speed of *Encarsia formosa* females a parasitoid of whitefly, is three times greater on hairless cucumber than on hairy varieties (Bjorkman and Ahrne, 2005). Walking speeds, rates of turning, and the flight propensity of *Trichogramma exiguum* Pinto and Platner, an egg parasitoid of *Heliothis zea* Boddies, are influenced by differences in leaf structure, particularly trichome type and density (Onyambu, 2005; Keller, 1987). Malakar and Tingey (2000), also reported that the glandular trichomes of *Solanum berthaultii* Hawkes entrap small soft bodied pests like aphids, leafhoppers and spider mites leading to starvation and death or have antifeedant effects on larger insects such as the Colorado potato beetle.

Leaf hairiness is well known as a factor conferring insect resistance to a crop, either because dense hairs prevent access to the leaf surface for feeding and oviposition (Dalin and Bjorkman, 2003**)** or because the hairs or trichome trap or injure the insects as shown in studies using tomatoes (Kumar *et al.*, 1995). This study aimed at investigating the effects of density of trichome found on French bean varieties with a view of isolating those cultivars that suppress flower thrips populations as part of an effective IPM strategy.

3.2 Materials and Methods

Six French bean varieties at two experimental fields were evaluated for their resistance to thrips in two planting seasons. Ten leaves and ten flowers were randomly picked from each of the experimental plots in each site. The samples were kept in 60% ethanol in separate bottles in the field and taken to the laboratory for counting of thrips. The thrips and natural enemies were extracted by dissecting the flowers and then immersing them in ethanol three times. The number of thrips and natural enemies were counted under a dissecting microscope and identified to species as described in Chapter two.

The number of flowers per plant and plant height were also quantified on each sampling date from randomly selected plants from each plot. Five plants were selected randomly and the number of leaves, flowers and plant height for each sampled plant were counted/measured and recorded. Five plants were chosen from each plot, and one well developed leaf was chosen from each of the five plants starting when the crop was four weeks old and taken to the laboratory to determine the trichome density. The number of hairs per square cm was counted under dissecting microscope. The data was subjected to analysis of variance and where there were significant differences between the mean, mean separation was done using Turkey's Studentized range test.

3.3 Results

3.3.1 Susceptibility of French bean cultivar to attack by to Thrips

During the first planting, between August 2007 and November 2007, there were significant differences among the cultivars; Julia (JU), Alexandra (AL), Army (AM), Samantha (SA), Star (ST) and Paulista(PA), in the mean number of; *F. occidentalis* (dF =5, F =13, P= 0.0083) and *M. sjostedti* (dF = 5, F= 4.35, P=0.0006) at JKUAT farm (Fig. 3.1). Julia (JU) had the highest mean number of both species of thrips while Paulista had the lowest number of thrips.

Similarly, at Mwea experimental site, the different cultivars differed significantly in the number of; *F. occidentalis* (df= 5, F = 5.69, P = 0.0001) and *M. sjostedti* (df = 5, F = 3.16, P= 0.0078) as shown in Fig. 3.2.

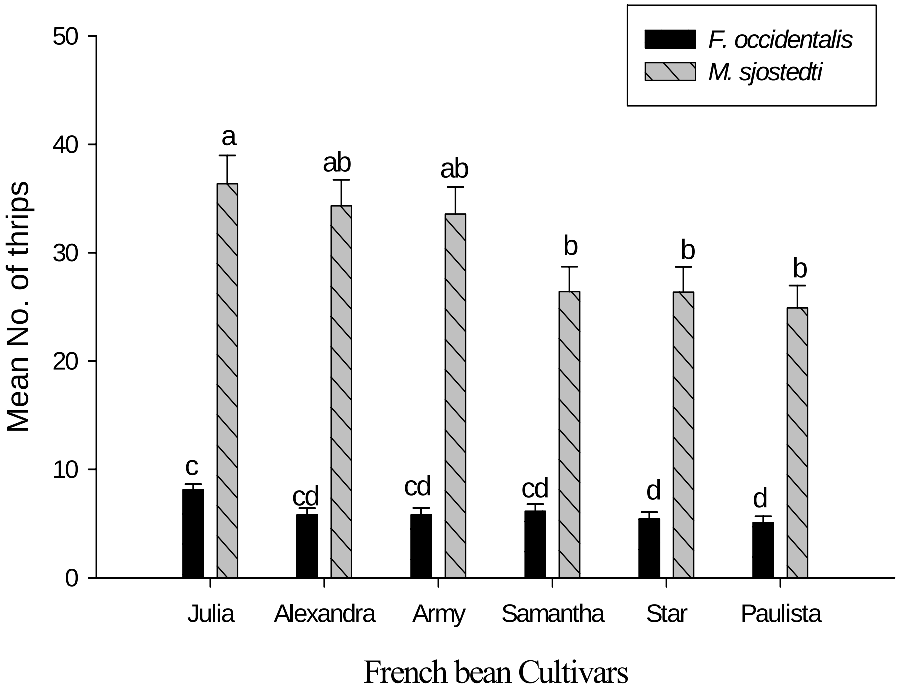

Fig. 3.1 Mean number of *Megalurothrips sjostedti* and *Frankliniella occidentalis* on different French bean cultivars in the crop planted in August 2007 at JKUAT farm. Bars with the same letters are not significantly different according to Tukeys Studentized Range (P=0.05) Test.

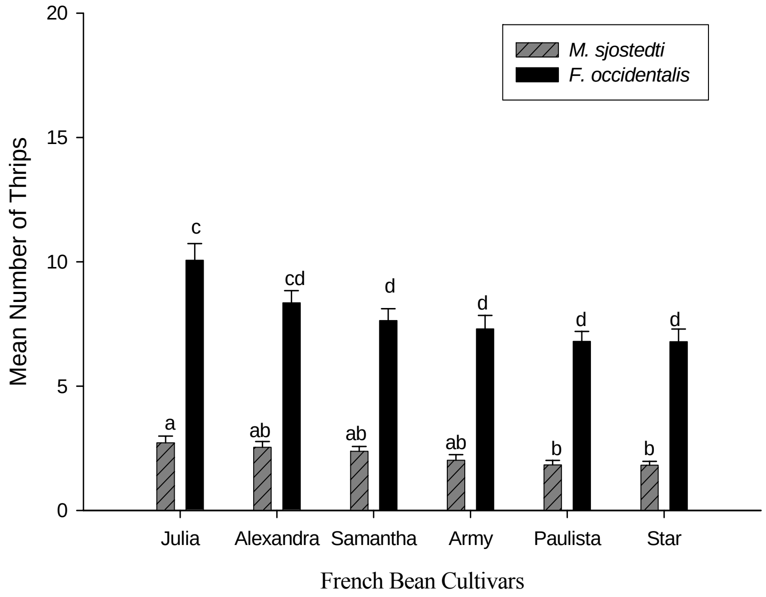

Fig. 3.2 Mean number of *Megalurothrips sjostedti* and *Frankliniella occidentalis* on different French bean cultivars in the crop planted in August 2007 at Mwea. Bars with the same letters are not significantly different by Tukeys Studentized range (P=0.05) Test.

During the second planting season, (Nov- 07 to Jan-08) cultivars had significant differences in the number of *F. occidentalis* (dF = 5, F = 2.04, P= 0.0071) and *M. sjostedti* (dF = 5, F = 1.95, P=0.008) at JKUAT site, (Fig. 3.3). The mean number of thrips in Julia deferred significantly from Paulista. Fig. 3.4 shows the mean number of both species of thrips in each French bean at Mwea. Julia had the highest mean number of thrips while Paulista had the lowest number There was also a significant variation among the cultivars Julia and Paulista in the number of both

F. occidentalis (dF = 5, F = 4.35 P = 0.0007) and *M. sjostedti* (dF = 5, F = 3.02, P = 0.0105).

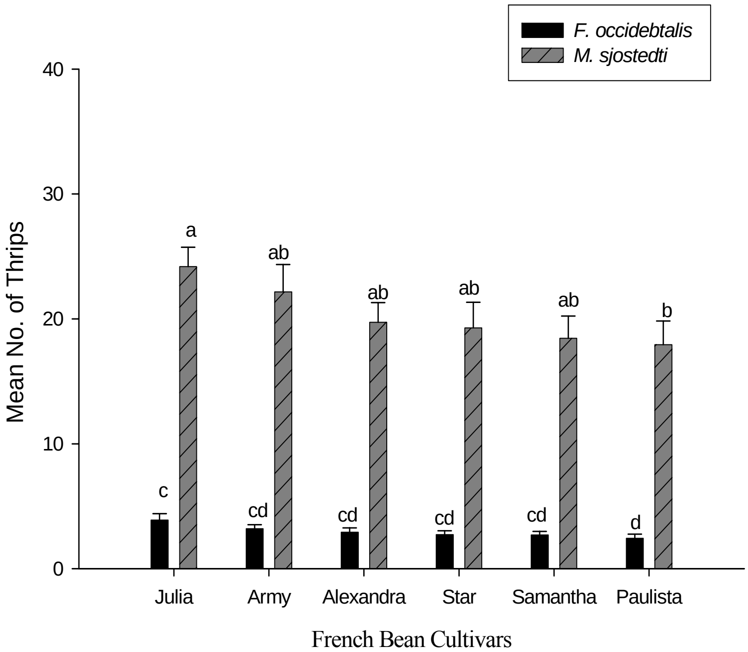

Fig. 3.3 Mean number (± SE) of *Megalurothrips sjostedti* and *Frankliniella occidentalis* on different French bean cultivars in the crop planted in November 2007 at JKUAT farm. Bars with the same letters are not significantly different according to Tukeys Studentized range (P=0.05) Test.

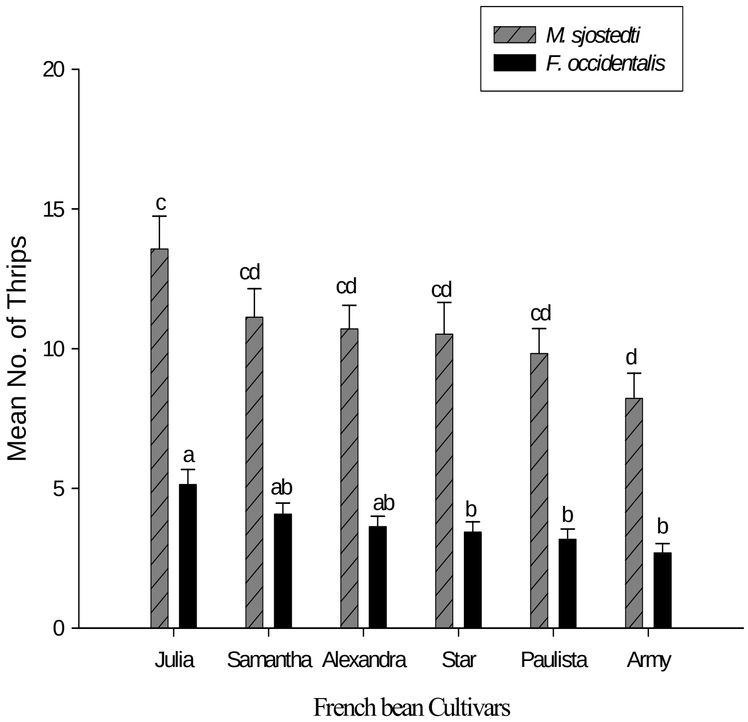

Fig.3.4 Mean number of *Megalurothrips sjostedti* and *Frankliniella occidentalis* on different French bean cultivars in the crop planted in November 2007 at Mwea. Bars with the same letters are not significantly different according to Tukeys Studentized range (P=0.05) Test.

Mean number of *F. occidentalis* and *M. sjostedti* in each cultivar for the entire study period were then compared to determine the overall cultivars performance in order to identify the most susceptible cultivars. Table 3.1 shows the overall mean populations for *F. occidentalis* and *M. sjostedti* in the six French bean cultivars for the entire study period.

Table 3.1 Comparison of overall mean of Thrips per cultivar in six French bean cultivars for the entire experiment period, during the first and second growing seasons, in JKUAT and Mwea.

French bean cultivar	Mean±SE (*F. occidentalis)*	Mean±SE (*M. sjostedti)*
Julia	6.973±0.30a	19.2097±0.82a
Samantha	5.5794±0.26b	16.743±0.89ab
Alexandra	5.0861±0.25bc	16.821±0.80ab
Star	4.9916±0.25bc	14.500±0.84bc
Army	4.6486±0.24bc	14.59±0.90bc
Paulista	4.3936±0.22c	13.621±0.79c

In each column (for each thrips Spp. separately), values followed by the same letter are not significantly different at P< 0.05 significance level (Tukeys Studentized range test.

3.3.2 Evaluation of the number of Trichome in French bean cultivars

There were significant differences in the mean number of trichome among the French bean cultivar during the first planting season (df = 5, F = 1.76, P = 0.019) in JKUAT and (df = 5, F= 5.5, P = 0001) in Mwea. Paulista had the highest number of trichomes per square cm where as Julia had the lowest number. A similar trend was also observed during the second planting season where there were significant differences in the number of trichome among the French bean cultivars in, (df = 5, F= 1.96, P = 0.0018) in JKUAT and (df = 5, F= 1.88, P = 0.042) in Mwea experimental site, as shown in Table 3.2

Table 3.2 Mean Number of Trichome in six French bean varieties at Mwea and JKUAT over the sampling period.

French bean Cultivar	JKUAT		Mwea	
	Season 1	Season 2	Season 1	Season 2
Paulista	119.64±8.40a	118.81±8.45a	133.51±8.20a	130.81±12.07a
Army	112.223±9.15ab	109.28±9.15ab	126.38±10.6ab	128.05±11.48a
Star	105.11±6.54ab	108.11±6.54ab	116.80±7.77ab	109.94±8.91ab
Alexandra	100.91±5.94ab	102.3±6.02ab	110.84±7.15bc	101.88±9.51ab
Samantha	99.16±5.88ab	99.16±5.88ab	104.90±8.41c	98.14±10.35b
Julia	91.01±5.05b	90.73±5.06b	90.09±5.81c	97.41±7.278b

In each column, values followed by the same letter are not significantly different at ($P< 0.05$) significance level (Tukeys Studentized range (HSD) test.

3.3.3 Comparison between number of thrips and that of trichomes

The mean number of trichome per square cm and the mean numbers of thrips in each cultivar for the two planting seasons were examined to establish whether there was any relationship between the number of thrips and the trichome density. There was a negative correlation between the number of thrips and trichome density. Julia had the highest number of thrips across the two growing seasons, whereas Paulista had the least number of thrips, both *F. occidentalis* and *M. sjostedti.* On the other hand, Julia had the lowest number of leaf trichome per square cm while Paulista had the highest number, as depicted in Table 3.3.

Table 3.3 Comparisons between the overall Mean number of Trichome and Thrips per cultivar in six French bean varieties during the two planting seasons at Mwea and JKUAT**.**

French bean Cultivar	Mean ± SE (*F. occidentalis)*	Mean ± SE (*M. sjostedti)*	Mean ± SE (Trichome)
Julia	6.973±0.30a	19.2097±0.82a	95.465±5.10a
Samantha	5.5794±0.26b	16.743±0.89ab	115.325±6.79ab
Alexandra	5.0861±0.25bc	16.821±0.80ab	122.975±6.4b
Star	4.9916±0.25bc	14.500±0.84bc	118.87±5.97ab
Army	4.6486±0.24bc	14.59±0.90bc	116.0655±6.95ab
Paulista	4.3936±0.22c	13.621±0.79c	126.585±8.05b

In each column, values followed by the same letter are not significantly different at P< 0.05 significance level (Tukeys Studentized range (HSD) test

3.3.4 Comparison between the number of flowers and that of flower thrips.

The number of flowers differed significantly (dF = 5, F =7.82, P= 0.001) among the different cultivars at JKUAT experimental site for the entire study period. Paulista had the highest number of flowers compared to the other cultivars during the first planting season. Similar trend was also observed during the second planting season, where the number of flowers in the variety Paulista was significantly higher compared to the number of flowers in cultivars Army and Samantha and these also had a significantly high number of flowers compared to Alexandra, Julia and Star at as shown in Table 3.4.

Table 3.4 Mean number of flowers per cultivar in six French bean varieties in the two planting seasons at JKUAT farm.

French bean Varieties	Mean No. of flowers (Season 1)	Mean No. of flowers (Season 2)
Julia	54.37±3.570b	37.41±0.559a
Samantha	64.75±3.919ab	69.90±5.062b
Alexandra	54.24±4.135b	37.28±0.663a
Star	50.95±3.690b	36.77±0.589a
Army	56.31±3.813b	72.75±5.449b
Paulista	79.64±3.159a	103.37±5.874c

In each column, values followed by the same letter are not significantly different at 5% significance level (Tukeys Studentized range (HSD) test

Similarly, at Mwea there were differences in the number of flowers among the different cultivars. During the first planting season, Paulista had the highest number of flowers than the other cultivars, although this difference was not statistically significant. During the second planting season, varieties differed significantly ($P<0.05$) in regard to the number of flowers, with Paulista having significantly high number of flowers compared to Army, and Star (Table 3. 5).

Table 3.5 Mean Number of flowers in the six French bean varieties in the two planting seasons at Mwea.

French bean Cultivars	Mean No. of flowers (Season 1)	Mean No. of flowers (Season 2)
Paulista	49.87±2.475a	27.99±1.480a
Samantha	48.20±3.229a	24.41±0.945ab
Alexandra	47.19±3.369a	22.94±1.049b
Julia	47.13±3.077a	21.10±1.020ab
Army	46.02±3.376a	17.23±1.437c
Star	38.71±2.813a	17.22±1.275c

In each column, values followed by the same letter are not significantly different at 5% significance level (Tukeys Studentized range (HSD) test

To examine the effects of the number of flowers on population size of *F. occidentalis* and *M. sjostedti* regression analyses were performed. Data for both seasons were pooled, and sorted by date. For each analysis the dependent variables of total *F. occidentalis* (Fig. 3.5) and *M. sjostedti* were examined in relation to the independent plant variable of flower number. (Fig.3.6),

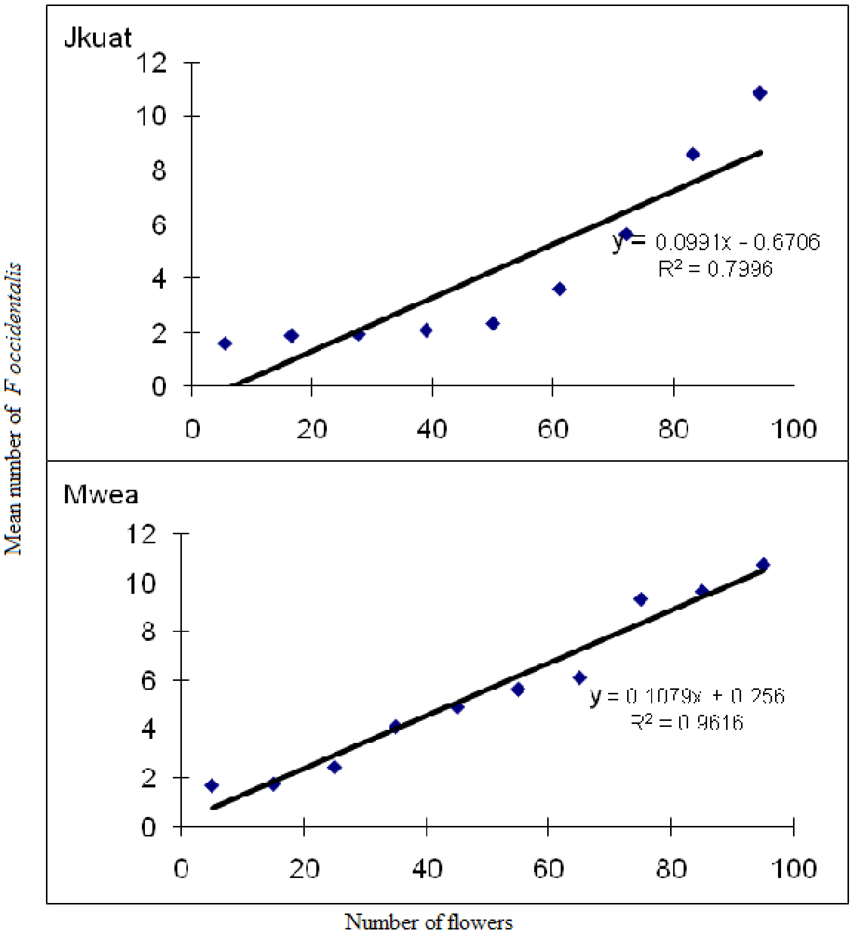

Fig. 3.5 Regression analysis of Number of flowers per plant vs. abundance of *Frankliniella occidentalis i*n the in both first and second planting seasons.

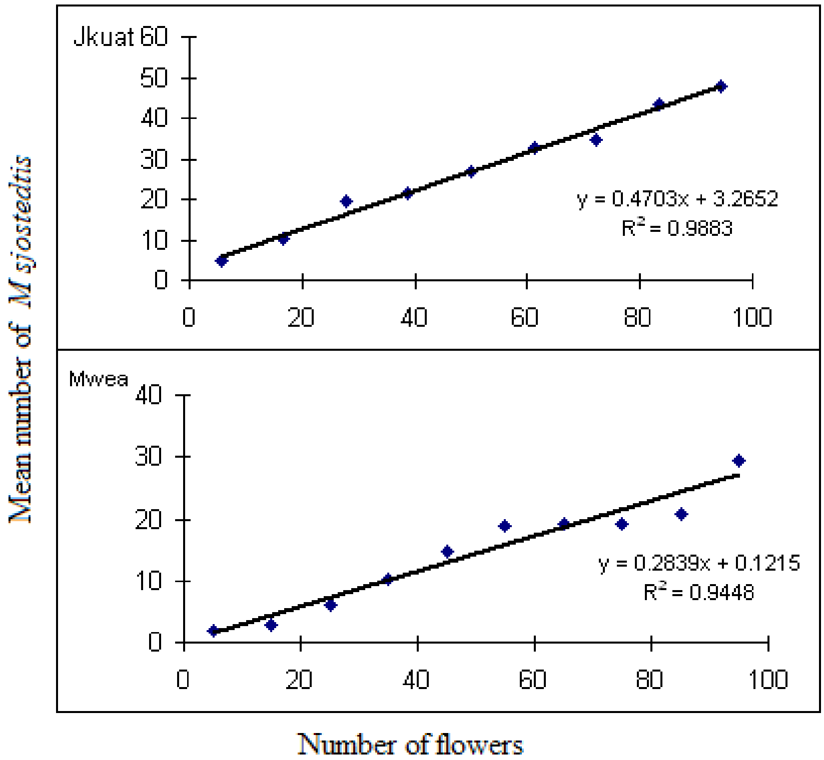

Fig. 3.6 Regression analysis of Number of Flowers per plant vs. abundances of *Megalurothrips sjostedti* in the entire sampling period.

3.4 Discussion

There was significant variation in the mean number of both *F. occidentalis* and *M. sjostedti* among the six French bean cultivars. The development and use of resistant cultivars to control thrip populations and plant diseases is a promising avenue that may provide an economic and efficient solution to pest problems and can be exploited as an alternative control method against many crop pests (Nderitu *et al*., 2007). Host plants vary in their suitability for thrips, not just between species but also among cultivars (Gitonga, 1999). Genetic resistance to damage from WFT feeding has beeninvestigated in many crops; in tomatoes (Kumar *et al*. 1995), cucumber (Soria and Mollema, 1995) sweet pepper (Fery and Schalk, 1991) and pepper (Maris *et al.,* 2003).

Results from this study demonstrated that some French bean cultivars were more resistant to flower thrips. Julia had an overall high population of thrips during both planting seasons in both JKUAT and Mwea, , . Paulista, on the other, hand had the least number of thrips. On pooling the data for the entire study period and comparing the means in each cultivar, Julia had the highest overall mean. This suggests that Julia was the most susceptible variety among the six and Paulista is the least susceptible. From the results one can separate the best three based on their performance as being Paulista, Army and Star, while Julia, Samantha and Alexandra would be said to be the most susceptible to both species of thrips viz : *F. occidentalis and M. sjostedti.* The differences in resistance to attack by thrips resistance observed among the cultivars is in agreement with earlier work done on cowpea and common bean varieties where significant differences in the number of thrips among different varieties was reported (Owusu *et al.,* 1999; Nderitu *et al*., 2007).

In the view of the stringent quality requirement and maximum pesticide residual levels by EurepGAP on export, use of resistant cultivars would be advantageous. However, the choice of varieties is more market and consumer oriented (Nderitu *et al*., 2007). Hence, Studies should be conducted on yield effect by or the quantifying the damage on the pods to conclude on this cultivar since a cultivar can have high thrips count but less damage, an indication that it might be thrips tolerant though susceptible.

In this study, the trichome densities were compared between the six French bean cultivars. The results indicated that Paulista had a significantly higher number of leaf trichome compared with other cultivar like Julia and Samantha. It has been shown that high trichome density usually hinders insects' movement and therefore feeding (Bjorkman and Ahrne, 2005). *Phratora vulgatissima* L. (Coleoptera: Chrysomelidae) were negatively affected by increased trichome density because their feeding was reduced and became more dispersed on leaves with trichome density. The plant response has therefore been suggested to be an inducible defense mechanism (Dalin and Bjorkman, 2003).

Leaf hairiness is well known as a factor conferring insect resistance to a crop, either because dense hairs/ trichomes prevent access to the leaf surface for feeding and oviposition (Dalin and Bjorkman, 2003) or because the hairs or trichome trap or injure the insects as shown in studies using tomatoes (Kumar *et al.*, 1995). Several studies have shown that plant characteristics such as leaf structure and trichome density influence the natural enemies of herbivorous insects (Hare, 2002; Krings *et al.,* 2003; Bjorkman and Ahrne, 2005). For instance, *Encarsia Formosa* females a parasitoid of whitefly, is three times greater on hairless cucumber than on hairy varieties. Kauffman & Kennedy (1989) found a significantly negative relationship between the percentage parasitism of *Heliothis* spp. by *Trichogramma* spp. and the density of glandular trichomes. Non-glandular trichomes may form physical obstacles that hinder small animals from moving on the plant or from feeding, whereas glandular trichomes may release various forms of chemical repellents (Krings *et al.,* 2003).

Comparing the numbers of trichome in the six French bean cultivars, Paulista, Army and Star had higher trichome density than Alexandra, Samantha and Julia. Considering the number of *F. occidentalis* and *M. sjostedti* in the cultivars, those cultivars that had higher number of thrips had a lower density of trichome. The higher density of trichome could possibly be a reason for lower thrip numbers in Paulista, Army and Star and this is consistent with conclusion by Kumar *et al.*, (1995) that leaf hairiness is a factor conferring insect resistance to a crop, either because dense hairs prevent access to the leaf surface for feeding and oviposition because the hairs or trichome trap or injure the insects as shown in studies using tomatoes.

The main preferred feeding and oviposition site for thrips being flowers, the probable effect of trichome density would therefore be trapping and injuring the insects during movement or probably release of toxic chemical which when in contact with flowers might affect the thrips. The findings of this study show that the three cultivars could be resistant varieties. However, the trichome numbers alone may not give a conclusive evidence of resistance of a cultivar to thrips as specific trichome types contain toxic substances, and these are reported to be responsible for resistance, for instance in some tomato accession (Onyambu, 2005). Non-glandular trichome may form physical obstacles that hinder small animals from moving on the plant or from feeding, whereas glandular trichomes may release various forms of chemical repellents (Krings *et al.,* 2003). It would, therefore, be important to conduct detailed study on trichome in the three French bean cultivar, Paulista, Army and Star, to establish the trichome types present and their phytochemical components and their effect on thrips before being recommended as resistant varieties.

In this study, flower numbers were compared among the six cultivars. Overall Julia had the least number of flowers while Paulista had a higher number of flowers on average. Contrary to expectation, cultivars with more flowers had fewer thrips. This is an indication that, though thrips may be attracted by colour and ultimately the appearance of the plant as described by Gillespie and Vernon (1990); and Yaku *et al.* 2007) they are affected by other factors or a combination of factors in their choice of food. Therefore, though a cultivar like Paulista had more flowers, it might be a thrips resistant cultivar and Julia on the other hand though with fewer flowers is a more susceptible cultivar since other factors come into play in thrips choice of food.

Brodbeck (2001) reported that seasonal fluctuations in the abundance of thrips on tomato closely reflected seasonal changes in the number of flowers per plant. *Frankliniella* species are attracted to hues of color including yellow (Gillespie and Vernon, 1990; and Yaku *et al.,* 2007); thus, increasing flower number may increase plant apparency besides providing more of the preferred host tissue. In tomato, high flower number also provides a more predictable food source (Brodbeck, 2001).

This study was able to classify Paulista, Army and Star as more resistant cultivars compared to the Julia, Samantha and Alexandra based on their performance in the number of thrips on each cultivar and can be used as a basis to recommend them to the growers/ farmers. Future studies could, therefore, concentrate on laboratory experiments to further classify these cultivars based on mechanisms of plant host resistance that have been reported such non-preference /antixenosis (Ohta, 2002); antibiosis (Schoonhoven *et al*., 1998) and tolerance (Nderitu *et al.,* 2007)..

CHAPTER 4

4.0 EFFECT OF NITROGEN FERTILIZER AND NATURAL ENEMIES ON THRIPS POPULATION

4.1 Introduction

Several lines of research suggest the importance of dietary nitrogen to thrips. Pollen has comparatively higher concentrations of nitrogen and preference for this tissue is often cited as a means of obtaining a higher protein diet (Kirk, 1997). Artificial diet studies have shown that addition of pollen increases rates of growth, development, and fecundity of *F. occidentalis* (Trichilo and Leigh, 1988). Pollen is a natural food source for many flower thrips and the extent to which thrips are able to profit from the addition of pollen depends on the biological and ecological attributes of thrips species and the pollen characteristics (nutritional value, size, adhesiveness, presence of a feeding stimulant(Hulshof *et al.,* 2003)

Increased soil nitrogen has been shown to increase population of thrips (Vos and Frinking, 1997; Schuch *et al*., 1998; Joseph *et al.,* 2000). Brodbeck *et al.* (2002) showed that population growth of *F. occidentalis* on tomato is well correlated with flower number, which is consistent with the hypothesis that total flower nitrogen is important to *F. occidentalis.* Brodbeck *et al.* (2001) manipulated nitrogen content of plants through addition of fertilizer, and found that the peak abundance of *F. occidentalis* adults in tomato flowers was positively correlated with the concentration of the primary aromatic amino acid, phenylalanine, in the flowers. Higher rates of nitrogen fertilizer also resulted in higher populations of *F.*

occidentalis in chrysanthemums (Schuch *et al.* 1998). *Frankliniella occidentalis* populations have been shown to consistently respond to increasing soil nitrogen, although some thrips species commonly found feeding on *L. esculentum* do not respond to varying soil nitrogen (Stavisky *et al*., 2002).

If addition of fertilizer can be manipulated to slow pest population growth, this tactic may be used with biological control (Berndt *et al*., 2004), host plant resistance (Maris *et al*., 2004), and other cultural practices (Schuch *et al*., 1998; Stavisky *et al*., 2002) for effective control of important pests such as thrips. Given that topdressing with nitrogenous fertilizers is a standard practice in French bean production in Kenya, the importance of nitrogen in the diet of flower thrips is an activity that this research aimed to investigate in order to come up with recommendations fitting into an effective IPM strategy.

Thrips are difficult to control because pesticides do not reach their feeding places deep in the flower or bud (Ekesi and Maniania, 2000; Michalik, *et al*., 2001). Additionally, there is development of resistance to major classes of insecticides, pest resurgence and environmental damage as well as adverse effects on non-target organisms, which is not as yet established in French bean growing. The search for alternatives to chemical pesticides has stimulated interest in exploiting biological control agents in integrated thrips management strategies in glasshouses (Waturu *et al.,* 2005)). Some of the reported natural enemies of thrips include *Orius* sp (Anthocordiae: Hemiptera.), *Aeothrips fasciatus* (Thysanoptera.), *Amblyseius cucumeris* (Acarina) and *Ceranisus menes* (Hymenoptera.) (Loomans *et al*, 1995;

Gitonga, 1999; Gitonga *et al.,* 2002 a, b; Gitonga, 2008). The predators of the genus Orius are used in the improved method of biological control of thrips in greenhouses and they are included in the integrated control of crop pests. *Orius insidiosus* Say has proven to be effective in the control of *F. occidentalis*, thereby decreasing ltheir populations (Deligeorgidis, 2002). Understanding interactions that occur between the predator *O. insidiosus* and its thrips prey can provide important insights into thrips population dynamics at larger ecological scales and a better understanding of how to manage pest thrips (Stuart *et al.,* 2006). However, the natural enemy complex in French bean farming systems has not been fully understood. *Orius albidipennis* Reuter and *Cerenisus menes* Walker have been recorded in Kenya (Gitonga, 1999) but there is need to broaden the studies in spatial, temporal, survival and host range terms with a view to identifying candidates for mass rearing and release as part ofan IPM strategy in French bean production.

4.2 Materials and Methods

Studies were carried out in two experimental sites; Kari Mwea and JKUAT farm as indicated in Chapter two. Prior to sowing of beans in each season, soil samples were obtained from each of the experimental sites and taken to the laboratories for testing and analysis to determine the soil nitrogen content. During sample collection, four auger holes drilled to a depth of 20 cm were made in each of the four rows (as described in Chapter 2) and mixed thoroughly in 2 kg sample polythene bags to obtain one composite sample in each of the blocks.

To evaluate the effect of d nitrogen levels on the population of thrips s, three nitrogen fertilizer levels: 100 kg/ha, 200 kg/ha, 300 kg/ha were applied at the first trifoliate leaf stage. There were also control plots where no fertilizer (0kg/ha) was aplliied. This fertilizer treatment was administered by hand in the form of Calcium Ammonium Nitrate (C.A.N), at the base of the plants. Five randomly taken samples of flowers from each plot in the two sites were kept in specimen vials containing 70% ethanol and taken to the laboratory to determine the total flower nitrogen and also to count the number of thrips. This was done 45 and 70 days after sowing. To determine the total flower nitrogen, *Kjeldahl method* for Nitrogen (Benton, 1991) was used. The samples were oven dried at 70^{o} C and then digested in a digestion mixture; (Sulphuric Acid + Hydrogen Peroxide + Selenium powder + Lithium Sulphate) in a digestion of chamber. The digested samples were then distilled to recover nitrogen in the form of Ammonia and titrated to quantify the percentage nitrogen content in the samples.

The number of flowers per plant and plant size were also quantified weekly starting from the first sampling date (40 days after sowing) on randomly selected plants from each plot. Five plants in each plot were selected randomly and the number of leaves, flowers and plant height for each sampled plant estimated and recorded. Additionally, ten leaves and ten flowers were sampled at random from each of the experimental plot(described in Chapter 2) in each site and kept in specimen separate plastic cups containing 60% ethanol in the field and taken to the laboratory for counting of thrips and the natural enemies present. The flowers were first dissected, washed in 60% ethanol three times and then filtered through Whatman filter paper. Counting of adult thrips was done with the aid of a tally counter and identification was done using identification keys Palmer *et al.* (1990).

4.3 Results

4.3.1 Effect of fertilizer on thrips population

During the first planting season (August - November, 2007), there were no significant differences between French bean cultivars and fertilizer application rate in the thrips population; *F. occidentalis* (dF = 15, F = 0.36, P=0.9881), *M. sjostedti* (dF = 15, F = 0.58, P= 0.89461), in JKUAT and *F. occidentalis* (dF = 15, F = 0.74 P =0.7448), *M. sjostedti* (dF = 15, F = 0.37, P= 0.9857), in Mwea. Similarly, fertilizer level did not affect the mean number of *F. occidentalis* in Mwea (dF= 3, F = 0.32, P = 0.8127) (Fig. 4.1) as well as that of *M. sjostedti* (dF = 3, F = 0.35, P = 0.0 7914) as shown in (Fig 4.2). Likewise, at JKUAT experimental site, fertilizer level had no influence (dF = 3, F = 0.33, P = 0.8007) on the population of *F. occidentalis* (Fig. 4.3), and also *M. sjostedti* (df = 3, F = 0.29, P = 0.8323) (Fig. 4.4).

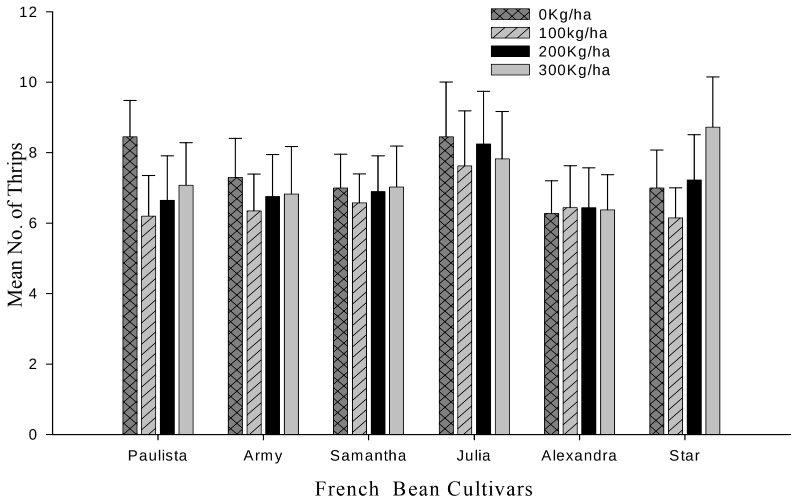

Fig. 4.1 The Mean number of *Frankliniella occidentalis* recorded from six French bean cultivars under different fertilizer regimes; in August 2007 crop at Mwea. (Vertical lines denotes standard error)

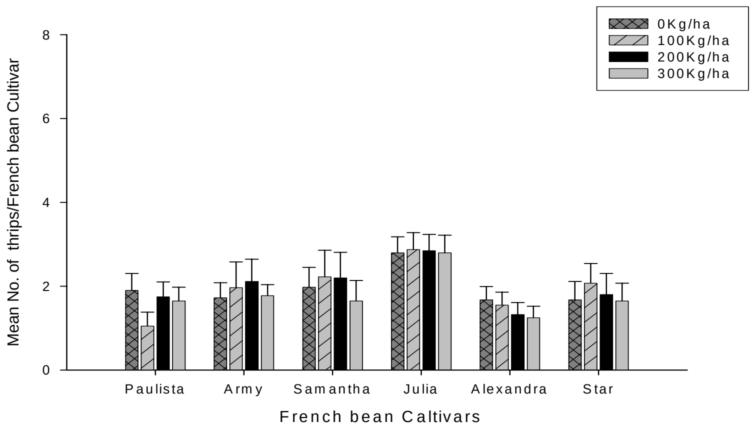

Fig. 4.2 The Mean number of *Megalurothrips sjostedti* recorded from six French bean cultivars under different fertilizer regimes; in August 2007 crop at Mwea. (Vertical lines shows standard error)

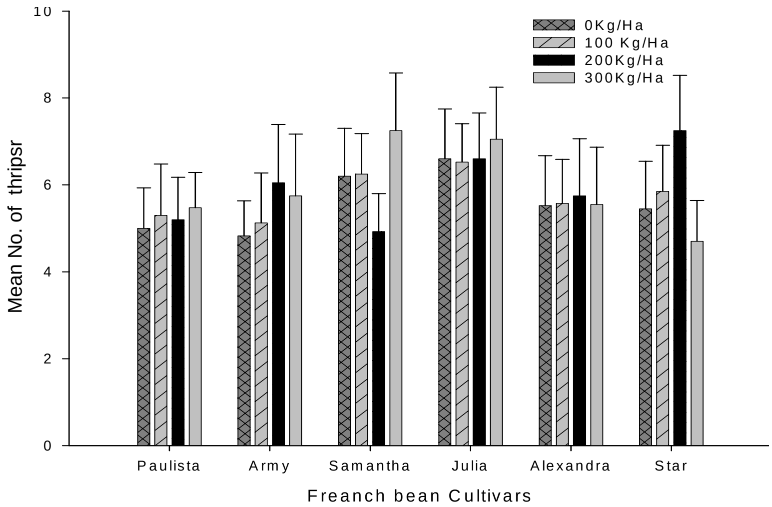

Fig. 4.3 The mean number of *Frankliniella occidentalis* recorded form six French bean cultivars under varied fertilizer regimes; in August 2007 crop at JKUAT Farm. (Vertical lines denote standard error).

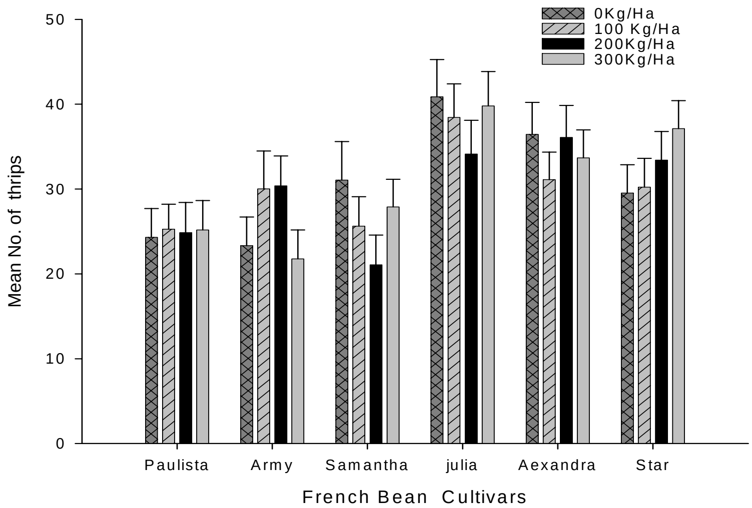

Fig. 4.4 The mean number of *Megalurothrips sjostedti* recorded from six French bean cultivars under varied fertilizer regimes; in August 2007 crop at Jkuat Farm. (Vertical lines denote standard errors).

During the second planting season there were no significant differences between the mean number of *F. occidentalis* (dF= 3, F =0.42, P = 0.7379) in JKUAT and (df=3, F =0.45, P = 0.7185) in Mwea in the different fertilizer levels.. Likewise, fertilizer levels did not affect the population of *M. sjostedti* (dF =3, F =0.16, P = 0.9202) at Mwea and (dF=3, F =0.35, P =0.7922) at JKUAT experimental sites.

With respect to the crop planted between November 2007 and January 2008 at JKUAT farm, rate of fertilizer application had not influence (P>0.05) on the number of the two species of *M. sjostedti* (dF =3, F =0.35, P=0.7922) and *F. occidentalis* (F = 0.42, dF =3, P =0.7379). This trend was also observed in the crop planted in Mwea where there was no difference, ((P>0.05), in the number of *M. sjostedti* (, df =3, F =0.16, P=0.9202) and *F. occidentali (*df =3, F= 0.45, P= 0.7185), at the different fertilizer levels.

4.3.2 Relation ship between fertilizer levels and plant parts

In Mwea experimental site, there were higher number of flowers and leaves on treatments receiving higher fertilization rates, however, this difference in the number of flowers was not statistically significant (P>0.05 as shown in Fig. 4.5 shows). In JKUAT, there were significant differences (P<0.05) in the number of flowers and leaves among the different fertilizer treatments (Fig. 4.6) The difference in plant height, though higher in plants receiving higher fertilizer treatments, was also not statically different among the different fertilizer levels throughout the experimental period.

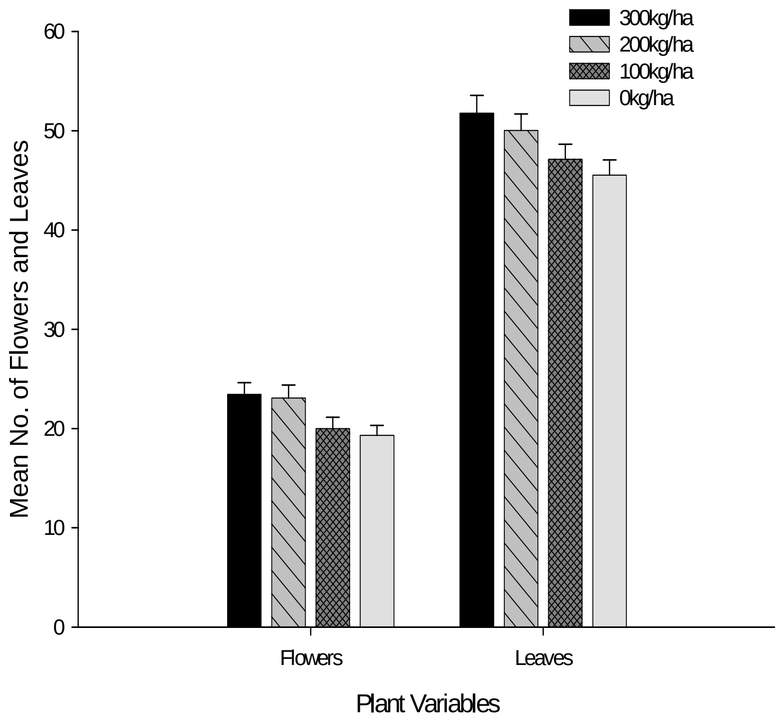

Fig. 4.5 Comparison of plant variable performance at varied nitrogen fertilizer levels French bean for the entire experimental time at Mwea experimental site

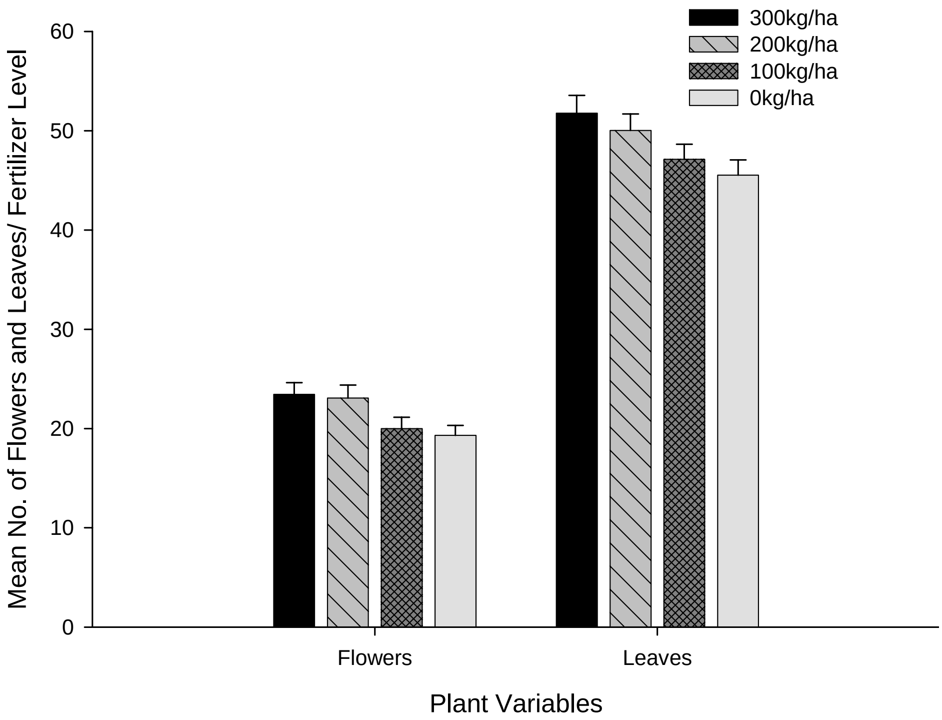

Fig. 4.6 Comparison of plant variable performance at varied nitrogen fertilizer levels French bean for the whole experimental time at JKUAT experimental site

4.3.3 Influence of natural enemies on the population of thrips

The experiment was carried out to investigate the presence of natural enemies on the two French beans experimental fields. The only natural enemies encountered during the entire study period were *Orius* Spp. which were not encountered until 54 and 61 d.a.s. in Mwea and JKUAT respectively during the first planting season. Results, however, indicated that the presence of these natural enemies did not have significant effect ($P>0.05$) on the population of either species of thrips, during the first planting season at Mwea (Fig. 4.7), as well as at JKUAT (Fig 4.8). A similar trend was also observed during the second planting season at Mwea (Fig. 4.9) and at JKUAT (Fig. 4.10).

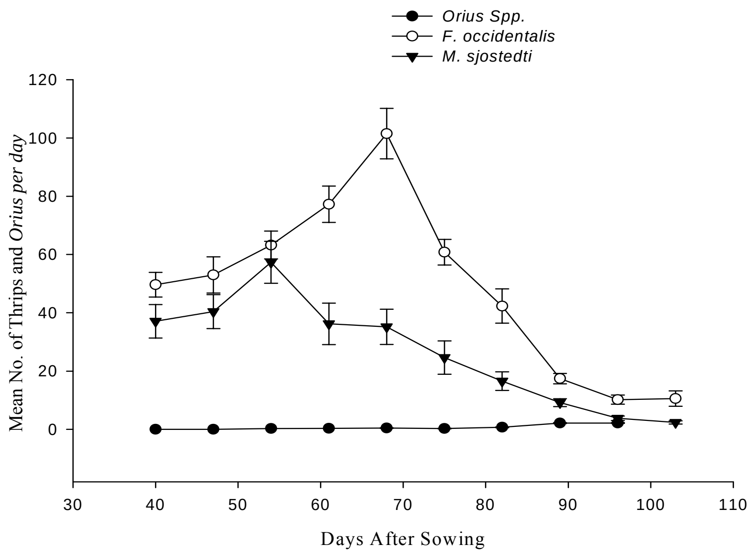

Fig. 4.7 Trends of the mean number of *Frankliniella occidentalis, Megalurothrips sjostedti* and Orius *sp*. on French bean cultivars during the first planting season at Mwea (Vertical lines denotes standard error).

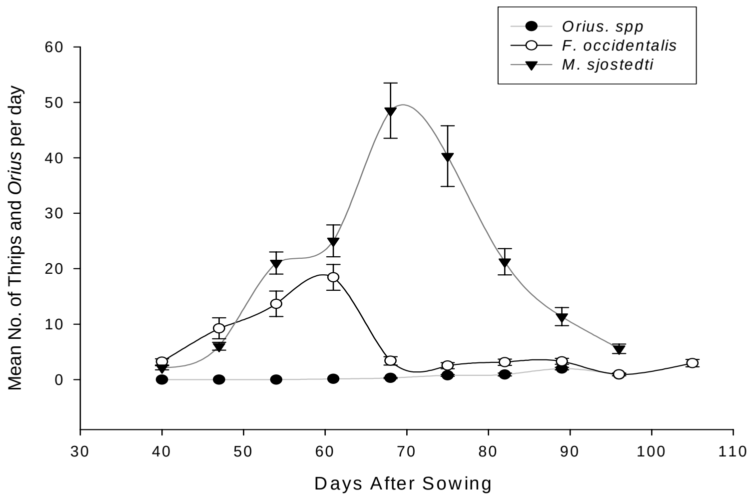

Fig. 4.8 Trends of the mean number of *Frankliniella occidentalis, Megalurothrips sjostedti* and *Orius sp*. on French bean cultivars during the first planting season at JKUAT (Vertical lines denotess standard error).

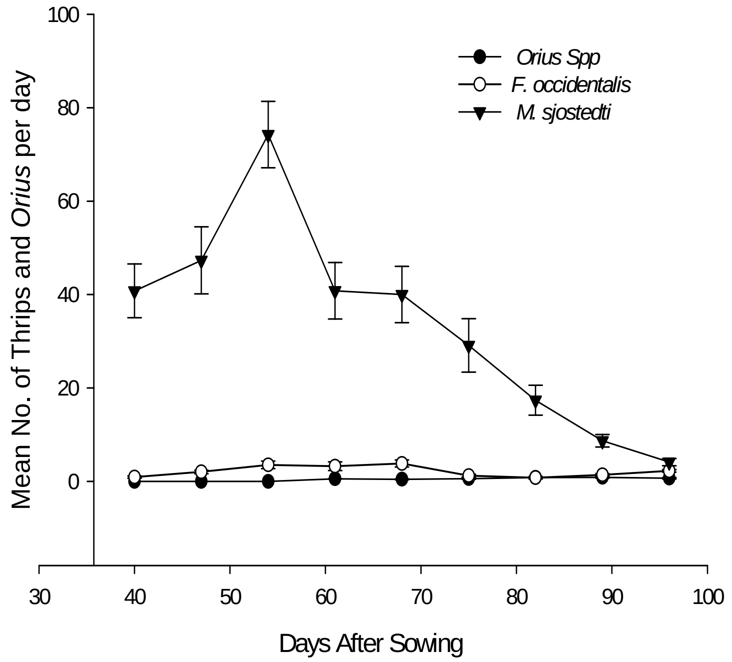

Fig. 4.9 Trends of the mean population of *Frankliniella occidentalis, Megalurothrips sjostedti and Orius sp.* on French bean cultivars during the first planting season at Mwea (Vertical lines denotes standard error).

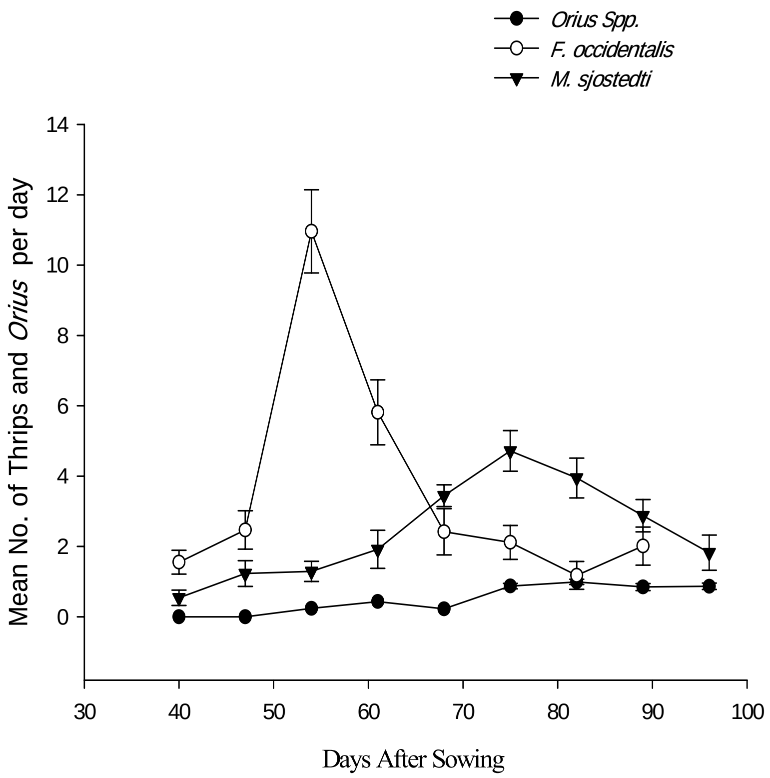

Fig. 4.10 Trends of the mean population of *Frankliniella occidentalis, Megalurothrips sjostedti and Orius sp*. on French bean cultivars during the second planting season at JKUAT (Vertical lines denotes standard error).

4.3.4 Percentage level of flower nitrogen

During the study, sampling for flower nitrogen was done twice; 45 days after sowing) and 70 d.a.s. The percentage concentration of nitrogen in flowers was higher in plants that had received higher level of fertilizer in both Mwea and Jkuat during the first planting season. However, the concentrations were significantly higher in young plants, during the first percentage nitrogen analysis, (45 d.a.s), compared to the older plants during second analysis at 70 d.a.s. Similarly, during the second planting season, plants receiving higher levels of nitrogen fertilizer had a higher level of nitrogen in flowers compared to those receiving lower level of fertilizer in both experimental sites. The difference was however not significant between the three levels of nitrogen except for the plants which did not receive any amount of fertilizer as shown in Table 4.1

Table 4.1 Mean level of Nitrogen in French bean flowers during the first planting season.

	N fert. Level	%N at 45 d.a.s	%N at 70 d.a.s
	0kg/ha	7.65±0.72a	6.48±0.62a
	100Kg/ha	11.96±0.75ab	8.59±0.90ab
	200Kg/ha	16.76±1.03b	13.84±0.52b
	300Kg/ha	15.3±0.83b	12.30±0.68b
	0kg/ha	7.10±0.92a	5.51±0.92a
	100Kg/ha	10.11±1.34ab	7.45±1.34ab
	200Kg/ha	14.24±1.10b	11.25±1.10b
	300Kg/ha	14.20±1.01b	11.42±1.01b
JKUAT	0kg/ha	8.925±0.92a	7.52±0.71a
	100Kg/ha	15.93±0.85ab	15.83±0.84ab
	200Kg/ha	20.06±1.12b	18.63±1.02b
	300/Kg/ha	19.02±1.10b	17.79±1.43b
Mwea	0kg/ha	10.38±1.00a	9.90±0.93a
	100Kg/ha	15.38±1.17ab	11.83±1.01ab
	200Kg/ha	19.52±1.25b	15.64±1.16ab
	300/Kg/ha	19.47±1.24b	15.81±1.25b

In each column for each experimental site, values followed by the same letter are not significantly different at 5% significance level for each site separately (Tukeys Studentized range (HSD) test

4.3.5 Soil Nitrogen Content

The amount of nitrogen in the soil sample, on average, was between high and moderate level according to the KARI Soil Nutrition interpretation table. The first experimental site in Jkuat, however, had low levels of nitrogen in one block although the other blocks had adequate levels of nitrogen in the soil (as per the KARI classification). Comparing the JKUAT and Mwea, the latter was higher in terms of soil nitrogen content, as shown in Table 4.3.

Table 4.3 Percentage Soil Nitrogen Content for the two experimental sites during the study Period.

Experiment site	Sample No.	% soil Nitrogen	KARI rating
1st season : JKUAT	1	0.12	Moderate
	2	0.09	low
	3	0.19	Moderate
	4	0.20	Adequate
Average		**0.15**	**Moderate**
Mwea	1	0.25	High
	2	0.30	High
	3	0.20	adequate
	4	0.33	High
Average		**0.27**	**High**
2nd season: JKUAT	1	0.18	Moderate
	2	0.26	High
	3	0.29	High
	4	0.32	High
		0.26	**High**
: Mwea	1	0.32	High
	2	0.28	High
	3	0.26	High
	4	0.31	High
Average		**0.29**	**High**

4.4 Discussion

Results from this study indicated that the different fertilizer treatments did not have a significant impact on the populations of *F. occidentalis* and that of *M. sjostedti.* This was observed at both JKUAT and Mwea experimental sites. The results are in line with those reported by Reitz, (2002) who reported that addition of fertilizer did not have significant impact on the population of *F. occidentalis* on chrysanthemum. Lack of effect after addition of fertilizer in the study by Reitz (2002) was attributed to the method of application (top dressing as opposed to pre-planting application.) where plants did not have enough time to assimilate the nitrogen. In the current study, this would not be the case since there was enough time between fertilizer application time and the time nitrogen analysis was done. Moreover, the application was done twice in the growing period which ensured ample supply of nitrogen throughout the growing period.

Work done by Chau and Heinz (2006) on thrips in chrysanthemum demonstrated that population abundance of *F. occidentalis* could be reduced by either lowering the amount of fertilizer to 50% of the recommended level, or raising it to 150% or higher. The authors also reported that the mean rate of change in *F. occidentalis* abundance increased from 0.02 to 0.05 (day^{-1}) when the amount of fertilizer was increased from 20 to 100% of the recommended level but did not increase beyond the recommended level (375 parts per million N). Manipulation of the amount of fertilizer would be a useful tactic for managing thrips if plant productivity and postproduction longevity are not significantly compromised (Chau and Heinz, 2006).

In view of experimental crop used, French bean, which is a nitrogen fixing plant, adding more nitrogen to the plants may not have affected the nutritional quality and attractiveness of the plants to thrips. Lack of fertilizer effect in the present study could partially be attributed to the mode of irrigation. Furrow irrigation was used during the study and considering the nature of nitrogenous fertilizer which has a high leaching potential, this mode of irrigation could possibility have increased the nutrients leaching. It would, therefore, be important to carry out similar study under controlled environment where effect of leaching would be controlled or using less water intensive irrigation method like drip irrigation. In this study, only the effects of fertilization levels on thrips population growth were investigated, but it would be imperative to also investigate its effects on crop damage as a result of feeding by thrips. The mode of irrigation not-withstanding, this study did not find any association between the amount of fertilizer applied and population of thrips.

The only natural enemies encountered during the entire study period were *Orius* Spp. Results of the analysis, however, indicated that the presence of these natural enemies did not have significant effect on the population of either species of flower thrips. The predators of the genus *Orius* are used in the biological control of thrips in greenhouses and form an important part of IPM strategies (Reitz *et al.,* 2006). *Orius insidiosus* has proven to be effective in the control of *F. occidentalis,* decreasing large populations of the thrips in greenhouse cultivation of pepper and cucumber (Coll and Ridgeway, 1995). *Orius* species have been used for successful control of Thysanopteran pests in glasshouses. For example, *O. insidiosus* was introduced into sweet pepper and cucumber glasshouses in Europe, originally against *Thrips tabaci* (Lindeman) and later against the introduced *F. occidentalis* (Ravensberg *et al.,* 1992). *Orius albidipennis* and *Cerenisus menes* have been recorded in Kenya (Gitonga, 1999, 2002, 2008,).

Anthocorids have many characteristics of ideal biological control agents. These includes, high searching efficiency, an ability to increase more rapidly when prey is abundant, a density-dependent decrease in fecundity resulting from interference and the ability to aggregate in regions of high prey density ((Maria and Manuele, 2000; Deligeorgidis, 2002 and Gitonga, 2002a). However, Looman *et al.* (2005) concluded that parasitoid releases (*C. menes* and / or *C. americensis*) in commercial and experimental greenhouses played only a very minor role in thrips control, possibly because of negative interactions (intra-guild predation) between *Orius* and *C. menes,* in the commercial greenhouses, preying on parasitized larvae. In the current study, lack of relationship between *Orius* and thrips could be explained by the lower numbers of the natural enemies, compared to those of thrips encountered in the experimental fields. Several studies have enumerated different reasons for low rate of parasitism; one partly being explained by a reduced searching ability on flowers of various plants. This also includes the difference in encounter probability with hosts of different sizes in particular when the vulnerable host stage is concealed in buds and flowers and thus unavailable for the parasitoid (Loomans *et al*., 1992; 1993). Fritsche and Tamo (2000) have cited two main reasons for the lower predation rates on *M. sjostedti* larvae by *Orius sp*. Firstly, *M. sjostedti* larvae are more difficult to catch and yet they are a more appropriate food. This is because the predator is not adapted to them or to the environment, and secondly, because the *M. sjostedti* larvae have a more effective defense mechanism than the other thrips species.

The study by Tamo *et al*. (1993) indicates that *Orius* sp. might not be an efficient biological control agent against *M. sjostedti*, because it did not show a numerical response of predation to increasing thrips population levels. One possible reason for this behaviour could be that *M. Sjostedti* is not a suitable prey of *Orius* sp. In fact, it is known that Anthocoridae in general, and *Orius* spp. in particular, are not only polyphagous, preying on different arthropods (Maria and Manuele, 2000), but their younger nymphal instars are also omnivorous, feeding on plant juice and pollen (Kiman and Yeargan, 1985; Coll, 1996, Looman *et al.*, 2006 and Stuart *et al.,* 2006). One would, therefore, conclude that though natural enemies may exist in association with thrips in the field, their number may not be sufficient to adequately control thrips population and hence, a combination of pest control strategies would need to be employed. In this study though some natural enemies, Orius spp. were encountered in association with thrips, their numbers were not sufficient to have any substantial change to the population of thrips.

CHAPTER 5

5.0 GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion and Conclussion

In view of the stringent quality requirement and maximum pesticide residual levels by EurepGAP and the stringent European Union regulations on export, use of resistant cultivars would be advantageous. Use of resistant cultivars pose no technical difficulties to farmers and would be more preferable. However, the choice of varieties is more market and consumer oriented (Kasina *et al* 2006*;* Nderitu *et al*., 2007). From this study one can identify the best tcultivar based on its performance as being Paulista, , while Julia, would be said to be the most susceptible to both species of thrips viz *F. occidentalis and M. sjostedti.*

Leaf hairiness is well known as a factor conferring insect resistance to a crop, either because dense hairs prevent access to the leaf surface for feeding and ovipositor or because the hairs or trichome trap or injure the insects as shown in studies using tomatoes (Kumar *et al.*, 1995). Comparing the numbers of trichome in the six French bean cultivar, Paulista, had higher trichome density than Julia. Considering the mean number of *F. occidentalis* and *M. sjostedti* in this cultivar, those cultivars that had higher number of thrips had a lower density of trichome. The higher density of trichome could possibly be a reason for lower thrips numbers in Paulista, which is consistent with findings by Kumar *et al.* (1995) who reported that leaf hairiness was a factor conferring insect resistance to a crop. Though the preferred feeding and oviposition site for thrips is flowers, the probable effect of trichome density would, therefore, be trapping and injuring the insects during movement or probably release of toxic chemical which, when in contact with flowers might kill or repel the thrips. From the findings of this study, resistance to thrips attack in French beans is cultivar dependant.

Though it has been reported that *Frankliniella* species are attracted to hues of color including yellow (Gillespie and Vernon, 1990; and Yaku *et al*., 2007), thus, increasing flower number may increase plant apparency as well as by providing more of the preferred host tissue, this was not the case in this particular study with French bean cultivars. Contrary to expectation, cultivars with more flowers had fewer thrips. This could, therefore, be an indication that thrips, though attracted by colour and ultimately the appearance of the plan, their choice of food is affected by other factors or a combination of factors. This could also be another indication that these varieties are resistant to thrips.

The performance of the French bean cultivars in terms of their resistance/susceptibility to thrips did not depend on the amount of nitrogen fertilizer applied. Although several studies have shown that increased nitrogen fertilizer level results in higher populations of *F. occidentalis* in tomato (Brodbeck *et al.,* 2001) and chrysanthemum (Schuch *et al*., 1998), Reitz, (2002) reported no effect on population of *F. occidentalis* in chrysanthemum. The presence of these natural enemies did not have significant effect on the population of either species of flower thrips. One would, hence, conclude that though natural enemies may exist in association with thrips in the field, their number may not be not be sufficient to adequately control thrips population and therefore a combination of pest control strategies would need to be employed.

5.2 Recommendations

- Further evaluation of on French bean cultivars Paulista, Army and Star to evaluate their thrips resistance or tolerant based on yield effect through the quantification of damage on the pods and compare them with the susceptible cultivars; Julia, Samantha and Alexandra. A particular cultivar could have high thrips count but less pod damage, an indication that the cultivar might be thrips tolerant though susceptible.
- Further assessment of the three French bean cultivar; Paulista, Army and Star, and conduct detailed study on trichome types present and their phytochemical components and their effect on thrips. This could also include laboratory experiments to evaluate these cultivars for plant characteristics that cause host plant resistance to herbivores non-preference /antixenosis, antibiosis and tolerance further.

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