Sciknow Publications Ltd.
Journal of Renewable Agriculture
©Attribution 3.0 Unported (CC BY 3.0)

JRA 2014, 2(2):27-37
DOI: 10.12966/jra.06.02.2014

Management of Thrips in French Bean by Integrating Biological and Synthetic Pesticides in Conventional Spray Regimes

Bernard Ouma, James Muthomi[*]**, John Nderitu and Faith Toroitich**

Department of Plant Science and Crop Protection, University of Nairobi, P. O. Box 30197-00100, Nairobi, Kenya

*Corresponding author (Email: james_wanjohi@yahoo.com)

Abstract - Thrips are major pest of snap bean that cause losses as high as 60% but the use of synthetic pesticides is restricted due to strict market regulations on maximum residue levels (MRLs). This study aimed at reducing the use of synthetic pesticides by integrating biological and botanical pesticides in the management of thrips in snap bean. On farm experiments were carried out over two cropping cycles to evaluate the efficacy of spray regimes consisting of different combinations of the following: Thunder® (Imidacloprid 100g/L + Betacyfluthrin 45g/L), biological (*Metarhizium anisopliae* ICIPE 69), botanical (*Azadirachtin* 0.15%), and Decis (Deltamethrin). Data on thrips population and pod yield were collected and benefit-cost ratio of each spray regime calculated. Integrating synthetic chemical with biological *Metarrhizium anisopliae* was the most cost effective causing more than 69% thrips reduction, and 50% increase in yields, while integrating *Azadirachtin* with *Metarrhizium anisopliae* was the least effective causing less than 20% thrips reduction, and 30% increase in yields compared to control. Integrating synthetic pesticide with *Metarrhizium anisopliae* had the highest benefit-cost ratio. The results indicated that integrating synthetic pesticides with neem-based and *Metarrhizium anisopliae* effectively reduces thrips infestation and increase yields, while reducing overall costs and chemical residues in the produce.

Keywords - *Azadirachtin, Biospesticides*, French beans, *Metarhizium anisopliae*, Pesticide residues

1. Introduction

Snap bean (*Phaseolus vulgaris* L.) is a major export crop of Kenya with about 80% of production mainly from small to medium scale farmers [1]. Major constraints in the production of snap beans include marketing, pest and diseases. Thrips are important pests of snap bean at flowering and harvesting [2, 3], causing stagnated growth, abortion of premature flower buds and curved pods [4]. They also cause curling, coiling, and malformation of pods making them unfit for the export market. According to Nderitu et al., [2], the main challenges faced by farmers in the management of thrips include the cryptic habit of thrips that make pesticides ineffective due to inability to reach them. In addition, thrips infestation occurs during flowering and harvesting thus limiting the use of insecticides to avoid accumulation of pesticide residues in the produce. Yield reduction due to thrips could be as high as 40% at farm level and 20% at collection points [5].

Snap bean varieties grown in Kenya are imported from developed countries and are not adapted to the local conditions. They are also highly susceptible to pests and diseases leading to frequent use of pesticides [5]. Over use and misuse of pesticides lead to health risks to growers, environment, and threats of interception of pesticides residue on produce [6, 2]. There are also reports of use of banned pesticides resulting in interception and rejection of significant amounts of export vegetables to the European market [7, 8]. The strict maximum residue level requirements (MRLs) could result into shortage of beans because small holder farmers may stop production due to fear of non-compliances, high costs, limited number of analytical laboratories and delays in clearing of consignments [9]. The stringent pesticide regulations has also affected export business resulting in reduced export volumes due to constant change in the MRLs that result in increased interception of produce in the international market.

The negative effects of using synthetic pesticides has stimulated continued search for alternative pest control approaches which include reduced pesticide application frequency and use of environmentally friendly options such as seed dressers, bio-pesticides and modification of cropping systems [10]. Biopesticides used to manage pests in vegetable production include *Metarhizium anisopliae*, *Bacillus thuringiensis*, *Beauveria bassiana*, and *Paecilomyces* sp. and botanical pesticides such as neem (*Azadirachtin*) [11]. Entomopathogenic fungi such as *Metarhizium anisopliae* have been shown to be effective as bio-control in management thrips [12, 13, 14]. Ekesi et al., [15] reported that three applications of the fungus *M.anisopliae* at flower bud stage and two applications at flowering were effective against

Megalurothrips sjostedti on cowpea. The fungal products have no toxic residues, are harmless to beneficial organisms and pose minimal risk to the environment and humans [16]. Microbial pesticides can multiply on or in vicinity of the target pest thus giving self-perpetuating control [17]. Botanical pesticides have also been shown to be as effective as the synthetic chemicals in reducing pest damage. Thoeming et al. [18] showed that dressing bean seeds with neem extracts effectively reduced population of thrips in flowers. Spray of neem extracts have also been shown to manage flower thrips [19]. The active ingredient in neem extracts, azadiractin, disrupts moulting in insect pests [20] while entomopathogenic fungi possess ovicidal, larvicidal and pupicidal effects [21].

Although biopesticides have high compatibility with other pest management techniques, the use of incompatible pesticides may lead to inhibition of the development and reproduction of entomopathogens and therefore restrict their application in IPM strategies [22]. In addition, most biopesticides are slow acting and give better results when integrated with approached in an IPM programme. Therefore, this study was carried out with the objective of reducing synthetic pesticide applications in French bean production by incorporating biological and botanical pesticides in spray regimes.

2. Materials and Methods

2.1. Experimental design and layout

On farm experiments were carried out over two planting season in Embu district of eastern Kenya, The area falls under the main coffee agro ecological zone or upper midland zone two (UM2) at an altitude of 1478m above sea level and it receives an average annual rainfall of 1395mm, with a mean temperature of 18.9^0 C to 20.1^0C (Jaetzold *et al*., 2006). The soils are well drained, dusky red to dark reddish brown, friable clay, with an acid humic top soil. The first planting was in June 2012 and the second planting in October 2012. Snap bean (variety Amy) was planted in plots measuring 3x4 m, and paths of 2 m within the plots were maintained. Intra row spacing of 30 cm was used and 15cm spacing between plants, a total of 270 plants per plot. To prevent damage from bean fly and other soil borne pests, the seeds were treated with Monceren GTFS 390 (Imidacloprid 233 g/L + Pencycuron 50g/L + Thiram 107g/L) at the rate of 6mls/kg before planting. The crop was watered as required through overhead irrigation three times in a week. The total rainfall received during the growing season was 172mm. The spray regimes evaluated for effectiveness in thrips management are outlined in Table 1 below. Each pesticide spray regime was applied on separate plots laid out in a randomized complete block design with four replicates. The population of adult and larvae thrips, pod yield, pod quality and price per unit were determined.

Table 1. Spray regimes evaluated for thrips management in French beans

	Treatment	First application	Subsequent applications
i)	Chemical + biological pesticide	Thunder® (Imidacloprid 10% + Betacyfluthrin 4.5%) 0.5 ml/L at 50% flowering	*Metarhizium anisopliae* 2ml/L 8 and 16 days after the first Thunder® application
ii)	Chemical + botanical pesticide	Thunder® (Imidacloprid 10% + Betacyfluthrin 4.5%) 0.5 ml/L at 50% flowering	Achook (*Azadirachtin* 0.15%) 1ml/L 8 days and 16 days after first Thunder® application
iii)	Chemical pesticide alone	Weekly application of Thunder® (Imidacloprid 10% + Betacyfluthrin 4.5%) 0.5 ml/L starting at the third week up to 50% flowering	Weekly application of Decis® (Deltamethrin) at 0.5 ml/l during the three weeks harvesting period
iv)	Botanical + Biological pesticide	Achook® (*Azadirachtin* 0.15%) 1ml/Lat 50% flowering	*Metarhizium anisopliae* 2ml/L 8 and 16 days after the first Achook® application
v)	Biological pesticide	*Metarhizium anisopliae* at 50% flowering	*Metarhizium anisopliae* 8 and 16 days after the first *Metarhizium anisopliae* application
vi)	Control	No pesticide application	

2.2. Assessment of thrips population

Thrips population was determined on flower samples collected from the inner rows of each plot following the procedure described by Nderitu *et al*., [2]. Ten open flowers were picked at random from each plot before application of the first spray at the onset of flowering and four days after. Thereafter, sampling was done at an interval of seven days for three weeks. The flowers were immediately placed in bottles containing 60% (v/v) ethyl alcohol in water. The thrips were counted under dissecting microscope by placing the ethanol solution containing thrips on Petri dish with square grids engraved on the bottom. Adult thrips were separated to species level based on the body colour, body setae and a comb on the eighth abdominal segment [23]. Immature thrips stages were counted separately.

2.3. Determination of pod yield and quality

Harvesting was done three times a week starting at the eighth weeks after planting. The pods were graded as marketable, unmarketable and rejects based on pod size (length 8-12 cm, width 5.5-6.5 mm), shape and absence of disease and insect pest damage. The marketable pods were further graded into fine and extra fine according to maximum width of the pods, maximum 6 mm for extra fine and 8 mm for fine [24]. Ten pods per plot were analyzed at every harvest, twice a week for thrips, damage on pods and rated as marketable and unmarketable. The cost of pesticides per hectare (CC), cost of chemical application per hectare (CA), gross return per hectare of marketable pods (GB), net return per hectare (NT) and the cost-benefit ratio for each treatment were calculated as follows:

Cost of chemical per Ha (CC) = Insecticide, *Azadirachtin and Metarhizium anisopliae* per unit cost x number of units used

Cost of application per ha (CA) = Number of man days per Ha x unit cost of labour

Gross returns per Ha (GB) = Total marketable yield per Ha x price of pods per kg

Net returns per Ha = gross return/Ha (GB) – [cost of chemical (CC) + cost of application (CA)]

Benefit-Cost ratio (BC) =

$$\frac{\text{Net returns (GB)}}{\text{[cost of chemical (CC) + cost of application (CA)]}}$$

2.4. Statistical data analysis

The data was subjected to analysis of variance (ANOVA) using GenStat 13th Edition (SP2) software. The means were compared by least significance difference (LSD) at 95% level of significance when the treatments effect showed significant F- test. Economic analysis was done by computing cost of pesticides, and labour used for controlling thrips for each spray regime, extrapolated to a hectare.

3. Results

3.1. Effect of integrating botanical and biological insecticides with synthetic chemicals on thrips population

Thrips species identified were *Megalurothrips sjostedti* (Trybom), *Frankliniella schultzei* (Trybom), *and Frankliniella occidentalis* (Pergande). *Megalurothrips sjostedti* was the most abundant whereas *Frankliniella occidentalis* had the least population (Table 2; Figure 1). All the spray regimes significantly reduced the adult thrip population compared to the unsprayed plots and alternating synthetic chemical sprays with both botanical and biological sprays were as effective as the continuous application of synthetic chemical alone. However, alternating application of botanical and biological based sprays and continuous application of biological sprays alone resulted in significantly higher population of *F. schultzei* and *M. sjostedti* compared to continuous application of synthetic sprays and alternating synthetic chemicals with both biological and botanical sprays (Table 2; Figure 1). Thrips population was high during season one crop than in season 2 crop. The population for all the three thrips species steadily increased with time, reaching maximum at seven days after 50% flowering (Figure 1).

Table 2. Numbers of adults of three thrips species in 40 snap bean flowers per treatment over two growing seasons in snap bean subjected to different spray regimes

	Frankliniella occidentalis		*Frankliniella schultzei*		*Megalurothrips sjostedti*	
Spray regime	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Chemical+Biological	3.4_a	1.9_a	6.8_a	1.6_{ab}	4.1_a	1.9_{ab}
Chemical+Botanical	2.9_a	1.6_a	9.2_a	1.4_a	3.7_a	1.7_a
Chemical alone	2.9_a	1.4_a	6.8_a	1.0_a	4.4_a	1.4_a
Botanical+Biological	6.8_b	2.2_a	14.1_b	2.8_{cd}	29.1_b	2.8_{bc}
Biological	7.8_b	2.1_a	17.1_b	2.4_{bc}	28.5_b	2.8_{bc}
Control	8.3_b	3.8_b	23.9_c	3.4_d	30.5_b	3.8_c
LSD $_{p \leq 0.05}$	1.55	1.0	4.9	0.9	5.6	0.9

Values followed by same letter within columns are not significantly different; LSD=Least significant difference; CV=Coefficient of variation

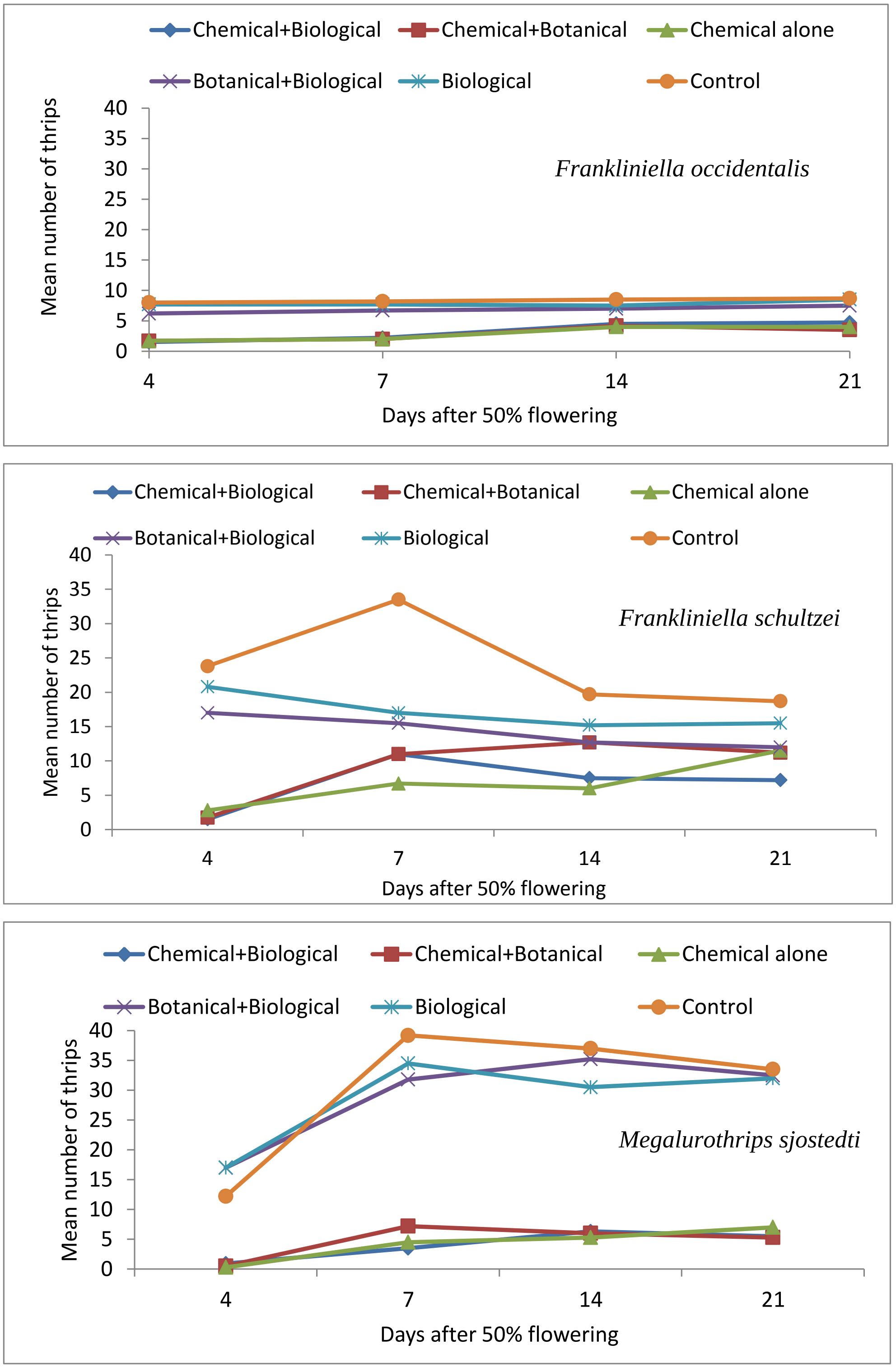

Figure 1. Number of three adult thrip species in 40 flowers sampled over time in snap bean crop subjected to different spray regimes of conventional, botanical and biological agents applied singly or in combination

The effect on population of thrips larvae was similar to that observed on the adult thrips for all the spray regimes (Figures 2 and 3). The number of larvae was significantly reduced by up to 76% in spray regimes where the application of synthetic chemical was alternated with either biological or botanical- based insecticides compared to the unsprayed plots for both season one and season two. Spray regimes consisting of alternate sprays of botanical and biological insecticides and biological sprays alone had significantly same number of thrips larvae compared to conventional spray regimes consisting of synthetic chemical insecticides. The spray regimes consisting of botanical and biological insecticides did not have significant effect on thrips larvae population compared to plots without any thrips management measures. Higher number of thrips larvae was observed in season one than in season two. All the spray regimes significantly reduced the mean number of thrips larvae at 4 days after the first spray application for the first season crop, and then increased thereafter in all the plots (Figure 3). In the second crop season, all the spray regimes showed no significant difference from each other at the first, second and third sampling periods. The highest thrips larvae population was observed at 14 to 21 days after 50% flowering in season one and at 21 days after 50% flowering in season two (Figure 3).

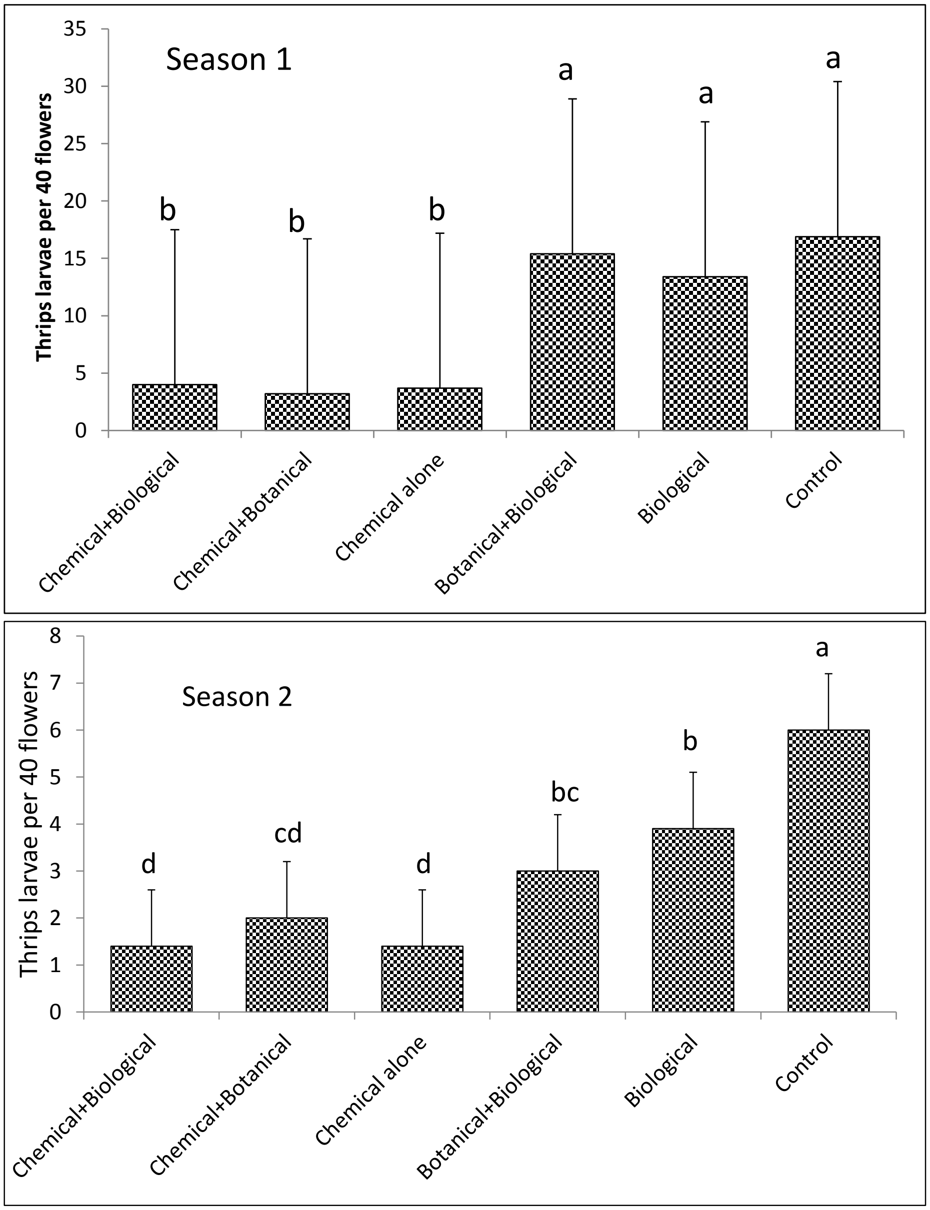

Figure 2. Total numbers of thrips larvae in 40 flowers per treatment in snap bean crop subjected to different spray regimes of conventional, botanical and biological agents applied singly or in combination (bars for treatments followed by the same letter are not significantly different at $P<0.05$ probability)

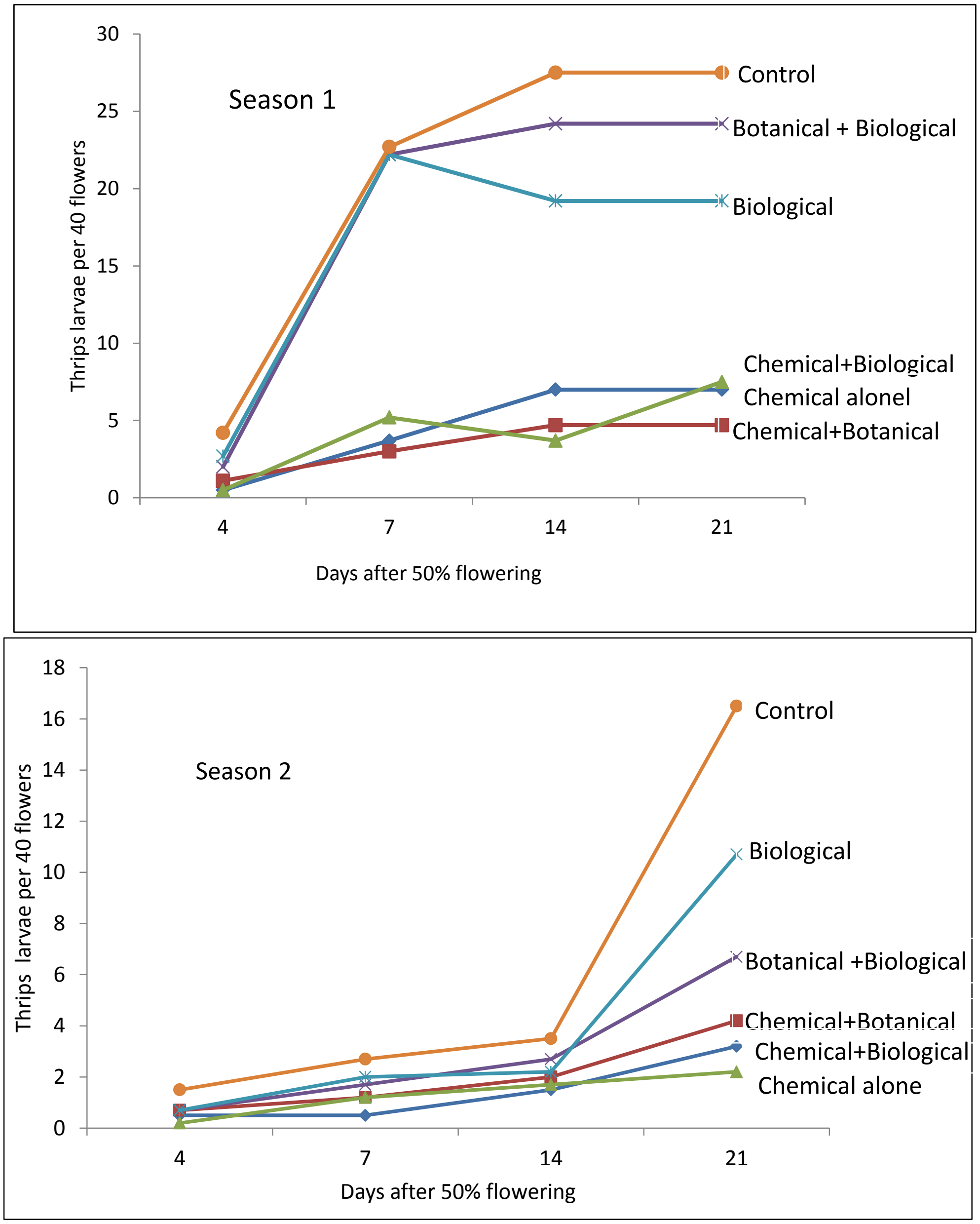

Figure 3. Mean numbers of thrips larvae in 40 flowers per treatment over time in snap bean crop subjected to different spray regimes of conventional, botanical and biological products

3.2. Effect of integrating botanical and biological insecticides with synthetic chemicals on pod yield and quality

The percent marketable pod yield from the various spray regimes significantly differed in both cropping seasons (Figure 4). Plots subjected to spray regimes consisting of synthetic insecticide alone had the highest percent marketable pods in both cropping seasons. Aside from the synthetic spray regime, spray regimes that integrated botanical or biological with synthetic insecticides had significantly higher percent of marketable pods compared to the yield from plots subjected to alternate sprays of botanical and biological insecticides and the unsprayed plots. However, plots subjected to spray regimes consisting of alternate sprays of biological and botanical or biological sprays alone had significantly higher percent marketable pods compared to the unsprayed plots.

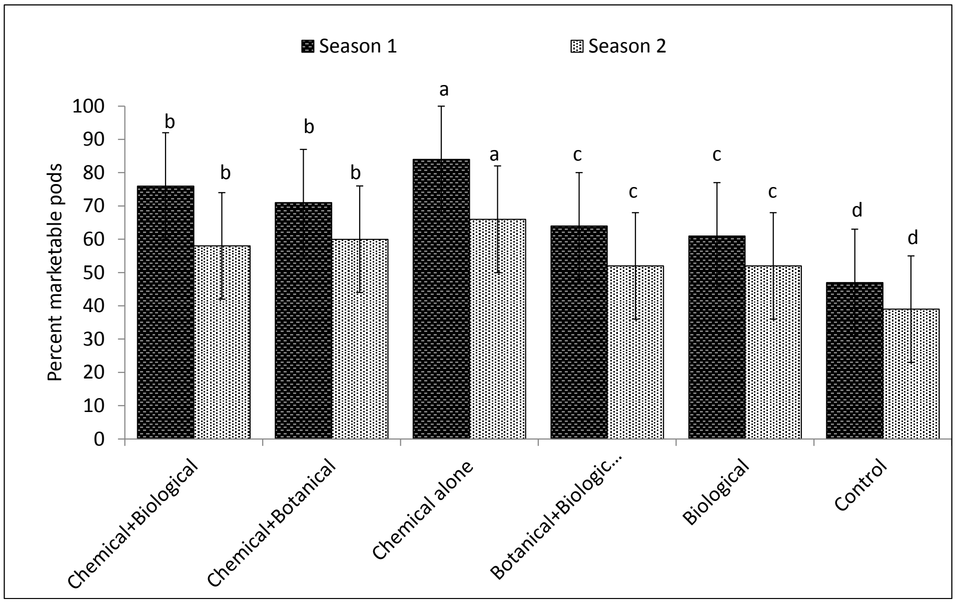

Figure 4. Percent marketable snap bean pods harvested from a crop subjected to subjected to different spray regimes of conventional, botanical and biological products applied singly or in combination (bars for treatments followed by the same letter are not significantly different at P<0.05 probability)

The different pod grades varied in total yield over the whole harvesting period, with the extra fine pods grade having the highest and fine grade having the least yield (Figure 5 and Table 3). There were significant differences among the spray regimes in total pod yield for both the extra fine and reject snap bean grades. Integrating biological based insecticide with synthetic spray increased fine and extra fine pod yields by up to 93% and 116%, respectively, and reduced the amount of reject pods by up to 42% compared to the unsprayed crop (Figure 5 and Table 3). This performance was comparable to that attained with application of synthetic chemical sprays. The least effective spray regime in improving pod marketable pod yield was application of neem based biological sprays alone and it was not significantly different to yields from crop without any spray application.

Table 3. Mean yield (Kg/Ha) per harvest for different pod grades in snap bean crop subjected to different thrips management spray regimes

	Fine pods		Extra fine pods		Reject pods	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Chemical+Biological	225.7$_{c}$	0	1020$_{c}$	1,663$_{c}$	323$_{ab}$	285$_{abc}$
Chemical+Botanical	174$_{bc}$	0	790$_{b}$	1,859$_{cd}$	393$_{bc}$	281$_{ab}$
Chemical alone	199.2$_{c}$	0	1347$_{d}$	2,06$_{6d}$	269a	245$_{a}$
Botanical+Biological	180.6$_{bc}$	0	636$_{ab}$	1,295$_{b}$	469$_{cd}$	353$_{bc}$
Biological	131.1$_{ab}$	0	609$_{a}$	1,129$_{b}$	514$_{de}$	386$_{c}$
Control	106.9$_{a}$	0	541$_{a}$	774$_{a}$	588$_{e}$	611$_{d}$
LSD $_{(P\leq 0.05)}$	71.8	0	481	825	177	302

Values followed by same letter within columns are not significantly different
LSD=Least significant difference, CV=Coefficient of variation

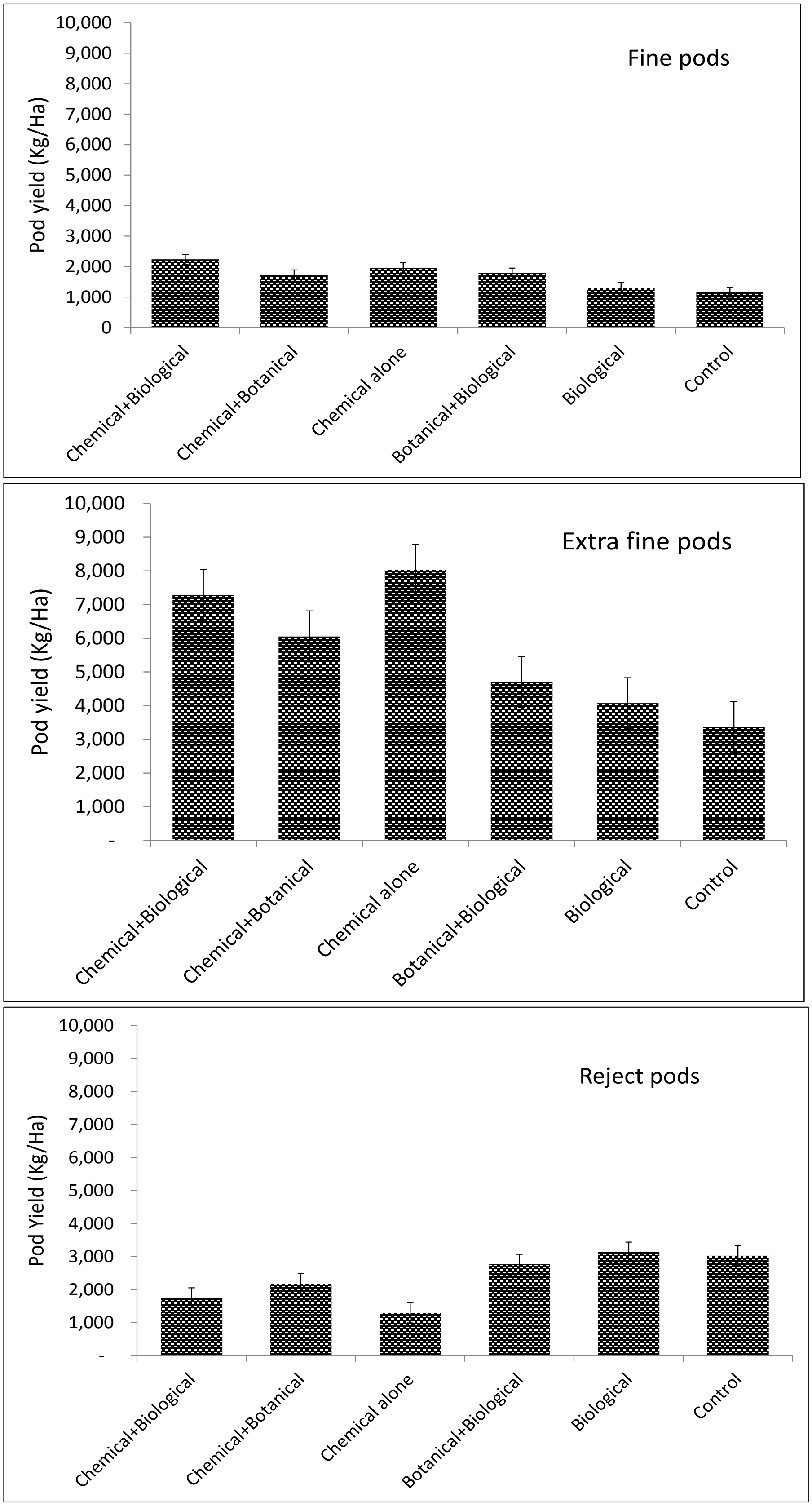

Figure 5. Mean pod yield (Kg/Ha) of different snap bean pod grades harvested from a crop subjected to different spray regimes of conventional, botanical and biological products

Integrating biological and botanical based insecticides in chemical spray regimes resulted in reduction of cost of chemicals and application by up to 51% compared to the spray regimes consisting of application of synthetic chemicals alone (Table 4). However, the marketable pod yields and net returns were comparable to those attained in plots sprayed with synthetic chemicals alone. The Highest benefit per unit cost was attained in spray regimes that integrated biological and botanical sprays and the least for spray regimes consisting of application of synthetic chemical alone, indicating an 80% improvement of benefit per unit cost.

Table 4. Cost-benefit analysis of different spray regimes of conventional, botanical and biological products applied singly or in combination

Spray regime	Cost of chemical	Cost of Application(Ksh)	Total cost	Marketable yield (Kgs)	Gross return (Ksh)	Net return (Ksh)	Benefit cost ratio
Chemical+Biological	6,190	750	6,940	1,454	58,174	51,234	7.4
Chemical+Botanical	6,150	750	6,900	1,412	56,482	49,582	7.2
Chemical alone	9,610	4500	14,110	1,806	72,244	58,134	4.1
Botanical+Biological	5,760	750	6,510	1,055	42,223	35,722	5.5
Biological	6,000	750	6,750	934	3,7360	30,632	4.5
Control	-	-	-	711	28,440	28,440	-

4. Discussion

The results of this study indicated that integrating Thunder® (Imidacloprid 10% + Betacyfluthrin 4.5%) and *Metarhizium anisopliae* ICIPE 69 and Thunder® with Achook® (*Azadirachtin* 0.15%) in a spray regime effectively reduced population of all thrips species, compared to *Metarhizium anisopliae* ICIPE 69 and *Azadirachtin* 0.15% plus *Metarhizium anisopliae* ICIPE 69 spray regimes that only reduced population of *F. occidentalis* and the thrips larvae. This agrees with the results by Nderitu *et al*. [2] who reported significantly lower numbers of *F. occidentalis* compared to *M. sjostedti* in the plots treated with *Azadirachtin* 0.15 %. The effectiveness of integrating synthetic pesticides and *Azadirachtin* 0.15% pesticides in the management of thrips on chilli (*Capsicum frutescens)* has been reported by Mandi and Senapati [25]. Our study showed that insecticide Thunder® (Imidacloprid 10% + Betacyfluthrin 4.5%) was the most effective in thrips reduction, followed by Thunder® in combination with *Metarhizium anisopliae* ICIPE 69 which also had the highest benefit cost ratio. This was in line with the findings by Shivolo [26], who reported that *Metarhizium anisopliae* ICIPE 69 biopesticide was more cost effective when used in rotation with synthetic chemicals. Similar results were also reported by Abd El-Mageed *et al.* [27] while working on the sucking pests of cotton in Egypt. The results show that sprays regimes consisting of Thunder®® (Imidacloprid 10% + Betacyfluthrin 4.5%) and *Metarhizium anisopliae* ICIPE 69 or Thunder® combined with *Azadirachtin* 0.15% spray regime can be recommended for use in Snap beans to manage all thrips species. Synthetic chemicals could be used during the early stages of the crop to manage *F. schulzei and M. sjostedti* that are much difficult to control with Thunder® and *Azadirachtin* 0.15% pesticides.

Conventional spray regime consisting of weekly application of Thunder® (Imidacloprid 10% + Betacyfluthrin 4.5%) starting at the third week up to 50% flowering followed by weekly application of Decis (Deltamethrin) during harvesting showed the least mean number of thrips. This confirms the result of several studies on the effectiveness of different synthetic chemicals for use in IPM in management of thrips [5, 4]. However, the extensive use of synthetic pesticides is undesirable due to its adverse effects on human health, the environment, natural enemies, and pollinators [28, 29]. Their continued use leads to development of resistant pests, accumulation of residues in agricultural produce and eliminates natural enemies [21, 30]. Kenya is among the main exporters of French bean to the European Union but the strict MRL requirements means that crops should be allowed longer pre-harvest intervals (PHI) even when sprayed with permitted pesticides [30]. In addition, the EU recently imposed a 10% sampling restrictions on French beans from Kenya in an effort to enforce pesticide maximum residue levels [31].

Spray regimes consisting of *Azadirachtin* 0.15% plus *Metarhizium anisopliae* ICIPE 69 and *Metarhizium anisopliae* ICIPE 69 alone had the least reduction in thrips population compared to the unsprayed plots. This could be explained by the slow acting nature of most biopesticides and they are also susceptible to unfavourable environmental conditions [17]. Therefore, they are not suited for use alone in pest management spray regimes. In addition, studies have shown that the use of incompatible pesticides may lead to inhibition of the development and reproduction of entomopathogenic fungus *Metarhizium anisopliae* [22]. Niassy *et al.* [14] reported that *Azadirachtin* was toxic to *M.*

anisopliae ICIPE 69 and adversely affected its vegetative growth. The results of this experiment showed that the effectiveness of *Metarhizium anisopliae* ICIPE 69 when used alone did not significantly differ from the unsprayed controls. The result contradicts a study by Ekesi *et al.* [12] who found no significance difference in the grain yield of cowpea between the plots treated with *Metarhizium anisopliae* and synthetic insecticides. It however agrees with Maniania *et al*. [13] who recommended the use of *Metarhizium anisopliae* in combination with a chemical insecticide for the control of *F. occidentalis* and immature thrips on chrysanthemum.

In the current study, the effectiveness of integrating microbial and botanical biopesticides with conventional insecticides in spray regimes was also manifested by the improved French bean pod quality. Application of conventional insecticide Thunder$^{®}$ (Imidacloprid 10% + Betacyfluthrin 4.5%) followed by *Metarhizium anisopliae* ICIPE 69 or *Azadirachtin* 0.15%, or conventional insecticide Thunder$^{®}$ alone resulted in higher number of marketable pods than plots treated with *Metarhizium anisopliae* ICIPE 69 alone or *Metarhizium anisopliae* ICIPE 69 followed by *Azadirachtin* 0.15%. Although the application of conventional insecticide Thunder$^{®}$ had the least mean number of thrips, the benefit-cost ratio was lower compared to the application of insecticide Thunder$^{®}$ followed by *Metarhizium anisopliae* ICIPE 69 or that of insecticide Thunder$^{®}$ followed by *Azadirachtin* 0.15% spray regimes. This is in addition to the other benefits of biopesticides such as reduced chemical residues, reduced health risks to workers, reduced environmental pollution, minimum danger to natural enemies, potential for recycling and ease of disposal [3, 5, 20]. The results of this study show that it would be profitable for French bean farmers to reduce the number of synthetic chemical sprays to a single spray before harvesting and use *Azadirachtin* or *Metarhizium anisopliae* ICIPE 69 biopesticides during harvesting to keep pests population below economic injury level. This is in line with other studies that have reported good compatibility and cost-effectiveness of biopesticides with other pest management approaches such as natural enemies, resistant varieties and synthetic chemicals, thereby enhancing the performance of IPM strategies [21, 22, 26]. The results demonstrated that Kenya French bean farmers can reduce the cost of pest management and meet the stringent European market MRL requirements by applying approved synthetic insecticides during the vegetative growth stages before flowering and maintaining sprays of biopesticides after flowering. This would significantly reduce the number of interceptions and rejections of Kenya's vegetable exports to the EU as has been the case in the past [7].

Acknowledgements

This research was funded by the Kenya Agricultural Productivity and Agribusiness Project (KAPAP).

References

[1] Ndegwa, A. M., Chegeh, B. K., Wepukhulu, S. B., Wachiuri, S. M., and Kimamira, J. N. (2006). Evaluation of advanced snap bean (*Phaseolus vulgaris* l.) breeding lines for resistance to bean rust, yield potential and pod quality. Report. Thika : KARI.

[2] Nderitu, J. H., Mwangi, F., Nyamasyo, G., and Kasina, M. (2010). Utilization of synthetic and botanical insecticides to manage thrips (thysan.: thrip.) on snap beans (fabaceae) in Kenya. International Journal of Sustainable Crop Production. 5(1), 1-4.

[3] Nyasani, J. O., Meyhöfer, R., Subramanian, S., and Poehling, H.-M. (2012). Effect of intercrops on thrips species composition and population abundance on French beans in Kenya. Entomologia Experimentalis et Applicata, 142: 236–246.doi: 10.1111/j.1570 7458.2011.01217.x

[4] Nderitu, J. H., Kasina, M. J., Nyamasyo, G. N., Waturu, C. N., and Aura, J. (2008). Management of Thrips (Thysanoptera: Thripidae) on French beans (fabaceae) in Kenya: Economics of Insecticide Applications. Journal of Entomology, 5, 148-155.

[5] Nderitu, J. H., Wambua, E. M., Olubayo, F., Kasina, J. M., and Waturu, C. N. (2007). Management of thrips (Thysanoptera: Thripidae) Infestation on French beans (Phaseolus vulgaries L.) in Kenya by Combination of insecticides and Varietal resistance. Journal of Entomology, 4, 469-473.

[6] Aktar, M. W., Sengupta, D., and Chowdhury, A. (2009). Impact of pesticide use in Indian agriculture - Their benefits and hazards. Interdisciplinary Toxicology, 2(1), 1-12.

[7] Agritrade. (2013). New EU maximum residue levels hit Kenyan vegetable exports http://agritrade.cta.int/en/Agriculture/Commodities/Horticulture/New-EU-maximum-residue-levels-hit-Kenyan-vegetable-exports

[8] European Commission. (2012). Amending Annex I to Regulation (EC) No 669/2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin. Official Journal of the European Union. L. 350/44. 20/12/2012.

[9] KEPHIS. (2012). The introduction of increased checks on Kenyan exported beans and peas in pods by the European Union. Presented at a meeting with stakeholders exporting beans and peas. Nairobi, Kenya. http://www.kephis.org Accessed on 30th January 2013.

[10] Nderitu, J., Mwangi, F., Nyamasyo, G., and Kasina, M. (2009). Evaluation of cropping systems as a strategy for managing snap bean flower thrips in Kenya. International Journal of Sustainable Crop Production.4(6), 22-25.

[11] SP-IPM. (2006). Biological alternatives to harmful chemical pesticides. IPM Research Brief No.4. SP-IPM Secretariat, International Institute of Tropical Agriculture (IITA), Cotonou, Benin.

[12] Ekesi, S., Maniania, N. K., Ampong-Nyarko, K., and Onu, I. (1998). Potential of the entomopathogenic fungus, *Metarhizium anisopliae* (Metsch.) Sorokin for control of the legume flower thrips, *Megalurothrips sjostedti* (Ikybom) on cowpea in Kenya. *Crop Protecrion.* 17(8), 661-668.

[13] Maniania, N. K., Ekesi, S., Löhr, B., and Mwangi, F. (2002). Prospects for biological control of the western flower thrips, *Frankliniella occidentalis*, with the entomopathogenic fungus, *Metarhizium anisopliae*, on chrysanthemum *Mycopathologia* 155, 229–235.

[14] Niassy, S., Maniania, N. K., Subramanian, S., Gitonga, M. L., Maranga, R., Obonyo, A. B., and Ekesi, S. (2012). Compatibility of *Metarhizium anisopliae* isolate ICIPE 69 with agrochemicals used in French bean production. International Journal of Pest Management, 58(2), 131-137.

[15] Ekesi, S., Maniania, N. K., Ampong-Nyarko, K., and Akpa, A. D. (2001). Importance of timing of application of the entomopathogenic fungus, *Metarhizium anisopliae*, for the control of legume flower thrips, *Megalurothrips sjostedti* and its persistence on cowpea. Archives of Phytopathology and Plant Protection 33, 431–445.

[16] Goettel, M. S., Hajek, A. E., Siegel, J. P., Evans, H. C. (2001). Safety of Fungal Biocontrol Agents. 2001. In: Butt T, Jackson C, Magan N, editors. *FungalBiocontrol Agents — Progress, Problems and Potential*. CABBI Press; 2001. pp. 347–375.

[17] Chandler, D., Bailey, A. S., Tatchell, G. M., Davidson, G., Greaves, J., and Grant, W. P. (2011). The development, regulation and use of biopesticides for integrated pest management. Philosophical Transactions of the Royal Society B, 366, 1987–1998.

[18] Thoeming, G., Poehling, H.-M. (2006). Integrating soilapplied *Azadirachtin* with *Amblyseius cucumeris* (Acari: Phytoseiidae) and *Hypoaspis aculeifer* (Acari: Laelapidae) for the management of *Frankliniella occidentalis* (Thysanoptera: Thripidae). Environmental Entomology, 35, 746–756.

[19] Oparaeke, A. M,, Dike, M. C., Amatobi, C. I. (2006). Botanical pesticide mixtures for insect pest management on cowpea, *Vigna unguculata* (L.) Walp Plants — The legume flower bud thrips, *Megalurothrips sjostedti* (Trybom). Journal of Sustainable Agriculture. 29(1),5–13.

[20] Lomer, C. J., Bateman, R. P., Dent, D., De Groote, H., Douro-Kpindou, Kooyman, C., Langewald, J., Ouambama, Z., Peveling, R., and Thomas, M. (1999). Development of strategies for the incorporation of biological pesticides into the integrated management of locusts and grasshoppers. Agricultural and Forest Entomology, 1, 71-88.

[21] Srinivasan, R. (2008). Integrated Pest Management for eggplant fruit and shoot borer (Leucinodes orbonalis) in South and Southeast Asia: Past, Present and Future. Journal of Biopesticides, 1(2), 105 – 112.

[22] Rashid, M., Baghdadi, A., Sheikhi, A, Hamid-Reza Pourian, H-R., Gazavi, M. (2010). Compatibility of *Metarhizium anisopliae* (ascomycota: Hypocreales) with several insectisides. Journal of Plant Protection Research 50(1), 22-27.

[23] Kakkar, G., Seal, R. D., and Kumar, V. (2010). Common blossom thrips -*Frankliniella schultzei* Trybom University of Florida. http://entnemdept.ufl.edu/creatures/veg. Publication Number: EENY-477 . Accessed 6th June 2012.

[24] Infornet-Biovision. (2012). Crops, fruits and vegetables. http://www.infonet-biovision.org-Beans. Accessed 11th May 2012.

[25] Mandi, N., and Senapati, A. K. (2009). Integration of chemical botanical and microbial insecticides for control of thrips, *Scirtothrips dorsalis* Hood infesting chilli. The Journal of Plant Protection Sciences, 1(1), 92-95.

[26] Shivolo, T. O. (2009). Efficacy of *Metarhizium anisopliae* ICIPE 78 and Acaricides in the manageme Imidacloprid 100g/L + Betacyfluthrin 45g/L)nt of the two spotted spidermite, tetranychus urticae (Acari: Tetranychidae) on French beans. MSc Thesis. University of Nairobi.

[27] Abd El-Mageed, A. E., Anwar, E. M., Elgohary, L. R. A., and Dahi, H. F. (2007). Evaluation of Several Programs of Sequences Pesticides Application on Cotton Bollworms and Some Other Sucking Pests in Cotton Field. *Journal of Entomology, 4,* 93-103.

[28] Kasina, M., Nderitu, J. H., Nyamasyo, G., Waturu, C., Olubayo, F., Obudho, E., and Yobera, D. (2009). Within-plant distribution and seasonal population dynamics of flower thrips (Thysanoptera: Thripidae) infesting French beans (*Phaseolus vulgaris* L.) in Kenya. Spanish Journal of Agricultural Research 2009 7(3), 652-659.www.inia.es/sjar ISSN: 1695-971-X.

[29] Ajayi, C. O., and Akinnifesi, A. F. (2007). Farmers' understanding of pesticide safety labels and field spraying practices: a case study of cotton farmers in northern Cote d'Ivoir, Scientific Research and Essay. (6), 204-210

[30] Graffham, A. (2006). EU legal requirements for imports of fruits and vegetables (a suppliers' guide). Fresh Insights No. 1, DFID/IIED/NRI, www.agrifoodstandards.org.

[31] Mwangi, T. (2013). Threat to market access for Kenya's beans and snowpeas to EU. Hortfresh Journal. http://www.hortfreshjournal.com/articles/threat_%20to_Mmarket_access_for%20kenyas_beans.pdf Accessed 10th March 2014