

Uganda Journal of Agricultural Sciences by National Agricultural Research Organisation
is licensed under a Creative Commons Attribution 4.0 International License.

Based on a work at www.ajol.info

Effectiveness and profitability of insecticide formulations used for managing snap bean pests

M. Otim¹, M. Kasina², J. Nderitu³, M. Katafüre⁴, M. Mcharo⁵, M. Kaburu⁶, G. Bwire⁷,
J. Bwire¹, G. Cheminingw'a³, F. Olubayo³ and M. Ugen⁸

¹National Crops Resources Research Institute, Namulonge, P. O. Box 7084, Kampala, Uganda

²Entomology Section, Kenya Agricultural Research Institute, NARL-Kabete, P. O. Box 14733-00800,
Nairobi, Kenya

³Department of Plant Science and Crop Protection, University of Nairobi, P. O. Box 29053-00625,
Nairobi, Kenya

⁴(RIP)

⁵Private Bag, P. O. Box 38561 – 00623, Nairobi, Kenya

⁶Ministry of Agriculture, Meru County, P. O. Box 1705, Meru 60100, Kenya

⁷International Potato Center (CIP) -Uganda, P. O. Box 22274, Kampala, Uganda

⁸National Semi-Arid Resources Research Institute (NaSARRI), P. O. Soroti, Serere, Uganda

Author for correspondence: motim9405@gmail.com, hotim@nacri.go.ug

Abstract

Snap bean (*Phaseolus vulgaris* L.) farmers rely mostly on insecticides to manage pests and to satisfy the stringent market requirements for insect and blemish-free pods. However, the cost of these pesticides lowers farm incomes. In addition, heavy and wrong use of pesticides could result in residue accumulation, which reduces market access by the farmers. To identify optimal pest control with lower economic risks to farmers, we investigated the effectiveness and profitability of different insecticides and insecticide formulations against bean fly (*Ophiomyia* spp.) and bean flower thrips (*Megalurothrips sjostedtii*). Two separate experiments were conducted during 2009 to 2012. The first experiment targeted bean fly and bean flower thrips, comprising the treatments: seed dressings, soil drenches, foliar sprays and an untreated control. We used randomised complete block design, with four replicates. All the seed dressing and soil drenching insecticides, except Apron, significantly lowered bean fly infestation by two to 60 fold when compared with control. These insecticides, however, did not control flower thrips. Confidor® resulted in a marginal returns of 0.89 and Actara® -0.11 compared to seed dressings, which ranged from 0.47 to 1.82. The second experiment laid in a randomised complete block design involved the foliar application of Romet® under different spray regimes. Application of Romet® reduced infestation of thrips, and resulted in positive MRR in all the seasons.

Key words: *Frankliniella occidentalis*, marginal rate of returns, *Megalurothrips sjostedtii*, Neonicotinoids, *Ophiomyia phaseoli*

Introduction

Snap bean (*Phaseolus vulgaris* L.) also referred to as French bean or green bean -is produced in east Africa mainly for the export market. There is also increasing local consumption in the region. Uganda and Kenya exported 5,239 and 96,772 metric tonnes of green beans valued at US\$ 1.822 and 96.772 in 2013, respectively (FAO, 2016). Like other legumes, snap bean provides dietary protein in the form of immature fresh pods and is rich in iron, which is an important mineral for expectant and lactating mothers. Being predominantly a commercial crop, snap bean has a potential to increase incomes and living standards of small scale farmers, who form majority of producers.

Insect pests and diseases, however, pose a major challenge in the production of snap bean in East Africa. Bean flies (*Ophiomyia* spp) and thrips (*Frankliniella occidentalis* and *Megalurothrips sjostedtii*) are the most important insect pests of beans in the region (CIAT, 1992; Nderitu *et al.* 2001). Bean fly females lay eggs on the upper surface of the leaf. Hatched maggots mine through the leaf petioles and stems, and pupate below the epidermis of the stem at or above the ground level in seedlings, or at the base of the petiole in older plants. Pupation causes cracks, which weaken the plant, and also act as entry points for pathogens. Bean fly damage may result in seedling death under severe infestation (Abate and Ampofo, 1996). In contrast, flower thrips start infesting at the vegetative stage and migrate later into flower buds and flowers (Kasina *et al.*, 2009). Thrips infestation levels were higher in snap beans planted in the first dry season (January 2002) than in the second dry season (July 2002) in Mwea-

Tebere (Kasina *et al* 2009). Damage by flower thrips results in premature fall of flower buds and flowers. This was estimated to cause 40% yield loss. In addition, feeding damage leads to 20% loss at collection points (Lohr, 1996).

In order to avert pest damage, farmers in Uganda and Kenya practice routine spray every one or two weeks to control pests, often spraying 8 to 15 times in a season (Nderitu *et al.*, 2001; Makokha *et al.*, 2001; Otim *et al.*, 2011). Repeated sprays are time and labour consuming, increase cost of production, lead to secondary pest problems, insecticide resistance buildup, undesirable accumulation of pesticide residue in the produce, and pesticide poisoning (Seif *et al.*, 2001; Nderitu *et al.*, 2008; Oesterlund *et al* 2014). Exposure to agrochemicals was estimated to cause poisoning of approximately three million agricultural workers each year globally, and about 300,000 deaths (Gunnell *et al.* 2007). Pesticide use alone was estimated to account for 14% percent of the total production costs (Nyambo, 2006). This reduces the profit margins. The case of high residue in produce has resulted into interception of produce and trade barriers (Agritrade, 2013).

These drawbacks have heightened the need to shift from persistent insecticides and reduce the frequency of pesticide application on snap bean, and hence, adopt the concept of Integrated Pest Management (IPM). Therefore, less persistent insecticides such as neonicotinoids, applied in different ways, have been promoted in the past to offer better protection of snap beans against the pests. The systemic activity of neonicotinoids provides an alternative to organophosphates (Wyman and Chapman, 2004) in view of the strict snap bean

export requirements. Use of systemic seed dressing and soil drenching insecticides can cut down the number of sprays by protecting the crop for up to nine weeks of growth (Bethke and Redak, 1997; Wyman and Chapman, 2004). This could be complemented with a few applications of foliar sprays after five weeks to protect against flower and pods pests such as thrips. This intervention would reduce growers' production costs, and improve human and environment safety (Nault *et al.*, 2004). Considering the level off operation, seed dressing and onward sowing does not result in pesticide dust formation, hence has practically minimal effects on bees and other pollinators. Well-timed and fewer application of foliar sprays would not have significant effect on pollinators.

In this study, we evaluated the effectiveness and profitability of neonicotinoid insecticide formulations and a pyrethroid and organophosphate combination in snap bean pest control across seasons. The economic assessment is geared towards enabling farmers make informed decisions on the choice of insecticides.

Materials and methods

Studies were carried out under the framework of a regional project funded by the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) supporting research in Uganda, Kenya, Tanzania and Rwanda. In this undertaking, we use studies in Kenya and Uganda as case studies. We conducted studies on seed dressing and soil drenching in Kenya, while the foliar spray experiment was conducted in Uganda. These were based on the premise that information generated from

one country has potential utility in another, and would only require validation of the results.

Seed dressing and soil drenching

The study was carried out at Kimbimbi in Mwea, Kirinyaga South District in Central Kenya for three seasons, 2009-2011. The site has an elevation of 1214 m a.s.l. while its geographical location is 0°36'21.66" S and 37°22'01.24"E (Google, 2010). The area is a main centre for small-scale export snap beans production in Kenya. It is a warm lowland area, which records minimum and maximum temperatures of 17°C and 26°C, respectively. Annual rainfall ranges from 356 to 1,625 mm with an average of 950mm per year. The rainfall pattern is bimodal, with first rains coming in April/May and second rains in the months of October/December. Relative humidity varies from 52 to 67% (Manene, 2010).

The trial was planted in a randomised complete block design, with three replicates. Each block consisted of seven plots, giving a total of 21 plots. The plots measured 3 m x 3 m which were separated by 0.5 m between plots and 1 m between blocks. Four seed dressing chemicals were used namely Gaucho®350FS, Monceren® GTF 390 Apron® Star 42WS and Cruiser®350FS (Table 1). Application rates were 2 g, 8 ml, 2.5 g and 4 ml per kg of seed for Gaucho, Monceren, Apron and Cruiser, respectively. The seed and chemical were put in a 10 cm x 15 cm clear polythene bag of gauge 150 µm and a few drops of water added and then shaken continuously until the seeds were fully coated with the chemical. The seeds were then dried out on newspapers for three hours under shade, and planted the same day. In addition, two more chemical formulations (Confidor® WG70 and

Table 1. Chemicals and rates used on snap beans in Mwea, Kenya

Trade name	Chemical name	Active ingredient	Rate applied (/kg of seed or m ²)
Gaucho® 350FS	Imidacloprid	Imidacloprid 350 g/l	7 g
Monceren® GTF390	Imidacloprid	Imidacloprid 233 g/l + Pencycuron 50 g/l + Thiram 107 g/l	8 ml
Apron® Star 42WS	Thiamethoxam	20% w/w Thiamethoxam+ 20% w/w Metalaxyl-m + 2% w/w Difenconazole	2.5 g
Cruiser® 350FS	Thiamethoxam	Thiamethoxam 250 g/kg	4 ml
Confidor® WG70	Imidacloprid	Imidacloprid 700 g/kg	Soil drench 0.5 ml/m ² foliar spray 5 g per 20 litre water
Actara® 25WG	Thiamethoxam	Thiamethoxam 250 g/kg	Soil drench 0.28 ml/m ² foliar spray 8 g per 20 litre water

Source: Product labels

Actara® 25WG) were assessed, as soil drench as alternative to seed dressing (Table 1). Both were drenched twice at three days after emergence; followed by a foliar spray ten days later. Soil drenching with Confidor was done on the surface after diluting with water at a rate of 0.5 ml per m² (5 g in 10 litres); followed by foliar spray at a rate of 5 g in 20 litres. Actara drench was done along the bean rows, at a rate of 0.28 g m⁻² and foliar spray at a rate of 8g per 20 litres of tap water. Polythene sheets were placed on both sides of a plot to shield neighboring plots against drift.

Di-Ammonium phosphate (DAP) fertiliser was applied at planting, at a rate of 133 kg ha⁻¹ and Calcium Ammonium Nitrate (CAN) as top dressing at 35 days after emergence at the same rate. The plots were ridged at a spacing of 60 cm, giving six furrows per plot. DAP was put in furrows and mixed with soil, then a single seed planted in small holes made by a stick at the edge of the furrow at 10 cm apart. This gave about 180 seedlings at emergence. Diseases were controlled in all the plots, using Ortiva (®) fungicide against angular leaf spot and Thiovit (®) fungicide against powdery mildew. All agronomic practices such as weeding, irrigation and fungal disease control were uniformly applied to all the plots. Supplemental irrigation was applied by flooding the furrows when the rains were insufficient.

Foliar application

This experiment was conducted at the National Crops Resources Research Institute, NaCCRI, in Namulonge, Wakiso, Uganda. It is located at 00 32' N of the Equator and 32° 37' E. It is 27 Km North of Kampala at an elevation of 1150 metres above-sea- level. It has a tropical wet and

mild dry climate with slightly humid conditions (average 65%), with two rainy seasons (Yada *et al.*, 2010). This location is ideal for evaluations on snap bean because; (i) it is located in the snap bean growing area in the country; and (ii) the two rainy seasons of approximately the same length (3 months each) offer the chance to carry out trials twice a year.

The experiment was conducted between 2009 and 2012. Treatments comprised five spray intervals (5, 10, 15, 20, 25 days) of Rokat® (Profenofos 40% + Cypermethrin 4%) and an untreated control. Rokat® was used because it is the most widely used pesticide in vegetable production in Uganda (Otim *et al.*, 2011). The treatments were laid in a randomized complete block design (RCBD), replicated four times, making a total of 24 plots. The gross experimental area was 37 m x 25 m (925m²) and the net experimental area was 30 m x 20 m (600m²). Each plot had dimensions of 5 m x 5 m (25m²). Plant spacing was 30 cm between rows and 10 cm between plants. Rokat® was applied at rate of 30 ml per 15 L of tap water, starting at two weeks after planting. Agro-zeb® (80% WP, AI-Mancozeb 80%) was applied regularly at a rate of 30 g per 15 L of water to protect against fungal diseases. All these amounts were calculated from instructions on the users' manual.

Data collection

Seed dressing and soil drenching.

Data were collected on bean fly oviposition punctures, immature (larvae and pupae) and pod yield. The oviposition punctures were counted weekly from 15 leaves, randomly picked per plot from the inner four lines. The number of maggots/pupae in bean stems was scored by randomly uprooting five plants per plot, at

three and five weeks after emergence. The stems were then dissected and the number of maggots/pupae recorded. Thrips on leaves were counted with the aid of a hand lens. To count thrips on flowers, 15 fully open flowers were randomly picked per plot then inserted into bottles containing 50% alcohol. The flowers were taken to the laboratory where they were macerated carefully in 50% alcohol to extract all the thrips, which were then counted and recorded for each plot. At harvest, green pods were picked from the entire plot twice a week from week six to week twelve, washed and graded into marketable and unmarketable lots.

Foliar application. In this experiment, we collected data on thrips infestation and pod yield. Thrips infesting French beans were randomly collected on 10 flowers from the inner rows of each plot. This was done at an interval of three days from first appearance of flower buds and continued throughout the flowering period. Samples were preserved in 70 % ethanol solution for processing. The contents were handled as described above.

Data analysis

Data on the number of insects were analysed using GenStat Software (14th edition), using analysis of variance (ANOVA). Means were separated using the Least Significant Difference (LSD) at $P < 0.05$.

Profitability analysis

Profitability in both experiments was calculated using the gross marginal rate of returns. This is the ratio of net returns to the cost of control. The net rate of returns were calculated by subtracting the total cost incurred for each spray regime

used from the corresponding gross returns obtained from selling French bean pods. At the time of the experiment, the farm gate price of French beans was Uganda shillings 3,000 per kilogramme, equivalent to US\$ 1.215. The cost of 1 L Rokat® was USD 16. The cost of pesticides was obtained from the purchase price and computed to a hectare while the cost of application was obtained from the farmers and researcher's own records.

Results

Seed dressing on bean flies and thrips infestation

The number of bean fly immatures was significantly ($P < 0.001$) different across the treatments in 2009 and 2011 plantings (Table 2). Snap beans in plots treated with soil drenching insecticides (Confidor and Actara) consistently recorded the lowest bean fly infestation levels, when compared to the seed dressing chemicals and the untreated control. The effect of the seed dressing chemicals, Gaucho and Cruiser, resulted into significantly lower bean fly infestation. The effects of Monceren and Apron star, drenching was significantly better in the control of bean fly compared with seed dressing. Control had the highest number of bean flies compared with the chemicals though bean flies on snap beans treated with some seed dressers were not significantly different from those in control.

Thrips infestation on snap beans treated with seed dressing and soil drenching insecticides was significantly different in the first and third season (Table 3). Snap beans treated with Apron star (seed dresser) recorded the highest mean number of thrips while those treated with Confidor (soil drenching) recorded the lowest infestation in the first planting. However, in the third planting, Actara (soil

Table 2. Mean number of bean fly immatures infesting French beans under different insecticide treatments at Mwea, Central Kenya in 2009, 2010 and 2011

Insecticide	Mode of application	2009	2010	2011
Confidor	Soil drenching	0	0	0.5
Actara		0	0.3	0.8
Gaucho	Seed dressing	11.2	0.8	4.7
Monceren		16.8	1.2	7.0
Cruiser		20.0	0.7	4.7
Apron Star		34.3	1.0	3.3
Control		30.8	2.8	6.2
P - value		<0.001	0.06	<0.001
SEM		4.21	0.559	1.033

Table 3. Mean number of flower thrips infesting French beans under different insecticide treatments at Mwea, Central Kenya in 2009, 2010 and 2011

Insecticide	Mode of application	2009	2010	2011
Confidor	Soil drenching	6.9	18.3	63.4
Actara		7.0	23.3	66.3
Gaucho	Seed dressing	8.1	14.9	57.2
Monceren		8.1	13.8	51.4
Cruiser		10.2	13.8	50.6
Apron Star		12.3	11.3	44.6
Control		7.9	12.8	49.7
P - value		0.006	0.117	0.018
SEM		0.06	0.172	0.098

drenching) treated snap beans had the highest thrips count while Apron star treated snap beans had the lowest. Overall, though not significant ($P>0.05$), seed dressing snap beans lowered thrips infestation compared with soil drenching and control.

The effect of foliar sprays on thrips infestation and snap bean yield

Thrips infestation on snap beans was significantly different between treatments

in all the five seasons (Table 4). Overall, the lowest number of thrips was recorded in snap bean sprayed at 5 d interval, while the highest was recorded in the unsprayed plots. Spraying starting at 25d after emergence resulted in lower infestation compared with other spray regimes (10, 15 and 20d after emergence) in three plantings (2010B-1, 2010B-b and 2012A). Profitability of chemical control

Insecticides used for drenching were the most expensive in terms of purchase

Table 4. Mean number of flower thrips infesting French beans under different spray intervals at NaCRRI, central Uganda in 2009, 2010, 2011 and 2012

Spray interval (days)	2010 A	2010 B-1	2010 B-2	2011 A	2012 A	Overall mean
5	26.2	10.9	29.9	20.4	24.7	20.3
10	39.8	18.8	38.8	22.2	30.0	26.4
15	22.3	35.2	44.4	25.5	57.5	32.9
20	36.9	43.0	50.1	28.6	40.7	39.2
25	45.2	13.4	26.5	34.0	29.2	27.9
No spray	83.4	41.3	41.3	39.6	52.8	42.99
P- value	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
SEM	0.0944	0.0605	0.0715	0.034	0.0459	0.05

price as well as application cost (Table 5). Amongst the seed dressers, Gaucho was the most expensive while Cruiser was the least. Snap beans protected with drench applications had the highest yields with Confidor treated crops having more than doubled the yield of the second best yielding treatment. Snap beans treated with Confidor also had the highest net returns followed by those dressed with Monceren and Cruiser. Apron star seed dressed snap beans had the lowest net returns. However, considering marginal returns from the investment in different formulations, Cruiser provided the highest gains followed by Apron star and Monceren. Investment in Confidor provided just above half of the gains from using Cruiser. Actara had the lowest gains, in fact, negative gains. The unprotected snap beans (control) had the lowest yields and returns.

In the case of foliar sprays, snap beans that received more insecticide sprays produced the highest marketable yield while those that received less sprays had the lowest amongst the insecticide treatments (Table 6). Unprotected snap

beans had the lowest crop yield. The marginal rate of return was always positives and not consistent across plantings. In the first planting of 2010A and second planting of 2010B, MRR was less than unity for all the spray applications. In the first planting of 2010B and 2011, however, plots that received between 2–4 spray applications of Romet had MRR of one. In 2012, only the plots that received two spray applications had a MRR of one, all the rest had less than one.

Discussion

Our results have shown that use of neonicotinoids as soil drench and seed dressing can effectively reduce severity of bean fly but may not manage thrips. Confidor and Actara were the most effective chemicals in controlling bean fly as shown by the low numbers of maggots and high yields. This is similar to earlier work on Borboti bean that showed that Actara soil mix was effective against bean fly (Rahman and Prodhan, 2007). Gaucho and Cruiser seed dressings were

Table 5. Mean cost of spray, yield of French beans, returns and marginal rate of return for different insecticides at Mwea, Central Kenya

Treatment	Chemical amount (ha ⁻¹)	Cost of chemical (USD ha ⁻¹)	Cost of application (USD ha ⁻¹)	Marketable yield (kg ha ⁻¹)	Gross returns (USD ha ⁻¹)	Net returns (USD ha ⁻¹)	Marginal returns
Cruiser	180 ml	17.1	7.1	213	68.6	44.4	1.83
Apron Star	112.5 g	8.2	7.1	124	40.0	24.7	1.60
Monceren	360 ml	25.7	7.1	229	73.6	40.8	1.24
Confidor	435 g	69.0	29.8	580	186.4	87.6	0.89
Gaucho	320 g	29.0	7.1	166	53.2	17.1	0.47
Actara	400 g	58.6	29.8	244	78.6	-9.8	-0.11
Control				112	36.1	36.1	

moderately effective whereas effect of Monceren and Apron Star were not consistent. The yield of various plots reduced with increased maggot/pupae infestation as reported by Peter *et al.* (2009) on common beans. Thus, failure to put in place any bean fly control strategy can lead to uneconomic yields (Seif *et al.*, 2001). Effectiveness of these seed dressing chemicals (Gaucho and Cruiser) may be enhanced by combining with cultural and biological management techniques in an integrated pest management system (Infonet-Biovision, 2010, Seif *et al.*, 2001). Ogecha *et al.* (2000) reported that combination of seed dressing with cultural techniques can increase crop tolerance to bean fly and improve crop yields. This is corroborated in similar work by Ampofo and Massomo (1998) on dry beans in Tanzania who found that combination of cultural techniques with seed dressing is more effective than seed dressing alone. However, spraying starting at 25d interval resulted in lower thrips infestation and higher MRR. This period coincides with flower bud formation and therefore curtailing the buildup of thrips.

Our study showed that neonicotinoid seed dressings and soil drenches, followed with a spray application were not effective in controlling bean flower thrips. In contrast, Nayasani *et al.* (2015) found that Imidacloprid reduced the number of Western Flower thrips on French beans plants and in flowers. Similarly, Seal *et al.* (2006) demonstrated that Imidacloprid significantly suppressed both adults and larvae of chilli thrips *Scirtothrips dorsalis* (Hood) on pepper in the field for at least 15 days. This may be explained by the differences in timing and number of insecticide application. In our study, we applied Imidacloprid as a soil drench and

Table 6. Mean marketable yield, returns, cost of sprays and marginal rate of return under different spray regimes at NaCRRI, Uganda

No. sprays/ Season	Cost of chemical (USD ha ⁻¹)	Cost of application (USD ha ⁻¹)	Marketable yield (kg ha ⁻¹)	Gross returns (USD ha ⁻¹)	Net returns (USD ha ⁻¹)	Marginal returns
2010 A						
11	4.4	330.1	837.4	1,004.9	670	0.7
6	2.4	180.1	1369.0	1,642.8	1,460	0.9
4	1.6	120.0	1172.7	1,407.3	1,286	0.9
3	1.2	90.0	917.1	1,100.5	1,009	0.9
2	0.8	60.0	767.1	920.5	860	0.9
Control			788.1	945.8		
2010 B-1						
11	4.4	330.1	2716.8	3,260.1	2,926	0.9
6	2.4	180.1	2702.6	3,243.2	3,061	0.9
4	1.6	120.0	2586.8	3,104.2	2,983	1.0
3	1.2	90.0	2212.4	2,654.8	2,564	1.0
2	0.8	60.0	3069.3	3,683.2	3,622	1.0
Control			2174.6	2,609.5		
2010 B-2						
11	4.4	330.1	1060.7	1,272.8	938	0.7
6	2.4	180.1	868.3	1,041.9	859	0.8
4	1.6	120.0	1031.5	1,237.8	1,116	0.9
3	1.2	90.0	1035.2	1,242.3	1,151	0.9
2	0.8	60.0	717.7	861.3	800	0.9
Control			1130.4	1,356.5		
2011						
11	4.4	330.1	1964.7	2,357.6	2,023	0.9
6	2.4	180.1	2507.1	3,008.5	2,826	0.9
4	1.6	120.0	2663.0	3,195.7	3,074	1.0
3	1.2	90.0	2587.7	3,105.3	3,014	1.0
2	0.8	60.0	2383.1	2,859.7	2,799	1.0
Control			2372.7	2,847.2		
2012						
11	4.4	330.1	1823.8	2,188.5	1,854	0.8
6	2.4	180.1	1324.0	1,588.8	1,406	0.9
4	1.6	120.0	1181.2	1,417.5	1,296	0.9
3	1.2	90.0	1477.7	1,773.2	1,682	0.9
2	0.8	60.0	1403.6	1,684.3	1,624	1.0
Control			1167.2	1,400.6		

*The cost of sprays includes cost of purchasing insecticide and labour for spraying

followed with a single foliar spray 10 days later. Thus in our study, the pest might have appeared when the Imidacloprid had become ineffective. Nyasani *et al.* (2015), however, applied Imidacloprid three times at 14d interval, starting at budding. This targeted the stage when the thrips were most abundant. This necessitates insecticide application as and when required following the loss of efficacy of seed dressing or soil drenching insecticides.

The results of our foliar application showed that increased frequency lowered thrips population, with five day interval being the most effective. This may in effect explain the dependence of farmers on frequent insecticide application and their rating as effective (Nderitu *et al.*, 2008; Otim *et al.* 2011).

Our studies have shown that seed dressing, soil drenching and foliar pesticide application are effective in lowering pest populations. However, producers have to be mindful of the profitability and dangers associated with their use. From our studies, Confidor and Actara were the most effective in controlling bean fly and gave the highest pod yields. However, the two were not the most profitable. For instance, application of Actara resulted to negative marginal rate of returns. Similarly, lower spray interval of Roket® resulted into lower marginal returns when compared to longer intervals. Calderón-Limón *et al.* (2002) reported that farmers who applied higher than the recommended concentrations of insecticide to control pests on hot pepper did not realize yield advantage. As argued by Karungiet *al.* (2000) and Nderitu *et al.* (2008), fewer sprays of insecticide are the most cost-effective for management of major field pests of cowpea and snap beans, respectively. In order to achieve these few

sprays, farmers should be guided by the thrips density or numbers. This requires developing economic injury levels and monitoring of the thrips build up in the season and only use insecticides when the thrips attain the action threshold level. This is possible when farmers can easily identify flower thrips (Nderitu *et al.*, 2001), or can be taught to do so. This will enable French bean farmers to gain from their investments economically, while maintaining the required market standards. Apart from economic benefits, few applications of insecticides have other benefits to the farmers themselves, the environment, as well as the consumers of the French bean product. Few sprays minimize the likelihood of pesticide residues on the crop produce, ground water sources, environment pollution as well as the negative effects on natural enemies. French bean pods are harvested continuously as the crop flowers and as such few applications would not endanger pickers.

The current global trends in the use of pest control products suggests promoting those products with low or no effect on humans and the environment. The reported decline of honey bees in North America and Europe is now a major concern and efforts to halt this have been suggested. One of the effects on bees is the use of neonicotinoids (e.g. Whitehorn *et al.*, 2012) and recommendations have been made to reduce their use in agriculture (e.g. Hopwood *et al.*, 2013). Thus, extension of knowledge about the effects of neonicotinoids on bees and other pollinators in East Africa should be explored. Among the European Union countries, France made a request on emergency measures relating to the potential risk of dimethoate and its derivatives. The European Food Safety

Authority (2016) recommended a comprehensive review of the existing EU MRLs to derive a final opinion on possible risks for consumers resulting from residues of dimethoate and its metabolites in food. We also recommend testing new chemistries and other consumer preferred insecticides for effectiveness and profitability.

Conclusion

Since the aim of small-scale farmers is to make profits at reduced costs, expensive chemicals such as Confidor and Actara and regular applications should be avoided. For bean fly control, Cruiser and Apron star are the most profitable and recommended options. In addition, two to three applications of foliar insecticide may suffice for control of thrips.

Acknowledgement

The study was made possible through a grant from ASARECA (FP05-Ugen-IRCO4-C1-01). Views expressed in this article are not necessarily those of ASARECA but authors. We thank our institutional management for their technical administrative support.

References

- Abate, T. and Ampofo, J.K.O. 1996. Insect pests of beans in Africa: Their ecology and management. *Annual Review of Entomology* 41:45 - 73.
- AgriTrade. 2013. New EU maximum residue levels hit Kenyan vegetable exports.
- Ampofo, J.K.O. and Massomo, S.M. 1998. Some cultural strategies for management of bean stem maggots (Diptera: Agromyzidae) on beans in Tanzania. *African Crop Science Journal* 6(4): 351-356.
- Bethke, J. A. and Redak, R. 1997. Effect of Imidacloprid on the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae), and whitefly parasitism. *Annals of Applied Biology* 130: 397-407.
- CIAT (Centro Internazionale de Agricultura Internazionale). 1992. Snap beans in the developing world. In: Henry, G. and Janssen, W. (Eds.). *Proceedings of an international conference*. CIAT, Cali, Colombia. 366pp.
- EFSA (European Food Safety Authority). 2016. Assessment of the risk to human health through the pesticide active substance for dimethoate and its metabolites in food. *EFSA Journal* 14 (4):4461, 38 pp. doi:10.2903/j.efsa.2016.4461
- Gunnell, D., Eddleston, M., Phillips, M.R. and Konradsen, F. 2007. The global distribution of fatal pesticide self-poisoning: systematic review, *BMC Public Health* 7(c):357. doi:10.1186/1471-2458-7-357.
- Hopwood, J., Vaughan, M., Shepherd, M., Biddinger, D., Mader, E., Black, S.H. and Mazzacano, C. 2013. Are neonicotinoids killing bees? A review of research into the effects of neonicotinoid insecticides on bees, with recommendations for action. <http://www.xerces.org/neonicotinoids-and-bees/> (Accessed May 20, 2013)
- Infonet-biovision. 2010. Farmer Information Platform (4th Edition) March 2010. www.infonet-biovision.org. Accessed 28th March 2011
- Karungi, J., Adipala, E., Kyamanywa, S., Ogenga-Latigo, M.W., Oyobo, N. and Jackai, L.E.N. 2000. Pest

- management in cowpea. Part 2. Integrating planting time, plant density and insecticide application for management of cowpea field insect pests in eastern Uganda, *Crop Protection* 19:237-245.
- Kasina, M., Nderitu, J., Nyamasyo, G., Waturu, C., Olubayo, F. and Obudho, E. 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* 7(3):652-659.
- Lohr, B. 1996. Integrated pest management in French beans in Kenya: Past achievements and some thoughts about the flower thrips problem. Proceedings of the Biennial Crop Protection Conference. 27–28 March 1996, Nairobi, Kenya.
- Makokha, A.O., Ombwara, F.K., Wamocho, L.S, Wesonga, J.M. and Sichangi, P. 2001. Farming characteristics among small scale French bean (*Phaseolus vulgaris* L.), farmers in Mwea, Kenya. In: J.M. Wesonga, T., Losenge, C.K. Ndungu, K., Ngamau, F.K. Ombwara and S.G. Agonga (Eds.), *Proceedings of the first horticultural seminar on sustainable horticultural production in the tropics*. JKUAT, Nairobi, Kenya. pp. 106 – 111
- Manene, S.K. 2010. Kirinyaga South District briefs. Ministry of Agriculture. Wanguru. Kenya.
- Nault, B.A., Taylor, A.G., Urwiler, M. Rabaey, T. and Hutchison, W.D. 2004. Neonicotinoid seed treatment for managing Potato leafhopper in snap bean, *Crop Protection* 23: 147-154.
- 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 (3): 148-155.
- Nderitu, J.H., Olubayo, F., Waturu, C.N., Aura, J. and Kasina, J. 2001. Current french bean pests and disease management at Mwea Tebere, Central Kenya. In: J.M. Wesonga, T. Losenge, C.K. Ndung'u, K. Ngamau, F.K. Ombwara, S.G. Agong, A. Fricke, B. Hau and Stützel H (Eds.), *Proceedings of the Horticulture seminar on Sustainable Horticultural Production in the Tropics*. JKUAT and Hannover, Nairobi, Kenya. pp. 118-122.
- Nyambo, B. 2006. Developing country initiative. *Pesticide News* 71. March 2006. 2p
- Nyasani, J., Subramanian, S., Poehling, H.M., Maniania, N., Ekesi, S. and Meyhöfer, R. 2015. Optimizing western flower thrips management on french beans by combined use of beneficials and imidacloprid. *Insects* 6(1):279–296. <http://doi.org/10.3390/insects6010279>
- Oosterlund, A.H., Thomsen, J.F., Sekimpi, D.K., Maziina, J. and Racheal, A. Jrs E. 2014. Pesticide knowledge, practice and attitude and how it affects the health of small-scale farmers in Uganda: A cross-sectional study. *African Health Science* 14(2):420-433. doi:10.4314/ahs.v14i2.19.
- Ogecha, J. and Ampofo, J.K.O. 2000. Development of an Integrated Pest Management strategy for controlling bean stem maggot in South Western Kenya. Participatory technology development for soil management by small holders in Kenya. In: *Proceedings of the 2nd Scientific*

- Conference of the Soil Management and Legume Research Network Projects*. Kenya Agricultural Research Institute Mombasa, Kenya pp. 311-317.
- Otim, M., Obia, P.O., Mugagga I. and Ugen, M. 2011. Farmers' perceptions and management of pests and diseases on snap beans in Uganda. In: M. Katafiire, M. Ugen and Mwamburi Mcharo (Eds.), *Proceedings of the Regional Stakeholders' Workshop*. ASARECA, Entebbe, Uganda, pp. 83-95.
- Peter, K.H., Swella, G.B. and Mushobozy, D.M.K. 2009. Effect of plant populations on the incidence of bean stem maggot (*Ophiomyia* spp.) in common bean intercropped with maize. *Plant Protection Science* 45(4):148-155.
- Rahaman, M.A. and Prodhan, M.D.H. 2007. Management of borboti bean fly (*Ophiomyia* spp.), *International Journal of Sustainable Crop Production* 2(3): 5-8.
- Seal, D.R., Ciomperlik, M., Richards, M.L. and Klassen, W. 2006. Comparative effectiveness of chemical insecticides against the chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), on pepper and their compatibility with natural enemies, *Crop Protection* 25:949-955.
- Seif A., Varela, A.M., Michalik, S. and Lohr, B. 2001. A guide to IPM in French beans production with emphasis on Kenya. International Centre for Insect Physiology and Ecology, Nairobi, Kenya, 72pp
- Whitehorn, P.R., O'Connor, S., Wackers, F.L. and Goulson, D. 2012. Neonicotinoid pesticide reduces bumble bee colony growth and queen production. *Science* 336: 351-352.
- Wyman, J. and Chapman, S. 2004. Insecticide seed treatments for snap beans. <http://www.soils.wisc.edu/extension/wcmc/2004proceedings/Wyman2.pdf>. Accessed May 27, 2015.
- Yada, B., Tukamuhabwa, P., Alajo, A. and Mwanga, R.O.M. 2010. Morphological characterization of Ugandan sweet potato germplasm, *Crop Science* 50:2364-2371.