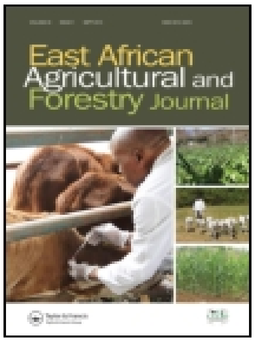

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Incidence and Severity of Common Bean (*Phaseolus vulgaris* L.) Pests in Agro-Ecological Zones and Farming Systems of Western Kenya

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ABSTRACT

Infestation by insect pests is a serious problem in legume up scaling activities and a threat to future production in Kenya. The survey aimed at determining incidence and severity of insect pests of common beans in different districts and agro-ecological zones of western Kenya. Foliage beetle incidence was highest in the hot and drier LM3 (72.6%) and LM4 (92.1%) zones during the long and short rains, respectively. Leaf hopper incidence was highest in LM4 (26.8%) and (59.3%) whereas bean fly incidence was highest in UM3 (12.4%) and LH1 (2.9%). Whitefly incidence was highest in LM3 (13.0%) and LM2 (17.9%) and aphid incidence was highest in LM1 (16.5%) and UM1 (40.8%). Plant bug incidence was highest in LM1 (16.5%) and LM2 (5.8%). Flower thrips incidence was highest in LM2 (20.7%) and (34.2%) in both seasons. Bean flies (7.2%) and *Spodoptera* (2.9%) incidences were higher during the long rains. Foliage beetle incidence (52.7%), aphids (22.6%), leaf hopper (27.9%) and flower thrips (17.8%) were higher during the short rains. Whitefly (7.9%), thrip (9.7%) incidences and foliage beetle severity (2.1) were lower on improved cultivars in LM2 areas in Homa Bay. Intercropping reduced aphid incidence (18.3%) and severity (1.3) in UM1 areas in Vihiga district. Inorganic fertiliser reduced bean fly (3.8%) and thrips (11.8%) incidences in UM1 areas in Vihiga and in LM2 areas in Siaya districts, respectively, compared with fields without fertiliser. The result is important in the development of strategies in bean insect pest management and control.

KEYWORDS

aphids; bean fly; flower thrip; foliage beetle; insect pest incidence; leaf hopper; plant bug; *Spodoptera*; whitefly

Introduction

Common beans (*Phaseolus vulgaris* L. Fabacea) are a protein, macro and some micro-nutrients and vitamins rich food crop contributing to household food and income (Broughton et al. 2003; Katungi et al. 2009). It is the second most important food crop after maize in Kenya. The total annual bean production figure is estimated at 613 902 tonnes from an area estimated at 1 058 920 ha (FAOSTAT 2012), which makes Kenya one of the largest producers in Sub Sahara Africa, accounting for 10% of the total protein consumed (FAOSTAT 2007).

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The production of this crop is constrained by a complex of biotic constraints, including insect pests that have led to decline in quality and yields in Africa (Nderitu and Buruchara 1997; Katungi et al. 2009). The most significant insect pests in the field are the aphid spp., the legume pod borer, *Maruca testulalis* or *Vitrata* Fab, bean fly, *Ophiomyia* spp. flower bud thrips, *Megalurothrips sjostedti* Tryomb, a host of plant sucking bugs, which include *Clavigralla tomentosicollis* Stal, *Anoplocnemis curvipes* Fab, *Aspavia armigera* Fab, *Nezera viridula, Riptortus dentipes*, leaf hoppers, *Empoasca dolichi* and *E. lybica* and white flies, *Bemisia tabacci* (Allen et al. 1996; Wortmann et al. 1998; Abate et al. 2011; Beebe et al. 2012) and foliage beetle species (CBI 1987: Minja 2005). The damage caused by the insect pests, whereas feeding on legumes is estimated at about 70% yield loss in East Africa (Edema and Adipala 1996) and therefore efforts should be made to manage the pests using novel methods that are cheaper and affordable by small scale farmers of Africa. The relative importance of these insect pests differs from region to region as influenced by weather and vegetation cover (Songa and Ampofo 1999), cropping systems and soil fertility conditions (Nderitu and Buruchara 1997).

Preliminary reports listing the constraints to legume production in eastern and central Africa (Wortmann et al. 1989; Katungi et al. 2009) together with reviews of legume pests and diseases in Eastern Africa (Hill 1975; Allen et al. 1996) do not provide quantitative values of pest prevalence or severity in the different agro-ecological zones, except for the attempt by Mwangombe et al. (2007) who described the relationship between disease severity and agro-ecological zones, there has been no similar studies on pests that affect legumes. Such knowledge gaps have hindered efforts to understand pest ecology, economic importance of specific pests and which should also be useful in developing integrated pest control strategies. Therefore, this study was aimed at gaining information on the occurrence and distribution of pest spectrum of common beans, in the major agro-ecological zones of western Kenya.

Materials and methods

Study area

The survey sites included all 11 districts of western Kenya and three in Rift valley located between 34° E and 35° and 0° 15’ N and 1° 45’ S and an altitude range of 1 140 to 2 500 m asl and covered eight main agro-ecological zones based on altitude, mean annual rainfall, temperature and evapotranspiration. The production environment ranged from, warm humid lower midland (LM1, LM2, LM3, LM4) to cool upper midland (UM1) and lower highland (LH1) agro-ecological zones (Table 1).

Pests incidence and severity was conducted on 325 and 175 farm households during the long and short rains seasons (April-June and October-December 2013, respectively) in Western Kenya. Fields were selected using a hierarchical design combining purposive and random sampling of between 6 and 72 farms per location depending on availability of the crop where we stopped along major motor able roads at the predetermined distance (1 to 5 km). Fields assessment of insect pests was timed to coincide with the period when bean plants were at flowering and pod formation stages of growth.

Table 1. A summary description and classification of the agro-ecological zones covered in the survey of the common bean pests in western Kenya.

AEZ	General description	R/PET[a] (%)	Altitude (m)	Mean temperature (°C)	Mean annual rainfall (mm)	[b]60% rainfall reliability (mm)
LM1	Warm-humid sugarcane zone	>80	1 300–1 550	20.5–21.7	1 600–1 800	900–1 000
LM2	Warm- humid marginal sugar cane zone	65–80	1 300–1 550	20.4–21.7	1 300–1 700	700–950
LM3	Warm-humid maize-cotton zone	50–65	1 140–1 550	20.4–22.7	900–1 500	500–900
LM4	Warm transitional maize and marginal cotton zone	40–50	1 140–1 450	20.9–22.7	800–900	350–500
UM1	Temperate-humid coffee-tea zone	>80	1 500–1 620	19.9–20.5	1 600–1 800	800–1 000
UM2/3	Temperate-sub-semi-humid coffee-tea zone	50–80	1 500–1 800	19.3–20.5	1 400–1 600	800–900
LH1	Temperate-subhumid tea-dairy zone	>80	2 000–2 500	19.3–20.5	1 600–2 000	850–1 000

Source, Jaetzoldt et al. 2009 [a] R/PET, Rainfall as a proportion of potential evapotranspiration, a measure of moisture availability, [b] Amount of rainfall exceeded in 6 of 10 years in the long and short rains rainfall, AEZ, agro-ecological zones, LM, lower midland, UM, upper midland, LH, lower highland zones,

The incidence was recorded from ten random plants in each field and then expressed as percentage of plants with pest or symptoms over total number of plants sampled from each field. The insect samples were put in a sampling bottles containing 70% alcohol and transported to the laboratory where they were identified using textbooks (Hill 1975; Allen et al. 1996) and through use of various identification keys and literatures, but no differentiation was made between the species. Pest severity rating is the degree of damage symptom or infestation level observed per plant. Severity was assessed by scoring the plants based on whole plant observation or alternative only on the affected parts (e.g. stem, leaves and flowers) on a scale of:

1 = no damage and infestation

2 = light damage and infestation <5% plant parts damaged or infested by pest

3 = average damage and infestation >5 and <50% plant parts damaged

4 = considerable damage and infestation >50% plants parts damaged and severe stunting or wilting

5 = Plants with very high infestation levels and severity of damage or wilted and dead plants

Additional information was collected on soil type, cropping systems, farming practices, altitude and the growth stage of the crop.

Data analysis

All the data were subjected to analysis of variance (ANOVA) using General Linear Model and correlation Procedures (SAS Institute 2013). Data on percent incidence and severity were transformed to ($\sqrt{x + 0.5}$) prior to the analysis.

The differences among the treatment means were tested using least significant differences (LSD) at the 5% probability level.

Results

General observations

The production environment ranged from warm humid lower midland (LM1, LM2, LM3, LM4) to cool upper midland (UM1) and lower highland (LH1) agro-ecological zones (Table 1). The altitude ranges of the different agro-ecological zones is also shown in Table 1.

A total of 14 common bean varieties were encountered, whereas 89.5 and 89.2% of the farmers cultivated improved bean varieties during the long and short rains, respectively. The most common improved varieties were Rose coco (32.2%), Wairimu (8.5%), KK8 (4.9%), GLP2 (10.5%), Canadian wonder (6.8%) and KatX56 (5.4%). Other improved varieties were Jessica, Zaire, KatX69, GLPX92, Red haricot, MAC 142 and NUA. During the long and short rains, respectively, 90.7% and 76.6% of the farmers intercropped beans with cereals. More than 65% and 60.9% of the farmers used soil fertility amendment practices to improve bean production whereas less than one percent used insecticides to manage the bean pests (Table 2).

Pest prevalence

Pest prevalence varied in the different regions and agro-ecological zones during the long and short rains, as shown in (Figure 1). Foliage beetle was more prevalent in Ndhiwa, Rongo and Siaya districts during the long rains and in Bondo and Butula during the short rains. Mean prevalence was 83.9% and 91.5% during the long and short rains, respectively. Leaf hopper was highly prevalent (100%) in Rongo, Bondo and Busia with a mean prevalence at 69.3 and 91.2% of the sites during the long and short rains, respectively. Aphids were found at 41 and 61.4% of the sites and was highly prevalent (70%) and (100%) in Bungoma and Nandi south districts during the long and short rains,

Table 2. Percentage of farmers growing local and improved common bean varieties, and practicing intercropping; soil fertility improvement and use of insecticides in different regions of western Kenya.

District	Agro-ecological zone	*Improved variety only% long rains	short rains	Intercropped% long rains	short rains	Soil fertility improvement Long rains	short rains	Use of insecticides % long rains	short rains
Bondo	LM3	100	78.9	100	84.2	84.0	21.1	0.0	0.0
Bungoma	LM1	71.6	–	78.6	–	67.9	–	3.6	–
Busia	LM2	88.2	100	64.7	100	58.2	100	0.0	0.0
Butula	LM1	–	90.0	–	80.0	–	40.0	–	0.0
Homa bay	LM2	96.0	56.3	96.0	87.5	44.0	25.0	0.0	0.0
Nandi South	LM2	–	75.0	–	100	–	100	–	0.0
Nandi Central	UM3	97.3	100	89.1	26.7	97.8	100	0.0	0.0
Nandi North	UM4	100	–	100	–	100	–	0.0	–
Nandi South	LH1	75.0	91.3	80.0	36.9	100	67.4	0.0	0.0
Ndhiwa	LM3	85.0	–	92.4	–	57.1	–	0.0	
Rarieda	LM4	90.0	100	100	92.9	20.0	7.0	0.0	0.0
Rongo	LM1	100	100	100	92.3	66.3	53.2	0.0	0.0
Siaya	LM2	93.1	–	86.2	–	65.5	–	0.0	–
Suba	LM4	100	–	100	–	0.0	–	0.0	–
Vihiga	UM1	66.7	100	93.1	65.0	77.8	95.0	0.0	0.0
Mean		89.5	89.2	90.7	76.6	65.5	60.9	0.3	0.0

LM, lower midland, UM, upper midland, LH, lower highland zones, *, Improved, elite varieties of beans bred for high yield and tolerance to some of biotic stressors

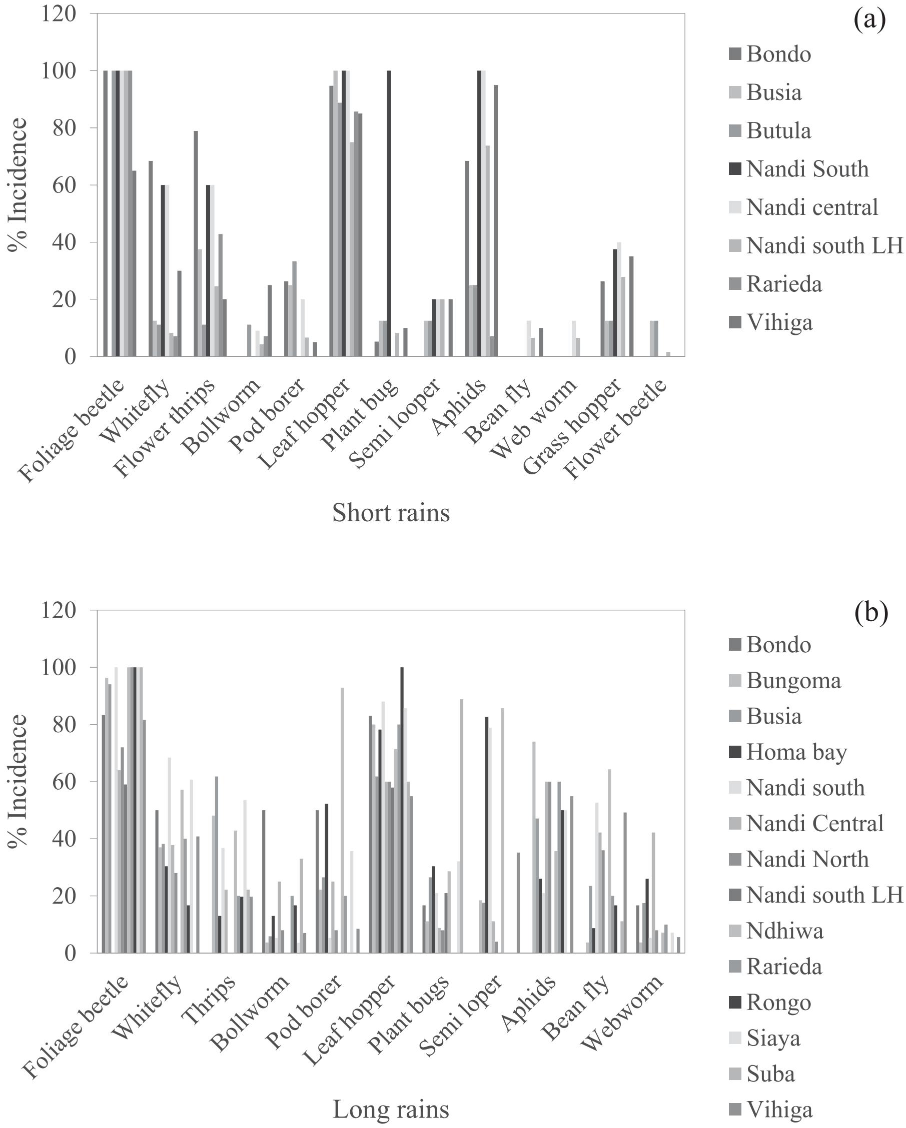

Figure 1. Prevalence of common bean insect pests in different districts of western Kenya during the long and short rains, 2013.

respectively. Bollworm was found in 13.7 and 70% of the sites during long and short rains, respectively and was more prevalent in Rongo and Rarieda during the long rains and in Butula during the short rains. Bean fly was found in 25.2% and 3.6% of the sites during the long and short rains, respectively and was more prevalent (64%) and (100%) in Ndhiwa and Nandi South districts during long and short rains, respectively.

Pest incidence severity

Pest incidence and severity also varied significantly ($p < 0.05$) among the districts and agro-ecological zones during the two seasons (Table 3).

Table 3. Mean incidence (%) and severity (scale 1–5) of insect pests on common beans in different Districts and agro-ecological zones of western Kenya during long and short rains, 2013.

Season and district	Foliage beetle incidence	severity	White fly incidence	severity	Thrips incidence	severity	Boll worm incidence	severity	Pod borers incidence	severity	Leaf hopper incidence	severity	Plant bugs incidence	severity	Semi-looper incidence	severity	Aphids incidence	severity	Bean Fly incidence	severity	Grass Hoppers incidence	severity	*Spodoptera* incidence	severity
Long rains Suba	86.7	2.2	0.0	1.0	6.7	1.1	8.9	1.0	2.2	1.0	26.7	1.3	0.0	1.0	0.0	1.0	1.1	1.0	1.1	1.0	7.8	1.0	0.0	1.0
Ndhiwa	80.7	2.2	10.7	1.0	14.3	1.2	0.0	1.0	29.3	1.4	12.9	1.1	2.9	1.0	1.4	1.0	5.7	1.1	12.1	1.1	12.9	1.0	0.0	1.0
Homa Bay	72.8	2.1	4.0	10.	2.4	1.0	1.6	1.0	12.4	1.2	24.8	1.3	3.6	1.0	7.2	1.1	2.8	1.0	1.6	1.0	4.4	1.0	2.4	1.0
Siaya	69.3	1.9	14.8	1.2	23.1	1.3	0.7	1.0	14.5	1.2	18.3	1.2	6.6	1.0	0.0	1.0	15.2	1.3	0.0	1.0	1.7	1.0	0.0	1.0
Busia	56.7	1.8	8.5	1.1	34.1	1.5	0.6	1.0	5.3	1.1	18.2	1.2	6.2	1.0	4.7	1.1	9.7	1.1	6.5	1.0	4.7	1.0	0.0	1.0
Rongo	55.0	1.8	5.0	1.0	10.0	1.2	1.7	1.0	0.0	1.0	31.7	1.4	0.0	1.0	0.0	1.0	10.0	1.2	1.7	1.0	3.3	1.0	0.0	1.0
Nandi South	50.0	1.7	15.5	1.2	10.0	1.2	1.0	1.0	5.0	1.1	15.0	1.2	2.5	1.0	0.0	1.0	6.0	1.1	11.0	1.1	6.0	1.0	0.0	1.0
Bondo	41.7	1.7	5.0	1.1	0.0	1.0	8.3	1.0	11.7	1.2	20.0	1.2	1.7	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Bungoma	39.3	1.6	6.4	1.1	15.0	1.2	0.4	1.0	7.1	1.1	23.3	1.3	1.8	1.0	0.0	1.0	17.9	1.3	0.7	1.0	0.7	1.0	0.0	1.0
Vihiga	26.1	1.4	8.8	1.1	5.3	1.1	0.7	1.0	1.1	1.0	11.7	1.1	0.3	1.0	0.4	1.0	15.9	1.2	12.1	1.1	2.2	1.0	0.0	1.0
Nandi Central	22.4	1.3	4.6	1.1	6.1	1.1	0.2	1.0	0.2	1.0	12.6	1.1	0.9	1.0	0.0	1.0	14.3	1.2	13.0	1.1	6.1	1.3	0.0	1.0
Rarieda	20.0	1.3	11.0	1.2	8.0	1.1	3.0	1.0	1.1	1.0	31.0	1.4	0.0	1.0	0.0	1.0	10.0	1.2	4.0	1.0	0.0	1.0	0.0	1.0
Nandi North	17.3	1.2	3.1	1.1	0.0	1.0	0.8	1.0	0.4	1.0	12.7	1.1	0.8	1.0	0.4	1.0	14.6	1.2	5.4	1.0	2.3	1.0	0.0	1.0
LSD $p < 0.05$	18.1	0.3	9.5	0.1	14.5	0.2	3.0	ns	8.9	0.1	11.8	0.2	5.2	ns	4.9	ns	12.4	0.2	9.5	ns	5.3	ns	ns	
Short rains Homa Bay	84.4	2.2	25.6	1.4	40.0	1.6	1.9	1.0	9.4	1.1	30.0	1.4	7.5	1.0	0.0	1.0	11.9	1.2	1.3	1.0	5.6	1.1	0.0	1.0
Busia	80.0	1.9	4.0	1.0	36.0	1.6	0.0	1.0	8.0	1.1	46.0	1.6	4.0	1.0	0.0	1.0	6.0	1.1	0.0	1.0	4.0	1.0	0.0	1.0
Rongo	80.0	2.1	21.1	1.2	32.7	1.7	0.4	1.0	10.8	1.2	21.9	1.3	2.7	1.0	0.4	1.0	10.0	1.1	1.9	1.0	7.3	1.1	0.0	1.0
Bondo	77.4	2.1	17.4	1.2	27.9	1.7	0.0	1.0	3.7	1.0	29.5	1.4	0.5	1.0	0.0	1.0	16.3	1.2	0.0	1.0	5.3	1.1	0.0	1.0
Nandi South	62.5	2.0	7.5	1.1	15.0	1.2	0.0	1.0	2.5	1.0	55.0	1.8	0.0	1.0	2.5	1.0	32.5	1.5	0.0	1.0	2.5	1.1	0.0	1.0
Vihiga	24.5	1.3	4.5	1.1	4.5	1.1	5.0	1.0	0.5	1.0	33.0	1.4	1.0	1.0	0.5	1.0	42.5	1.8	1.0	1.0	4.5	1.1	0.0	1.0
Butula	68.0	1.9	4.0	1.0	7.0	1.1	1.0	1.0	3.0	1.1	42.0	1.5	6.0	1.0	0.0	1.0	4.0	1.1	0.0	1.0	6.0	1.1	0.0	1.0
Nandi Central	26.0	1.3	1.3	1.0	4.0	1.0	0.7	1.0	0.0	1.0	14.0	1.1	0.0	1.0	0.7	1.0	16.0	1.2	0.0	1.0	0.7	1.0	0.0	1.0
Nandi South	15.7	1.2	0.9	1.0	11.3	1.1	0.9	1.0	1.1	1.0	15.2	1.2	1.3	1.0	0.2	1.0	43.3	1.7	3.9	1.2	7.4	1.1	0.0	1.0
Rarieda	92.1	2.7	0.7	1.0	12.9	1.2	1.4	1.0	0.0	1.0	59.3	1.9	0.0	1.0	0.0	1.0	0.7	1.0	0.0	1.0	0.0	1.0	0.0	1.0
LSD $p < 0.05$	18.7	0.3	11.7	1.2	20.2	0.5	ns	ns	7.4	ns	19.3	0.3	4.9	ns	ns	ns	20.6	0.4	ns	ns	ns	ns	ns	ns

Severity was scored on a scale of 1–5; 1 (no symptoms) and 5; plants with very high infestation levels and severity of damage or wilted and dead plants

Mean incidence of foliage beetle (86.7 and 92.1%) and severity (2.2 and 2.7) was highest in Suba and Rarieda located in LM4 zones during the long and short rains, respectively (Table 3). Cultivars significantly ($p < 0.05$) influenced foliage beetle incidence and severity of foliar damage in Homa bay district in LM2 zone. Mean incidence (2.1) and severity (2.6) was lowest on improved, compared with local bean cultivars. Type of fertiliser used in planting beans significantly ($p < 0.05$) influenced foliage beetle incidence and severity in Nandi south, Bungoma and Siaya Districts. Mean incidence (22.0% and 48.2%) and severity (1.3 and 170) was lowest in fields planted with organic, compared with those planted with inorganic and without in fertilisers in Bungoma and Siaya districts. In contrast, organic fertiliser increased foliage beetle incidence (90.0%) and severity (2.0) in Nandi south (Table 4).

Leaf hopper incidence (31.7 and 59.3%) was highest in Rongo and Rarieda, located in LM1 and LM4 zones during the long and short rains, respectively (Table 3). Cultivar significantly ($p < 0.05$) influenced leaf hopper incidence in LM1 zones in Bungoma and severity in LM2 zones of Homa bay districts. Mean incidence was highest on improved (29.5%), compared with local (7.6%) cultivars in Bungoma. Mean severity was lower (1.3) on improved, compared with (1.5) on local bean cultivars in Homa bay district. Fertiliser type significantly ($p < 0.05$) influenced leaf hopper incidence and severity in Siaya district. Mean incidence (27.2%) and severity (1.3) was highest in fields grown using organic than in those without (Table 4).

Aphid incidence and severity varied significantly ($p < 0.05$) among the districts and agro-ecological zones during the long and short rains seasons. Mean incidence was highest (17.9% and 43.3%) in LM1 and LH1 zones in Bungoma and Nandi south districts during the long and short rains, respectively (Table 3). Mean severity (1.3 and 1.8) was highest in Bungoma and Vihiga districts during the long and short rains, respectively. Cultivars and cropping system significantly ($p < 0.05$) influenced aphid incidence and severity in Vihiga district. Improved bean cultivars had high aphid severity (1.4), compared with local (1.2). Intercrop had lower aphid incidence (18.3%) and severity (1.3) than monocrop (41.7% and 1.7). Fertiliser type significantly ($p < 0.05$) influenced aphid incidence in Nandi South areas. Significantly high aphid incidence (45.8%) was observed in the fields grown with inorganic fertiliser than those with organic (Table 4). Flower thrips incidence and severity varied significantly ($p < 0.05$) among the districts and agro-ecological zones during the long and short rains (Table 3). Mean incidence (34.1 and 36.0%) and severity (1.4 and 1.6) was highest in LM2 areas in Busia, compared with other zones during the long and short rains, respectively (Table 3).

Cultivar type significantly ($p < 0.05$) influenced thrip incidence and severity in Homa bay district. Mean incidence (9.7%) and severity (1.2) were lower on improved, compared with local cultivars (Table 2). Cropping system significantly ($p < 0.05$) influenced thrip incidence and severity in Busia district. Thrip incidence (12.5% and 44%) and severity (1.1 and 1.6) were significantly lower in monocrop than intercrop, respectively. Fertiliser type significantly ($p < 0.05$) influenced thrip incidence and severity in the Bungoma Vihiga and Siaya districts. Mean incidence (6.0 and 0.4%) and severity (1.1 and 1.0) were lower in fields grown using organic, compared with those without in Bungoma and Vihiga districts, respectively. In contrast, thrip incidence and severity (0.0% and 1.0), compared with (42.0% and 1.7), were lower in fields grown using combinations of inorganic and organic fertilisers applied, than in those fields without application in Siaya (Table 4).

Table 4. Mean incidence (%) and severity (scale 1–5) of foliage beetle, thrips, whitefly, pod borer, leaf hoppers, aphids, bean fly and bollworm in relation to varieties of common beans, cropping systems and types of fertiliser used in western Kenya, 2013.

Farm management Practices	District	AEZ	Bean fly incidence severity		Foliage beetle incidence severity		White fly incidence severity		Thrip incidence severity		Aphid incidence severity		Leafhopper incidence severity		Bollworm incidence severity		Pod borer incidence severity	
Cultivar																		
Improved	Bungoma	LM1	0.5	1.3	42.0	1.6	8.0	1.1	12.5	1.2	18.5	1.2	29.5	1.4	0.5	1.0	9.5	1.1
Local			1.3	1.0	32.5	1.4	2.5	1.0	21.3	1.4	16.3	1.3	7.60	1.1	0.0	1.0	1.3	1.0
LSD			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	16.8	ns	ns	ns	ns	ns
Fertility amendment																		
None			1.1	1.2	62.2	1.9	4.4	1.0	34.4	1.6	1.2	1.2	25.7	1.4	0.0	1.0	10.0	1.1
Inorganic			0.0	1.0	52.5	1.8	12.5	1.1	5.0	1.1	20.0	1.4	20.0	1.2	0.0	1.0	15.0	1.3
Organic			0.7	1.0	22.0	1.3	6.0	1.0	6.0	1.1	17.3	1.2	22.7	1.3	0.7	1.0	3.3	1.0
LSD			ns	ns	26.0	0.3	ns	ns	26.9	0.5	ns	ns	ns	ns	ns	ns	ns	ns
Cropping system																		
Intercrop	Busia	LM2	5.2	1.1	65.9	1.9	7.8	1.1	44.1	1.6	6.7	1.0	21.1	1.3	1.7	1.0	6.7	1.0
Mono			6.7	1.1	45.8	1.7	8.3	1.1	12.5	1.1	15.0	1.2	23.3	1.3	1.0	1.0	3.3	1.0
LSD			ns	ns	ns	ns	ns	ns	20.7	0.3	ns	ns	ns	ns	ns	ns	ns	ns
Fertility amendment																		
None			1.0	1.0	60.5	1.8	7.9	1.1	38.9	1.5	10.0	1.2	23.7	1.3	0.0	1.0	4.7	1.0
Inorganic			7.1	1.1	58.6	1.8	7.1	1.1	47.1	1.7	5.7	1.1	20.0	1.2	2.9	1.0	8.6	1.1
Organic			11.5	1.2	59.2	1.8	8.5	1.1	20.8	1.3	10.0	1.1	20.0	1.2	0.0	1.0	5.4	1.0
LSD			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.7	ns	ns	ns
Cultivar																		
improved	Homa bay	LM2	1.8	1.0	74.5	2.1	7.9	1.0	9.7	1.2	5.5	1.1	23.9	1.3	1.2	1.0	9.7	1.1
Local			0.0	1.0	88.8	2.6	31.3	1.5	47.5	1.7	10.0	1.1	38.8	1.5	3.8	1.0	17.5	1.2
LSD			ns	ns	ns	0.3	14.5	0.2	17.4	0.3	ns	ns	ns	0.2	ns	ns	ns	ns
Cultivar																		
improved	Nandi South	LH1	3.9	1.1	26.7	1.3	5.0	1.0	9.6	1.1	31.2	1.5	15.9	1.2	0.9	1.0	1.8	1.0
Local			20.0	1.6	26.1	1.3	6.7	1.0	18.9	1.3	36.7	1.7	10.0	1.1	1.1	1.0	5.6	1.0
LSD			10.9	0.4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cropping system																		
Fertility amendment																		
None			8.7	1.2	34.6	1.4	9.7	1.1	9.7	1.1	20.9	1.4	16.1	1.2	0.6	1.0	3.3	1.0
Inorganic			2.6	1.1	13.2	1.1	0.6	1.0	11.6	1.2	45.8	1.7	15.2	1.2	1.3	1.0	0.9	1.0
Organic			15.0	1.0	90.0	2.0	5.0	1.1	20.0	1.2	0.0	1.0	0.0	1.0	0.0	1.0	5.0	1.0
LSD			ns	ns	30.9	0.4	ns	ns	ns	ns	40.4	ns	ns	ns	ns	ns	ns	ns
Cultivar																		
Cultivar																		

improved	Vihiga	UM1	10.4	1.1	26.8	1.4	5.9	1.1	5.1	1.0	24.7	1.4	16.5	1.2	1.9	1.0	0.4	1.0
Local			7.5	1.1	22.9	1.3	13.3	1.2	5.0	1.0	13.3	1.2	15.8	1.2	0.8	1.0	2.5	1.0
LSD			ns	ns	ns	ns	6.2	ns	ns	ns	ns	0.2	ns	ns	ns	ns	1.8	ns
Cropping system																		
Intercrop			10.3	1.1	26.3	1.4	7.9	1.1	4.3	1.1	18.3	1.3	15.3	1.2	0.8	1.0	1.1	1.0
Mono			5.8	1.1	22.5	1.3	7.5	1.1	10.8	1.2	41.7	1.7	23.3	1.3	7.5	1.1	0.0	1.0
LSD			ns	ns	ns	ns	ns	ns	ns	ns	15.6	0.3	ns	ns	3.9	ns	ns	ns
Fertility amendment																		
None			14.1	1.2	24.7	1.3	8.8	1.1	10.6	1.1	21.7	1.3	10.6	1.1	0.6	1.0	1.8	1.0
Inorganic			3.8	1.0	25.0	1.3	8.8	1.1	8.3	1.1	19.4	1.3	18.8	1.2	0.6	1.0	1.6	1.0
Organic			8.9	1.1	28.5	1.4	8.1	1.1	0.4	1.0	27.0	1.5	14.8	1.2	1.1	1.0	0.4	1.0
Both*			18.1	1.3	23.8	1.3	4.3	1.0	0.6	1.0	17.5	1.2	20.0	1.3	5.6	1.0	0.0	1.0
LSD			9.6	0.1	ns	ns	ns	ns	8.9	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fertility amendment																		
None	Siaya	LM2	0.0	1.0	71.0	1.9	4.0	1.0	42.0	1.7	24.0	1.4	13.0	1.1	0.0	1.0	9.0	1.2
inorganic			0.0	1.0	96.3	2.2	12.5	1.1	15.1	1.3	6.3	1.1	12.5	1.1	1.3	1.0	17.5	1.2
Organic			0.0	1.0	48.2	1.7	26.4	1.3	11.8	1.1	13.6	1.2	27.2	1.3	0.9	1.0	17.3	1.2
Both			0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	10.8	1.0	2.5	1.2	0.0	1.0
LSD			ns	ns	23.5	0.3	15.8	Ns	26.2	0.4	ns	ns	10.8	0.2	ns	ns	ns	ns

Both*, combination of organic and inorganic applied at same time, severity score scale of 1–5; 1 (no symptoms) and 5; plants with very high infestation levels and severity of damage or wilted and dead plants

Golden wing moth caterpillar, *Plusia orichalcea*, incidence varied ($p < 0.05$) significantly among the districts and agro-ecological zones during the long rains (Table 3). Mean incidence was highest in Homa bay (7.2%) and Busia (4.7%) districts, compared with other areas.

Plant bug incidence varied ($p < 0.05$) significantly among the districts and agro-ecological zones, although severities were similar across the regions in the two seasons. Mean incidence (6.6% and 7.5%) was highest Siaya and Homa bay located in LM2 agro-ecological zones, compared with Rarieda and Vihiga district during the long and short rains, respectively (Table 3).

Pod borer incidence and severity varied ($p < 0.05$) significantly among the districts and agro-ecological zones during the long and short rains, respectively. Mean incidence (29.3 and 14.5%) was highest in Ndhiwa and Siaya, respectively district during the long rain season. During the short rains the incidence (10.8%) was highest in Rongo, compared with Vihiga, Rarieda and Nandi districts. The severity was highest (1.4) in Ndhiwa district than in other locations during the long rains (Table 3). Pod borer incidence was significantly ($p < 0.05$) influenced by cultivar type and cropping systems in Vihiga and Nandi South districts, respectively. The mean incidence (0.4%) was lower on improved, compared with the local (1.8%) cultivar in Vihiga district. Mono crop (0.6%) had a lower incidence than (3.9%) intercrop (Table 4).

Boll worm incidence and severity varied ($p < 0.05$) significantly among the districts and agro-ecological zones during the long rains, compared with other areas. Mean incidence (8.8%) and severity (1.1) was highest in Suba located in LM4 agro-ecological zone, compared with other areas. Fertiliser type significantly ($p < 0.05$) influenced boll worm incidence in Busia district. The incidence was significantly higher (2.9%) in farms grown using inorganic, compared with those without (0.0%).

Bean fly Ophiomyia spp. incidence varied ($p < 0.05$) significantly among the districts and agro-ecological zones during the long rains, compared with other areas. Mean incidence (13.0% and 12.1%) was significantly highest in Nandi Central located in UM3 and in Vihiga located UM1 zones during long rains (Table 3).

Cultivars significantly influenced ($p < 0.05$) bean fly incidence and severity in in Nandi South. Mean incidence (20.0%) and severity (1.6) was highest on local, compared with improved bean cultivars with mean incidence of (3.9%) and severity (1.1). Fertiliser type significantly ($p < 0.05$) influenced bean fly incidence and severity in Vihiga district. Mean incidence (3.8%) and severity (1.0) was significantly lower in bean crops grown using inorganic than in those without (Table 4).

Whitefly, *Bemisia tabaci*, incidence varied ($p < 0.05$) significantly among the districts and agro-ecological zones during the long and short rains. Its severity varied significantly among the districts and agro-ecological zones during short rains only. Mean incidence (15.5 and 25.6%) was highest LH1 zones in Nandi South and in LM2 zone in Siaya districts during the long and short rains, respectively (Table 3).

Cultivar type significantly ($p < 0.05$) influenced whitefly incidence in Vihiga district. Mean incidence (5.9%) was significantly lower on improved than on local cultivars (13.3%). Fertiliser type significantly influenced whitefly incidence in Siaya district. Mean incidence was higher (26.4%) in bean crops grown using organic fertiliser than those without (4.0%). Grasshopper incidence varied ($p < 0.05$) significantly among the districts and agro-ecological zones during the long rains. Mean incidence (12.9%) was significantly highest in Ndhiwa located in LM3, compared with Siaya, Homabay, Bondo, Bungoma and Rarieda districts (Table 3).

Flower beetle incidence was (2.8%) during the long rains and (0.2%) in the short rains. Web worm, *Lamprosema indica*, was found in 11.5% and 1.6% of the sites during the long and short rains, respectively (Table 3). It was found in bean fields in Rarieda, Bondo, Siaya, Bungoma, Ndhiwa, Busia, Vihiga and Homa bay during the two seasons. Mean incidence was highest (6.2%) in Rongo districts during the short rains, although the incidence did not vary significantly among the districts and agro-ecological zones (Table 3).

There were significant seasonal differences in the incidence of foliage beetle, flower thrips, leafhopper, aphids, bean fly and *Spodoptera*. Significantly high foliage beetle incidence (52.9%), thrips (17.8%), leaf hopper (29.7%) and aphids (22.6%) was observed on plants during the short rain than in the long rains season. In contrast, there was high incidence of bean fly (7.2%) and, *Spodoptera* (2.9%) during the long rain season (Figure 2).

There was significant interaction between season and agro-ecological zones in the incidence of foliage beetle, thrips, leafhopper, aphids and *Spodoptera* insects on common beans, as shown in (Table 3).

Thrip incidence was higher LM2 than UM1 during both seasons. Bollworm incidence was higher in LM4 than UM1 during the long rains. The opposite was the case during the short rains. Leaf hopper incidence was higher in lower midland zone (LM4), compared with the upper midland zone (UM1) in both seasons. The incidence of semi-looper although low was highest in LM3 and UM2 zones than other areas during long rains.

Aphid incidence was higher in LM1 (16.5%) zone during long rains and in UM1 zone (40.8%) during the short rains, compared with other areas.

Results and discussion

The study has demonstrated variation in abundance and occurrence of insect pests of common beans in different agro-ecological zones. The species of insect recorded on legumes were foliage beetle, bean fly, leafhoppers, aphids, pod borers, a host of plant sucking bugs, thrips, whitefly, semi-looper, leaf worm, web worm, variegated grasshopper, bollworm, grey weevil, flower beetle and stripped bean weevil.

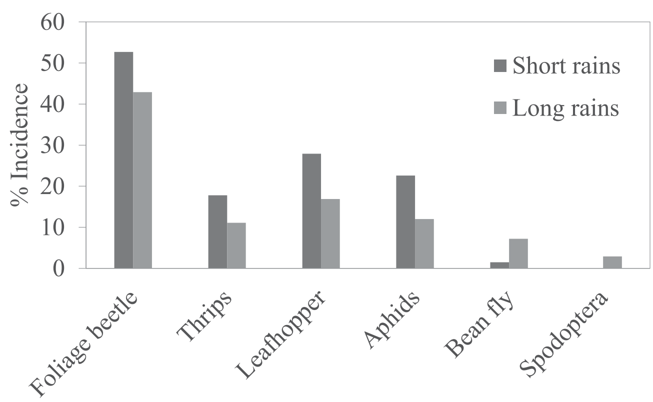

Figure 2. Mean incidence (%) of foliage beetle, thrips, leaf hopper, aphids, bean fly and webworm on common beans in western Kenya in the two seasons, 2013.

Many of them have been reported to be major causes of yield loss on legumes (Wortmann et al. 1998; Nampala et al. 2002; Minja 2005; Egho 2011). Foliage beetle, leafhoppers, whiteflies, pod borers, thrips were found attacking bean plants in all the districts and agro-ecological zones, but were more prevalent in lower midland agro-ecological zones (warm subhumid), compared with the upper midland and highland zones. This is consistent with past findings and reports that support the argument that environment is a major factor affecting the distribution of biotic stressors on legumes in Sub-Sahara Africa (Allen et al. 1996; Wortmann et al. 1998; Egho 2011). The incidences and severity of foliage beetle leaf hopper, plant bugs, flower thrips and whitefly and *Spodoptera* were higher in the lower midland agro-ecological zone than in upper midland zones.

The lower midland agro-ecological zones are characterised by warm humid climate that probably favour the rapid increase of the insect pest population and damage (Jaetzoldt et al. 2009). Bean foliage beetle was widespread in distribution and was found in all the districts and agro-ecological zones of western Kenya. According to Minja (2005) and CABI (1987), there are two species of bean foliage beetles that attack cow pea, common beans and other legumes and vary in their range of distribution based on altitude. *Ootheca mutabilis* prevails in the lower altitude areas, whereas *O. bennigseni* prevails in high altitude environments. The other explanation for current higher incidence of foliage beetle outside it traditional range of habitat in Upper midland zones is probably a consequence of climate change.

The incidence of aphids, bean fly and semi-looper was more prevalent in upper midland zones, compared with other areas, whereas leafhopper was more abundant in warmer lower midland LM4 zone in both seasons, compared with the other zones. The different agro-ecological zones vary in farming practices, population density, soil types, relative humidity, temperature and rainfall regimes (Jaetzoldt et al. 2009). These factors especially rainfall, temperature and farming practices, such as types of varieties of beans and soil fertility amendments technologies, affect insect pest population increase and subsequent damage. The other explanations for the high incidence and abundance of aphids, bean fly and semi-looper in the cooler upland and areas, compared with low altitude areas is probably owing to the presence of more alternative host plants in upper midland (Nderitu and Buruchara 1997; Mwangombe et al. 2007). These findings seem to disagree with the general view that abundance of aphids and other insect pests is influenced by increase in temperature (Kocourek et al. 1994; Kocmánková et al. 2009).

Upper midland agro-ecological zones are also characterised by high population and small parcels of land that have been depleted of nutrients, on account of nutrient mining, leading to poor performance of crops. Letourneau (1994) had reported increase of bean fly problem in densely populated areas that was associated with depletion of soil nutrients leading to weak plants that are susceptible to attack by bean fly and root rot disease complex.

There were differences in the level of insect pest's incidence during long and short rains, as well as severity of attack of bean plants. Pod borers, plant bugs, semi-looper, grass hopper and bean fly were more abundant during the long rains whereas foliage beetle, aphids, whitefly, leafhopper and thrips were more abundant in the short rains. Similar variation in the seasonal abundance of insect pests on legumes has been reported before. Nampala et al. (2002) reported a higher infestation of cowpea by pod sucking bugs during the long rains in Uganda. Bean stem maggot or bean fly population abundance and incidence was reported to be more during the short rain than in long rains in a survey conducted in eastern Kenya (Mwangombe et al. 2007). Byabagambi (1998) had similarly reported more abundance and damage of bean fly and aphids on common beans during the long than short rains season in Uganda.

Improved bean varieties had lower incidence of foliage beetle, leaf hoppers and whitefly, compared with the local varieties in Homa bay, Siaya and Vihiga districts. Moderate levels of insect pest's resistance have been reported in some of the commercially grown bean varieties (Mueke 1975; Ampofo et al. 1995; Nderitu et al. 1997). The current findings are inconsistent by observations made by Ssekandi et al. (2016) who reported traditional landraces to be more resistant to bean fly than improved bean cultivars in Uganda. Intercropped fields had lower aphid incidence and severity in Vihiga district, but increased foliage beetle, whitefly, flower thrips and leaf hopper infestation in other areas. Ogenga-Latigo et al. (1992) reported reduced black bean aphid infestation in maize bean intercrop than monocrop. This was attributed to reduce or interference with colonisation of host plant and high population of natural enemies in the intercropped beans, compared with monocrop. These results also support observations by Kisetu et al. (2014) who reported more foliage beetle infestation in intercropped than monocrop in Tanzania.

The results reveal that application of inorganic fertiliser reduced the incidence and severity of foliage beetle, bean fly and flower thrips insect pests on legumes in Bungoma, Nandi South, Vihiga and Siaya districts. These results are similar with observations by Iruland et al. (2012) who reported lower bean fly and pod borer on French beans grown using organic fertiliser, compared with those grown without. The current observations are inconsistent to those made by Byabagambi (1998) who reported increased bean fly and aphid infestation in plants grown with inorganic fertiliser in Uganda and also by Ghallab et al. (2014) who showed that there was high population of thrips in bean plants receiving NPK. Whereas our results show that fertiliser had an effect on some of the bean pests, previous studies indicated that fertiliser application had no effect on bean fly infestation in Taita District, Kenya (Ochilo et al. 2013).

Conclusion

The study shows variation the incidence and severity of legume pest in different zones of western Kenya influenced by weather conditions, soil types, and varietal and management practices employed by farmers. Whitefly, flower thrip, leaf hopper and foliage beetle varied among legume varieties and the incidence and severity were lower on improved, compared with local land races. Intercropping reduced aphid and boll worm incidence, but increased flower thrip incidences in some areas. The results also reveal that application of fertiliser reduced bean fly, foliage beetle and flower thrips incidences in in areas having soils of depleted mineral nutrients, but increased boll worm and aphid incidences in some areas. The implication of these findings is that, for effective development of adoption of improved varieties, intercropping and soil fertility management are major components of integrated management of legume pests in western Kenya.

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