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Effects of Common Bean (*Phaseolus vulgaris* L.) Cultivars and Their Mixtures with Other Legume Species on Bean Foliage Beetle (*Ootheca spp*) Incidence, Severity and Grain Yield in Western Kenya

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Abstract Bean foliage beetle injury is a major constraint to common bean production. The objective of the study was to evaluate the effect of mixtures of bean cultivars and legume species on the bean foliage beetle incidence, severity of damage and grain yield of beans. Field experiments were conducted at four sites in Busia County in western Kenya in 2015. A total of 21 and 22 farmers participated during the long and short rains seasons respectively. The sites were located between 34° 40′ and 34° 22′ East longitude and latitude 0°10′ N 0° 20′ North and at the altitude ranging 1139 and 1265 m.a.s.l. Bean foliage beetle leaf damage incidence (74.5%) and pod damage incidence (77.6%) was significantly higher in the long than short rain season. Grain yield was significantly higher (2.2t ha^{-1}) in the long rains than (0.9t ha^{-1}) in short rains season. Foliage beetle incidence was significantly reduced by 15% in plots with mixed bean cultivars compared to monoculture. Severity of pod damage was reduced by 10% but the incidence of pod damage increased by 15.4% in plots of mixed bean cultivars during the long and short rain season respectively. Grain yield was 0.5 and 2.4t ha^{-1} in monoculture plots compared to 0.8and 2.2t ha^{-1} in plots of mixed bean cultivar during the long and short rain seasons respectively. Foliage beetle incidence was positively correlated to pod damage (r =0.2, p=0.0021). These results indicate that mixed cropping systems has potential in bean foliage beetle management. Combining such systems with use of resistant germplasm and proper cultural practices could reduce bean foliage beetle damage and increase bean yield.

Keywords: *common beans (Phaseolus vulgaris), bean foliage beetle, Ootheca spp., cultivar mixtures, IPM, Kenya*

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1. Introduction

Common beans (*Phaseolus vulgaris* L.) is the most widely grown grain legume, second to maize in importance as source of cheap protein and energy for most poor people in Sub Saharan Africa and also in the World [6,14,24]. They are also able to fix atmospheric nitrogen [22].

Bean Foliage Beetles (BFB), *Ootheca mutabilis* and *O. bennigseni*, [Coleoptera: Chrysomelidae] species are among the most important insect pests that attack the bean crop. Their abundance and significance have increased in the recent years primarily due to the rapid increase in legume production. They are widely distributed in Eastern Africa where they attack beans and other leguminous crops. BFB is very polyphagous and feeds on a wide range of crops mainly the Fabaceae family such as beans, green peas, cowpea, and soya beans. *Medythia quartena* [Coleoptera: Chrysomelidae] is another species of foliage beetle reported attacking legumes in Africa [12,18]. The larvae of the BFB destroy the root tissue and seedlings and adults feed on the youngest leaves of the newly planted beans and cause extensive defoliation, heavy infestation can cause complete crop loss. Seed losses as a result of *Ootheca bennigseni* damage ranges from 18% to 31% [21]. BFB are also vectors of some cow pea viruses including cow pea mosaic and mottle virus [21].

Modern agriculture depend to great extent on use of pesticides to cope with pest and disease problems [2,38] and the continuing production of new crop varieties with specific resistance genes alongside implementation of integrated pest management [29]. Despite these efforts, damage by BFB has remained high. Growing mixtures of varieties and species of legumes is common in Africa, where farmers cultivate more than one crop of different species or varieties together. It is an aspect of introducing heterogeneity into the farming systems based on the ecological principles and has the potential of providing pests and disease suppression in a sustainable manner [37,42]. Studies have also shown that the other benefits of mixed cropping include, improved soil fertility, weed control and yield stability [20,23,28,36], labour efficiency, land use and profit maximization [28,31]. Faced with crop losses from rice blast disease, farmers in Chinas Yunnan Province who adopted a system of growing diverse rice varieties improved their yield by as much as 89%. At the same time the blast was 94% less severe and reduced use of fungicides [42]. Diversity has potential of pest suppression in a sustainable manner although there is limited data on its effect on foliage beetle.

The objective of the study was to determine the incidence, severity of damage and population dynamics of bean foliage beetle adults on three common bean cultivars and their mixtures in western Kenya and relate insect densities to the different growth stages of these three cultivars. The study also examined the differences in pod and seed damage and grain yield among the three cultivars.

2. Materials and Methods

2.1. Study Area

The study was conducted at four sites of Busia county western Kenya. (Madola, Bujumba, Busire and Alupe). The experiment was planted in 21 and 22 farms during the long and short rain seasons respectively. The sites were selected using geographical positioning systems (GPS) to capture socio economic and environmental variability in the study area. The sites were located between 34° 7′ and 34° 20′ East longitude and latitude 0°10′ 0° 29′ South and at the altitude ranging 1139 and 1265 m.a.s.l. All sites have bimodal rainfall averaging between 900-1200 mm per annum. The long rains begin from mid- March to July and the short rainy season from mid -October to January. The soils in Busia county areas are shallow to moderately deep of low fertility and classified as Ferrallisols [13].

Three common bean *cultivars* (Rosecoco, KATX56, KK8) and Red Valencia groundnut and K80 cowpea legumes were used. The legumes were planted in rows at 0.45 × 0.15m interow and intrarow spacing respectively in plots measuring 10 × 10m. Diammonium phosphate (DAP) fertilizer was applied at the rate of 33 kg ha^{-1} instead of the recommended 50 kg ha^{-1} to minimize confounding effects on foliage beetle infestation on the treatments. The experimental design was randomized complete block (RCBD) with different fields acting as replicates.

The treatments were:

1. Option one (sole Rosecoco bean cultivar)
2. Option two (Mixture of three bean cultivars Rosecoco, KATX56 and KK8) planted together
3. Option three (Mixture of the three bean cultivars planted together with groundnut and cowpea in a balanced mixture within a plot).

The treatments were assigned randomly within the plots in each individual farmer fields.

2.2. Data Collection

Bean foliage beetle incidence, severity of damage and density were determined by sampling ten random plants in each treatment at the seedling, vegetative and pod formation stages in both seasons except for the long rains where sampling was only made at the vegetative and pod formation growth stages. Frequencies of occurrence of the bean foliage beetle were calculated after realizing the presence of *Medythia* spp during the short rain season. However the incidence, severity of damage and counts per plant were not separated out by species in the two seasons

The incidence was then expressed as percentage of plants with pests or symptoms of damage over total number of plants sampled from each field and plot. Severity of damage was assessed by scoring the plants based on whole plant observation on a scale of:

1 = No infestation or damage

2 = Light damage and infestation < 5% plant parts damaged or infested by pest, 1-5 counts of foliage beetle population.

3 = Average damage and infestation> 5 and < 50 % plant parts damaged, 6-9 medium population foliage beetle

4 = High infestation and damage > 50% plants parts damaged and severe defoliation or yellowing of plants, 10-15 foliage beetle

5 = Severe damage resulting in dead plants or with infestation level >15 insects per plant.

Counts of pod damaged by foliage beetle were taken from ten random plants before harvest and percent pod damage calculated for each option treatment and each variety within the treatment. Grain yield was determined by weighing seed from the two inner rows for each variety and treatment.

All the data were subjected to analysis of variance (ANOVA) using General Linear Model Procedures and correlation procedure (SAS, Institute, 1989). Data on percent incidence 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.

3. Results and Discussion

3.1. General Observations

Two BFB species were observed attacking the crop. The frequency of occurrence of *Ootheca* species was 18.9% compared to *Medithyia* species (81.1 %) in the farms participating in the experimentation.

3.2. Bean Foliage Beetle Incidence, Severity of Damage and Densities in Different Locations

BFB incidence and severity varied significantly ($p<0.05$) among the locations during the long and short rains. Mean incidence was highest in Madola (90.7% and 83.8%) compared to other locations during the long and short rains respectively. Mean severity was similarly highest in Madola (2.1 and 1.8) during the long and short rains respectively compared to other locations. Alupe location had the lowest (64.1% and 1.6) incidence and severity during the long and short rains respectively. BFB counts per plant were not significantly different ($P<0.05$) among the locations in both seasons. (Table 1).

Table 1. Effect of BFB Incidence, Severity of damage and Population Density in Different Locations during the Long and Short Rain Seasons 2015 in Western Kenya

	Long Rains			Short Rains		
Location	**Percent incidence**	**Severity of damage scale (1-5)**	**Mean no. of beetles per plant**	**Percent Incidence**	**Severity damage scale (1-5)**	**Mean no. of beetles per plant**
Madola	90.7a	2.1a	0.1	83.8a	1.8a	0.1
Bujumba	72.5b	1.8ab	0.1	71.7b	1.7b	0.1
Busire	69.1bc	1.7ab	0.2	66.4bc	1.7b	0.1
Alupe	61.9c	1.7b	1.1	64.1c	1.6c	0.1
LSD (p≤0.05)	6.8	0.1	ns	5.9	0.1	ns
CV %	29.8	21.4	278.8	65.2	25.6	173.4

Means in the same column followed by same letters are not significantly (p≤0.05) using LSD.

3.3. The Incidence and Severity of Pod Damage and Grain Yield of Beans in different Locations

Severity of pod damage was slight below a score of 2.1 on average with significant differences (p<0.05) observed among location during the short rain season. Modala had significantly high severity of damage (1.8) compared to Alupe location. Different agro ecological zones and altitudes have varying farming practices, population density, soil types, relative humidity, temperature and rainfall regimes [13]. Both Madola and Alupe sites falls within lower midland (LM_1) agro ecological zones, although Madola is located at a slightly higher altitude and is relatively wet compared to Alupe. Furthermore, it was observed that most farms in Madola location were planted to several legume species as part of legume up scaling initiatives by N2 Africa project in western Kenya and the fields were poorly weeded. These factors especially rainfall and temperature and cultivation of other legume species that serve as alternative food source for foliage beetle probably explains the high incidence in Madola compared to Alupe area that had more farmers growing groundnuts and may be the possible reason for lower beetle populations. It has been shown that variation in environmental conditions influence severity of pest and disease intensity on common beans (Wortmann *et al.*, 1989). Ogecha *et al.*, (2012) reported variation in bean stem maggot infestation and grain yield between the two locations and seasons recording higher bean stem maggot infestation and grain yield in Kisii compared to Kabete this was attributed to variation in soil fertility and farming practices. Mugo *et al.*, (2011) similarly reported variation in thrip abundance in different environments of Kenya. The results showed more prevalence of coffee thrips, *Diarthrothrips coffeae* (Williams) in upper midland zones, compared to lower mid land agro ecological zones. A study by Aderu *et al.*, (2013) reported variation in abundance of insect pest on Amaranths in different locations in Nigeria. They also observed significant relation between pest abundance with relative humidity and rainfall.

The incidence of pod damage by BFB varied significantly (p<0.05) among the locations during the long and short rains respectively. Pod damage severity also varied significantly among the locations during the short rain season. Mean pod damage incidence was highest (90.1 and 49.8. %) in Busire and Madola than in Alupe (60.5 and 23.8%) during the long rains and short rains respectively. Mean pod damage severity score was significantly higher in Madola (1.9) than in Alupe location during shot rain season (Table 2). Grain yield varied significantly (p<0.05) 3,129) among the locations during the long rains season. Mean grain yield was significantly higher in Busire (1.4 t ha^{-1}) during the long rains and in Bujumba (3.1t ha^{-1}) during the short rain season. The yields were significantly higher in the short rain season compared to the long rain season. This could be attributed to late planting during the long rain season as opposed to timely planting during the short rain season.

A general agreement exists among authors that adequate soil nutrients is critical requirements for high legume yields [29]. Madola location falls under Mumias sugarcane out growers' zone. Some of the farms had previously been contracted to grow sugarcane that might have led to depletion of soil nutrients whereas soils in Alupe are shallow with a hard pan layer of marram and generally of low fertility level and probably would explain the relatively low yield in the two locations.

Table 2. Effect of Pod Damage Incidence, Severity and Grain Yield at Different Locations during the Long and Short Rain Seasons, 2015 in Western Kenya

	Long Rains			Short Rains		
Location	**Percent Incidence**	**Severity damage scale(1-5)**	**Grain yield Tons ha^{-1}**	**Percent Incidence**	**Severity damage scale(1-5)**	**Grain yield Tons ha^{-1}**
Busire	90.1a	2.3	1.4a	31.9b	1.7bc	2.0b
Alupe	86.9a	2.3	0.3d	23.8c	1.6c	2.1b
Bujumba	76.7b	2.4	1.1b	39.5ab	1.8ab	3.1a
Madola	69.3b	2.4	0.6c	49.8a	1.9a	1.9b
LSD(p≤0.05)	9.4	ns	0.3	10.6	0.2	0.8
CV %	24.3	15	64.6	54.9	15.9	54.2

Means in the same column followed by same letters are not significantly (p≤0.05) using LSD.

3.4. The Incidence of Foliage Beetle, Severity, Density on Leaves in different Cropping Systems

Mixed cropping significantly (P<0.05) influenced BFB incidence during the long rains and severity of damage during the short rains. The incidence (85.1%) recorded and severity of damage (1.9) on Rosecoco monocrop was significantly higher than the bean mixtures during the long and short rains seasons respectively (Table 3).

These could be due to the increased diversity leading to increased colour shades and smell influencing the insect cues. These results are in line with those from other studies Ssekandi *et al.*, [37], who reported reduced pest infestation and damage in the mixed cropping systems compared to monoculture. This results, however is in disagreement by observations made by Kisetu *et al.*, [17] who reported more foliage beetle infestation in intercropped cowpea than monoculture in Tanzania. The reduced pest abundance in mixed cropping systems compared to monoculture have similarly been attributed to efficacy and abundance of natural enemies [30] and in differences in food or resource concentration that makes it difficult for the insect pests to locate the host plants (Hooks and Johnson., 2003).

3.5. The Incidence of BFB, Damage Severity, Density on Pods and Grain Yield in Different Cropping Systems

Mixed cropping had no significant (P0<0.05) effect on the incidence of pod damage and severity in both seasons. Grain yield was significantly (p<0.05) influenced by the cropping systems during the long rains season. Mean yield was highest in (0.8 and 0.7t ha^{-1}.) in plots having mixtures of the bean cultivars or bean mixed with other legume species respectively. Generally, the grain yields were higher in the short rains than in long rains and this could be attributed to timely planting in the short rain season (Table 4).

The yield recorded in the two seasons was above average ranging from 0.5 to 2.4t ha^{-1} compared to national average 0.55t ha^{-1}. This could be due to low soil fertility conditions that are inherent in the area of the study, poor weeding by the participating farmers, abnormally wet weather conditions that provided conducive conditions for disease development. This observation is also corroborated by One Acre Fund report (2015) who recorded reduced yield, way below expected from the evaluation trial of bush bean varieties that was conducted in the same period.

Grain yield were higher in monoculture, suggesting increased diversification may compromise overall productivity probably due to competition. According to Sastawa *et al.*, [35], more complex mixed cropping systems led to reduction of soybean pests but decreased yield which they attributed to competition and shading by the intercropped plants. Mulumba *et al.*, [23] measured the effect of crop varietal diversity on pest and diseases incidence in farmers' fields in four agro ecological areas of Uganda and found that average levels damage by pest and disease and incidences decreased on crops with higher levels of diversity in production systems.

These results similarly corroborate those from other studies (Nyasani *et al.*, 2012, Nderitu *et al.*, 2009) who reported reduced thrip infestation in mixed cropping systems compared to monoculture. However these results indicate that mixed cropping did not reduce damage on the pods by foliage beetle, unlike the observations made by Nderitu *et al.*, (2009) who reported reduction of thrip damage in intercropped plots compared to sole plots that resulted in higher percent of marketable pods of snap beans.

Table 3. Effect of Mixed Cropping on BFB Incidence, Severity of Damage and Population Density on Bean Leaves during the Long and Short Rain Seasons, 2015 in Western Kenya

	Long Rains			Short Rains		
Cropping system	**Percent Incidence**	**Severity damage scale(1-5)**	**Mean no of beetles per plant**	**Percent Incidence**	**Severity damage scale (1-5)**	**Mean no of beetles per plant**
Rosecoo bean Monocrop	85.1a	1.9	0.1	79.2	1.9a	0.1
Mixture of three* bean cultivars	72.9b	1.8	0.1	72.5	1.7b	0.1
A Mixture of bean cultivars, groundnut* and cowpea*	72.4b	1.8	0.1	70.5	1.7b	0.1
LSD(p≤0.05)	5.9	ns	ns	ns	0.1	ns
CV %	33.3	23.1	279.9	66.4	26.2	173.6

Means in the same column followed by same letters are not significantly (p≤0.05) using LSD. * Bean cultivars: Rosecoco, Katx56 and KK8, cowpea k80 and groundnut Red Valencia.

Table 4. Effect of Mixed Cropping on Pod Damage Incidence, Severity of Damage and Grain Yield during the Long and Short Rain Season 2015 in Western Kenya

	Long Rains			Short rains		
Cropping system	**Percent incidence**	**Severity damage scale(1-5)**	**Grain yield Tons ha^{-1}**	**Percent incidence**	**Severity damage scale(1-5)**	**Grain yield Tons ha^{-1}**
Rosecoco planted sole	69.9	2.3	0.5b	31.2	1.7	2.4
Mixture of three bean cultivars*	77.9	2.3	0.7a	34.6	1.7	2.2
Mixture of bean cultivars*, groundnut* and cowpea*	79.7	2.3	0.81a	37.9	1.8	2.2
LSD (p≤0.05)	ns	ns	0.2	ns	ns	ns
CV%	25.4	14.9	81.6	61	16.8	57.2

Means in the same column followed by same letters are not significantly (p≤0.05) using LSD. * Bean cultivars: Rosecoco, Katx56 and KK8, cowpea k80 and groundnut Red Valencia

4. Conclusion and Recommendation

The study shows variation in locations season and mixed cropping systems in foliage beetle infestation, damage and very low population. Selections of common bean varieties that are less susceptible or have tolerance to insect pests and increasing diversification of common bean cultivars or species have potential in integrated management of common bean pests in regions. Future research efforts should focus on identifying a suitable plant arrangements and spacing in the mixed cropping systems that will lead to improved yield. The effect of mixture did not come out clearly hence there is need to repeat the experiment under high level of infestation. These results indicate that crop diversification has potential in foliage beetle and is a practice that is already being widely used in Africa. Combining such systems with use of resistant germplasm and proper cultural practices could reduce foliage beetle damage and increase yield.

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