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Farmers' knowledge and perception of grain legume pests and their management in the Eastern province of Kenya

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A B S T R A C T

Grain legumes play an important role in community livelihood and in the national economy in Kenya. Unfortunately, in many African countries, production doesn't satisfy the demand in grains due to various constrains. Understanding farmers practices and behavior in the management of grain legume pests is a crucial step in the development of sustainable management strategies. A total of 216 farmers were surveyed in eight districts of eastern Kenya to evaluate farmers' knowledge and perceptions of grain legume pests; to examine current pest management practices, and to identify other production constraints. Grain legumes are grown by a wide age-group of farmers, with both genders equally represented. Chemical control remains the main pest management strategy, and, to ensure pesticide effectiveness, farmers also use increased application rates, chemical alternation, frequent application and mixtures of chemicals. While farmers used other control measures, they showed only limited interest in biological control. The majority of the farmers had experience in grain legume farming and were able to identify the major pests, which were the legume flower thrips *Megalurothrips sjostedti* Trybom, the cowpea aphid *Aphis craccivora* Koch and the legume pod borer *Maruca vitrata* Fabricius. Our survey revealed that education and proximity to extension services contributed significantly to farmers' knowledge of grain legume pests, suggesting the need to provide continuous training and capacity building on integrated pest management in grain legume farming. The study also suggests integration of other pest management strategies such as the use of early maturing varieties, biopesticides and biofertilizer to reduce the use of chemical for sustainable pest management.

1. Introduction

Food and nutritional security through diversification of African smallholder production systems is an important requisite for sustainable development in Africa (Heidhues et al., 2004). Grain legumes complement the nutritional value of cereals and enable the sustainable intensification of farming systems through nitrogen fixation, extending land cover, and nutrient utilization by fitting into a wide range of intercropping configurations (Bressani, 1985; Broughton et al., 2003; Tarawali et al., 1997). In Sub-Saharan African countries (SSA), grain legume cultivation directly benefits women who are usually the primary cultivators of these crops and are employed in small scale processing, preparation, and marketing of foods derived from these crops (CGIAR, 2012). Common beans *Phaseolus vulgaris* L., cowpea *Vigna unguiculata* L. and pigeonpea *Cajanus cajan* L. are the three most important food grain legumes in Kenya (Kimani et al., 1994). The production of grain legumes has potential to alleviate food and nutrition security (CGIAR, 2012). Cowpea and common beans are the most popular sources of protein for many Kenyans, particularly for poor people who often cannot afford to buy meat (USAID, 2010).

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The Eastern province of Kenya represents a key area with high potential for grain legume production (Mergeai et al., 2001; Nagarajan et al., 2007). Although Kenya has two growing seasons for grain legumes, a significant number of farmers grow them once a year because of adverse climatic conditions. More than 90% of the total national production of grain legumes, especially cowpea, and approximately 89% of the total planted area is found in the Eastern region of the country (USAID, 2010). Annual production for Kenya is estimated at 65,941 and 436,279 tonnes for cowpea and common beans, respectively (FAO, 2012). This production volume however, is insufficient to meet demand, particularly for dry grains.

Grain legume production is constrained by several factors among which arthropod pests are considered the most important and pest attack occurs during all stages of growth (Abate and Ampofo, 1996; Omongo et al., 1997; Singh and Van Emden, 1978). The diversity of legume pests dictates that a single control strategy is unlikely to produce satisfactory control in a sustainable manner. The goals and values of long-term sustainability must be reflected in combinations of practices and methods consistent with an individual farmer's resources, including technical know-how and farming practices (Ikerd, 1993). Unfortunately, smallholder farmers in developing countries are resource-constrained, and this limits their capacity to pursue the goals of sustainability.

Pest management practices in traditional legume cropping systems are mainly based on chemical sprays combined with some cultural practices such as intercropping with maize *Zea mays* L and crop rotation (Ajeigbe et al., 2010). Integrated pest management (IPM) has long been proposed as the future for sustainable crop production (Pretty and Bharucha, 2015). However, failure by farmers to correctly diagnose pest problems, knowledge of the exact chemical dosage to use, and limited access to external inputs are likely limiting factors that hinder adoption of effective IPM (Midega et al., 2012; Parsa et al., 2014). Farmers still rely on the use of chemical pesticides despite the fact that these are toxic to the environment (Khan and Damalas, 2015a; Khan et al., 2015).

The IPM concept requires new ideas through knowledge of biological interactions and information on the crop and the surrounding environment (Adati et al., 2008) as well as understanding farmers' knowledge and perceptions on the pest constraints and IPM (Nwilene et al., 2008). Therefore, documenting crop protection practices is crucial in the development of sustainable pest control strategies in grain legumes. Hence, the objectives of the study were: (i) to evaluate farmers' knowledge and perceptions of grain legume pests; (ii) to examine farmers' current pest management practices in grain legumes; and (iii) to identify other grain legume production constraints that would impact grain legume productivity in eastern Kenya and the livelihood of the small land holder farmers in Sub-Saharan African countries.

2. Methodology

2.1. Study sites

The study was conducted between April and June 2013 in the main grain legume growing areas in eight districts of the Eastern province of Kenya. These were Embu-East, Machakos, Makueni, Masinga, Mbeere-North, Mwingi, Mwingi-Central and Nzambani (Fig. 1). These sites are located in lower midland, semi-arid agroecology zones that range between 500 and 1200 m above sea level and are characterized by erratic bimodal rainfall with an average annual rainfall of 640–1000 mm (Nagarajan et al., 2007). The main cropping systems comprise cereal crops such as maize *Z. mays* L., sorghum *Sorghum bicolor* L., and pearl millet *Pennisetum glaucum* L. that are generally grown in mixed stands and intercropped with a range of legumes, including common beans *Phaseolus vulgaris* L., cowpea *Vigna unguiculata* L., and pigeonpea *Cajanus cajan* L.

2.2. Data collection

The surveys were conducted through household interviews using a semi-structured questionnaire methodology adapted from Midega et al. (2012). A total of 216 farmers were interviewed by seven teams of trained enumerators. Farmers were selected with the help of Agricultural Extension informants who were also recruited as enumerators. Each team consisted of two enumerators and one of the team members was knowledgeable of the local language and familiar with the targeted study area. The questionnaire was pretested and interviewers translated the questions into the local language, but the responses were recorded in English. Farmers' knowledge of grain legume crop pests was scored by displaying a pictorial guide showing the pest and its damage to facilitate pest recognition by the interviewed farmer.

2.3. Data analysis

For all data, descriptive statistics (means, frequencies and percentages) were calculated. To examine the socio-economic characteristics of the rural households and the differences between districts, gender, and education levels with regard to the perceptions of pests and their management practices, Chi-square tests and one-way analysis of variance (ANOVA) were conducted using JMP statistical software version 5 (SAS, 2002). Significance level was set at 0.05 and means were separated by Tukey HSD test. To evaluate the knowledge of farmers on grain legume crop pests, we considered (1) the farmers' personal characteristics (age, gender, formal education, legume growing experience, and income), (2) exposure to sources of information about pest management and method of control practiced, (3) the perceptions of pest importance for the different grain legume pests; the variable was in terms of crop attack (i.e. no damage, some damage and significant damage), (4) farmers' knowledge of legume pests; this variable was measured using a score from 0 to 3 as follows: a farmer who could not mention a legume pest by a name, description or type of damage was given a score of zero; (i.e. no knowledge = 0); a farmer who gave the name of only one pest, one feature and one type of damage caused by the pest was given a score of one; (i.e. low knowledge = 1); a farmer who was able to give the name of two pests, describe at least one feature of each pest and at least one type of damage caused by the pests was given a score of two; (i.e. medium knowledge = 2). A farmer who was able to name three or more pests, describe one or more features of each, and identify at least one type of damage caused by each pest was given a score of three (i.e. high knowledge = 3). All the categorical and ordinal parameters were compared with the reference district (i.e) Nzambani. Nzambani was selected due to its excentric location with the other growing areas and also with extension services facilities (Fig. 1).

The dependent variable knowledge level was categorical and ordinal, thus we used multivariate ordered probit regression to analyse the data. In the context of this model, the dependent variable takes j ordered categories, where $j = 0$, if the knowledge score is zero, and $j = 3$ if knowledge is high. The observed ordered responses are assumed to be linked to a latent variable z_i that is normally distributed. This link is represented in the following equation: $z_i = \chi_i\beta + \varepsilon_i$, where x_i is a $n \times k$ matrix of explanatory variables, β is a $k \times 1$ vector of unknown coefficients to be estimated, and ε_i is a normally distributed random error term.

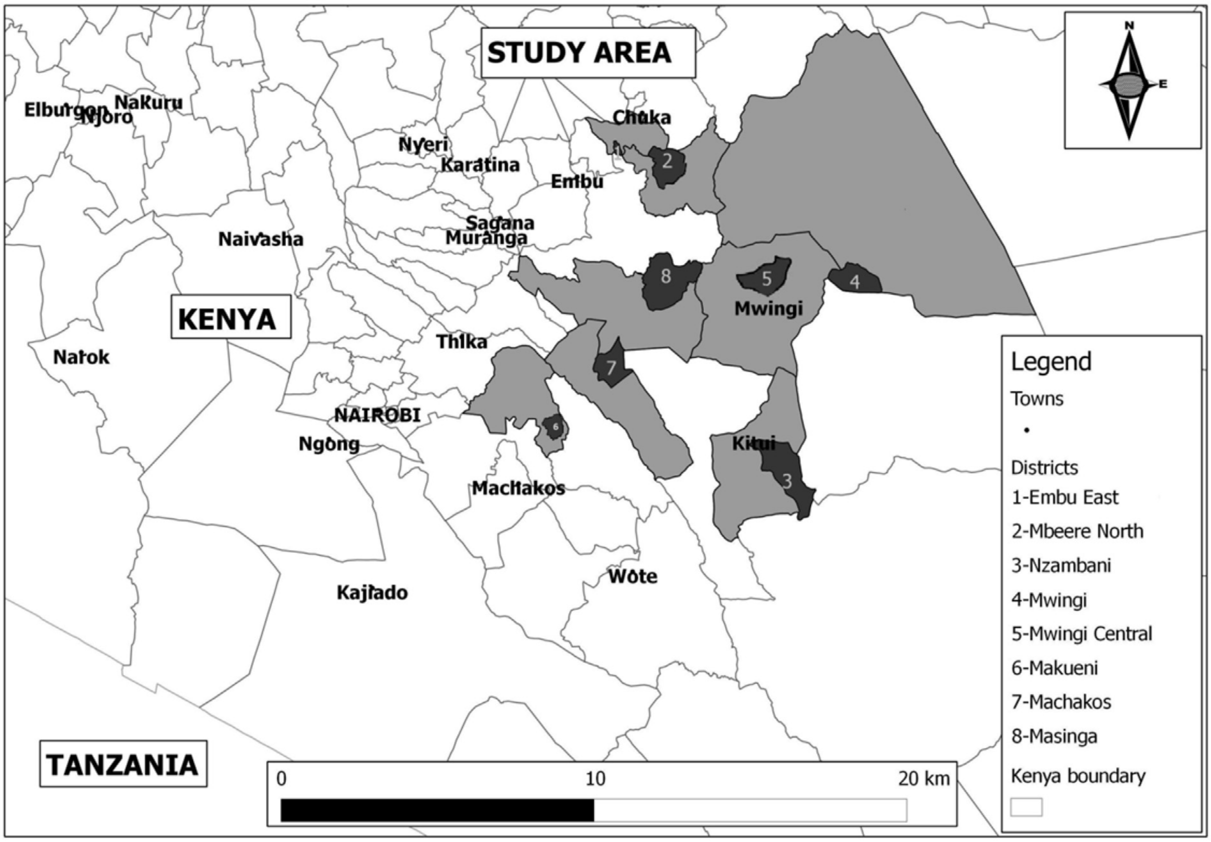

Fig. 1. Map of Kenya showing study districts and divisions in eastern province.

3. Results

3.1. Socio-economic characteristics, grain legume farming experience, yields and incomes of legume farmers in eastern Kenya

The farmers' age averaged 46.1 years with a minimum of 19 years and a maximum of 78 years. More than 44.4% were above 50 years-old, 37.1% were of the middle age category (31–50 years), and 18.5% were up to 30 years. There was no significant difference in the average age across districts (Table 1). Almost all the participants (95%) were the head of their families. There was no significant difference between gender across districts. Half of cowpea growers (51%) were women who grow the crop primarily for household food, and for whom crop sale occurs only in case of yield surplus. The majority of the respondents (0.79) had formal education. Among the respondents with formal education, 23.2% had ≤5 years of basic education, 22.0% had 6–10 years of education, 40.5% had 11–12 years of education, and 14.3% had >12 years of education. Almost one out of five respondents (22.2%) had no formal education. The overall average household size was 6.3 ± 0.41 individuals. Average household sizes varied significantly across districts particularly between Nzambani and Embu East showing the lowest household size and Mwingi the highest (Table 1). The most commonly produced grain legumes were cowpea (*Vigna unguiculata*) (99%), common beans (*P. vulgaris*) (88%), pigeonpea (*C. cajan*) (52%), green grams (*Vigna radiata* L) (23%) and horse gram (*Dolichos biflorus* L.) (2%). The average size of a grain legume farm is 1.2 ha, but this varied significantly across districts, ranging from 0.4 ha in Nzambani to 1.9 ha in Mwingi (Table 1). The majority of the respondents (93.5%) had more than five years experience in grain legumes cultivation. Actually the number of years cultivating grain legumes varied widely and significantly across districts, ranging from about 10 years in Masinga and Machacos to 27 years in Embu East. The interviewed farmers related yield loss to the level of pest attack. In 2012 for example, farmers estimated for cowpea a mean yield of 59.6–471.4 kg/ha with low levels of pest attack and a mean yield of 0.4–224.9 kg/ha with high levels of pest attack depending of the district (Table 1). For the same year, farmers estimated for common bean a mean yield of 64.3–845.5 kg/ha with low levels of pest attack and a mean yield of 2.5–237.4 kg/ha with high infestation levels depending of the district. The average annual income ranged from a minimum of USD 0.46 in Nzambani to a maximum of USD 272 in Makueni for cowpea and from a minimum of USD 1 in Nzambani to a maximum of USD 305.6 in Embu-East for common beans. In both cases, Nzambani district showed higher yield losses by pests. Overall, the mean annual incomes for 2012, obtained from the sales of grain legumes of cowpea and common beans, followed a similar trend with an average of USD 84.5 and USD 123.6 respectively (Table 1).

3.2. Pest management methods practiced by legume farmers in eastern Kenya

Almost all farmers (94%) experience grain legume pests. Table 2 shows that chemical control was the most commonly used pest control method (94%), with percentages varying across districts from 88% in Embu East to 100% in Makueni and Mwingi. Among the respondents, 19.9% of the total did not know the name of chemicals used to spray their grain legumes. The remaining 80.1% mentioned the use of broad spectrum pesticides from pyrethroids and organophosphorus family, with 38.8% reporting applying Karate 2.5 WDG (lambda-cyhalothrin 25 g/kg); 10.2% applying AlfaCyper-M EC

Table 1
Socio-economic characteristics, grain legume farming experience, yields and incomes of legume farmers in eastern Kenya.

Variables	Districts									
	Embu east	Machacos	Makueni	Masinga	Mbeere North	Mwingi	Mwingi central	Nzambani	Mean	F
Age (years)	50.6(3.00)a	42.0(2.54)a	44.9(2.50)a	44.8(2.91)a	43.3(3.11)a	48.5(2.61)a	48.4(2.83)a	46.6(2.55)a	46.1(2.76)	1.02
Gender (1 Male, 0 Female)	0.71(0.12)a	0.50(0.08)a	0.62(0.10)a	0.55(0.11)a	0.33(0.12)a	0.63(0.10)a	0.42(0.10)a	0.42(0.08)a	0.52(0.10)	1.39
F.Education (1 Yes, 0 No)	1.00(0.00)a	0.74(0.07)ab	0.58(0.10)b	0.80(0.09)ab	0.94(0.06)ab	0.71(0.09)ab	0.69(0.09)ab	0.86(0.05)ab	0.79(0.07)	2.66
Pri_Edu (1 Yes, 0 No)	0.53(0.12)a	0.14(0.05)bc	0.0(0.00)c	0.1(0.07)bc	0.44(0.12)ab	0.38(0.10)ab	0.12(0.06)bc	0.05(0.03)c	0.22(0.07)	7.08
Jun_Edu (1 Yes, 0 No)	0.12(0.08)ab	0.12(0.05)ab	0.15(0.07)ab	0.40(0.11)a	0.22(0.10)ab	0.04(0.04)b	0.23(0.08)ab	0.19(0.06)ab	0.18(0.08)	1.77
High_Edu (1 Yes, 0 No)	0.29(0.11)a	0.36(0.07)a	0.38(0.09)a	0.10(0.09)a	0.17(0.09)a	0.25(0.09)a	0.27(0.09)a	0.46(0.08)a	0.28(0.09)	1.79
Colle_Edu (1 Yes, 0 No)	0.06(0.06)a	0.14(0.05)a	0.04(0.04)a	0.20(0.09)a	0.11(0.08)a	0.04(0.04)a	0.08(0.05)a	0.16(0.06)a	0.10(0.06)	0.93
HH_size (Number of heads)	5.71(0.21)b	6.19(0.34)ab	6.77(0.43)ab	6.05(0.62)ab	5.94(0.37)ab	6.58(0.38)ab	7.92(0.70)a	5.34(0.26)b	6.31(0.41)	3.58
Pest mgt (1 Yes, 0 No)	0.41(0.12)a	0.05(0.03)c	0.00(0.00)c	0.10(0.07)bc	0.00(0.00)c	0.29(0.09)ab	0.04(0.04)c	0.07(0.04)c	0.12(0.05)	5.79
Legume farming (years)	27.9(2.91)a	10.8(0.98)c	14.4(0.80)bc	10.1(1.43)c	24.8(2.91)abc	17.58(1.95)abc	24.53(2.98)a	20.88(2.43)ab	19.0(10.2)	8.76
Land_ size (Ha)	0.99(0.18)b	0.91(0.07)b	1.09(0.09)b	1.71(0.13)a	1.02(0.18)b	1.92(0.09)a	1.23(0.10)b	0.38(0.04)c	1.15(0.11)	26.6
Cowpea farming (1 Yes, 0 No)	1.00(0.00)a	0.99(0.15)a	1.00(0.00)a	1.00(0.00)a	1.00(0.00)a	1.00(0.00)a	0.96(0.04)a	1.00(0.01)a	0.99(0.44)	0.67
Common beans farming (1 Yes, 0 No)	1.00(0.00)a	0.99(0.02)a	1.00(0.00)a	1.00(0.00)a	1.00(0.00)a	0.29(0.09)c	0.96(0.04)ab	0.81(0.06)b	0.88(0.02)	24.95
Cow pea yield (kg/Ha) least pest attack	154.7(37.1)bc	123.3(26.0)c	393.2(79.4)ab	59.6(11.5)c	325.7(101.0)abc	381.8(87.9)ab	471.4(89.5)a	125.5(17.8)c	254.4(56.2)	7.14
Cow pea (kg/Ha) High pest attack	24.9(4.84)b	37.3(6.7)b	60.9(10.8)b	24.2(4.24)b	85.5(30.04)b	224.9(67.6)a	96.6(34.6)b	0.4(0.35)b	69.3(96.9)	7.28
Common bean (kg/Ha) least pest attack	845.5(208.4)a	170.2(43.2)c	347.5(66.2)bc	64.3(26.5)c	758.0(205.9)ab	78.6(26.5)c	304.9(81.7)c	324.0(56.4)	362.0(423.0)	8.45
Common bean (kg/Ha) High pest attack	182(39.6)a	44.2(8.69)b	58.6(11.27)b	14.0(2.57)b	237.4(72.7)a	48.5(16.6)b	29.3(6.71)b	2.5(1.76)b	77.1(20.0)	12.67
Cowpea annual sales – Leg_Rev (USD)	69.3(12.0)c	49.8(13.2)c	272.7(22.4)a	136.2(19.9)b	46.5(6.73)c	45.2(4.02)c	55.5(25.4)c	0.46(0.07)d	84.5(13.0)	33.19
Common beans sales – Leg_Rev (USD)	305.6(48.7)a	36.6(6.4)c	255.5(19.9)a	228.5(19.9)a	122.4(32.6)b	7.0(2.77)c	32.2(20.2)c	1.00(0.10)c	123.6(18.4)	44.79

Mean (SE), df = 7, Means within a row followed by different letters are significantly different at $P = 0.05$ (Tukey HSD test).

Table 2
Pest management methods practiced by legume farmers in eastern Kenya.

Variables	Districts									
	Embu east	Machacos	Makueni	Masinga	Mbeere North	Mwingi	Mwingi Central	Nzambani	Mean	F
Experiencing legume pests	1.00(0.07)a	0.95(0.04)a	0.88(0.06)a	0.95(0.06)a	0.89(0.07)a	1.00(0.06)a	0.88(0.06)a	0.98(0.04)a	0.94(0.06)	0.73
Chemical control	0.88(0.08)a	0.93(0.04)a	1.00(0.00)a	0.90(0.07)a	0.89(0.08)a	1.00(0.00)a	0.96(0.04)a	0.98(0.02)a	0.94(0.04)	1.1
Biological control	0.00(0.00)a	0.00(0.00)a	0.00(0.00)a	0.00(0.00)a	0.00(0.00)a	0.00(0.00)a	0.00(0.00)a	0.00(0.00)a	0.00(0.00)	5.62
Cultural control	1.00(0.00)a	0.71(0.07)bc	1.00(0.00)a	0.95(0.05)ab	0.94(0.06)abc	1.00(0.00)a	0.65(0.49)c	0.12(0.05)d	0.80(0.04)	32.9
Physical control (weed removal)	0.76(0.11)a	1.00(0.12)a	1.00(0.00)a	0.00(0.00)b	0.78(0.10)a	1.00(0.00)a	0.31(0.09)b	1.00(0.00)a	0.74(0.05)	21.9
Knowledge of repellent plants	0.29(0.11)a	0.02(0.02)b	0.00(0.00)b	0.00(0.00)b	0.17(0.09)ab	0.00(0.00)b	0.12(0.06)ab	0.00(0.00)b	0.07(0.04)	5.15
Pesticide effectiveness	0.76(0.11)a	0.74(0.07)a	0.15(0.07)b	0.90(0.07)c	0.89(0.08)a	1.00(0.00)a	0.62(0.10)ab	0.95(0.03)a	0.75(0.07)	22.9
Mix pesticides	0.12(0.08)a	0.17(0.06)a	0.15(0.07)a	0.05(0.05)a	0.28(0.11)a	0.42(0.10)a	0.08(0.05)a	0.33(0.07)a	0.20(0.07)	2.69
Increase rates of insecticides	0.06(0.06)b	0.74(0.07)a	0.00(0.00)b	0.10(0.07)b	0.06(0.06)b	0.08(0.06)b	0.08(0.05)b	0.65(0.07)a	0.22(0.05)	24.7
Rotating chemicals	0.76(0.11)a	0.02(0.02)b	0.00(0.00)b	0.55(0.11)a	0.61(0.12)a	0.00(0.00)b	0.00(0.00)b	0.00(0.00)b	0.24(0.05)	37.2
Frequent spray	0.06(0.06)cd	0.05(0.03)cd	0.85(0.07)a	0.30(0.11)bc	0.06(0.06)cd	0.50(0.10)b	0.85(0.07)a	0.00(0.00)d	0.33(0.06)	35.9

Note: The figures in the table are the means of dichotomous data (Yes = 1 and No = 0) and represent the percentage (%) if multiply by 100. Mean (SE), df = 7, means within a row followed by different letters are significantly different at $P = 0.05$ (Tukey HSD test).

(alpha-cypermethrin 100 g/L), 8.7% applying Bestox 20 EC (alpha-cypermethrin 20 g/L), 7.8% applying Selecron 720 EC (profenofos 720 g/L), 6.5% applying Dimeton 40 EC (dimethoate 400 g/L), 5.1% applying Polythrin P 440 EC (profenofos 400 g/L + cypermethrin 40 g/L), 3.2% applying Trigger 5% EC (lambda-cyhalothrin 50 g/L) and 0.46% applying Agrinate 90 SP (methomyl 90%). Over 75% of farmer's claimed pesticide effectiveness; practices such as increased application rates, chemical alternation, frequent application and mixtures of chemicals were used by 27.8%, 25.9%, 22.7% and 19.9% of farmers, respectively. Cultural and physical control was also used to some extent. Among interviewed farmers some of them (7.0%) mentioned about the use of plant extracts with toxic or repellent properties. Among these plants, Mexican marigold *Tagetes minute* L., pepper *Capsicum annuum* L., neem *Azadirachta indica* A. Juss., aloe vera *Aloe secundiflora* Engl., basil *Ocimum basilicum* L. and wild sunflower *Tithonia diversifolia* Hemsl. are reported having repellent effect on insect pests. No use of biological control was reported in this study.

4. Factors determining farmers' level of knowledge of grain legume pests

The results of the ordered probit regression model (Table 3) showed that only education and location had a statistically significant relationship with farmers' knowledge levels of grain legume pests. However, the levels of primary and junior schooling education had no significant influence on farmers' knowledge, whereas high school and college education had positive and significant

Table 3
Factors determining farmers' level of knowledge of grain legume pests from an ordered probit regression analysis.

Variables	Coefficients		Marginal effects for different pest knowledge levels							
			No knowledge		Low knowledge		Medium knowledge		High knowledge	
	Coef.	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Gender	−0.213	0.174	0.018	0.015	0.029	0.024	0.027	0.024	−0.074	0.060
Age	0.009	0.007	−0.001	0.001	−0.001	0.001	−0.001	0.001	0.003	0.002
Primary education	0.384	0.283	−0.026	0.016	−0.047	0.032	−0.067	0.063	0.140	0.107
Junior education	0.095	0.278	−0.007	0.020	−0.013	0.036	−0.013	0.043	0.033	0.099
Higher education	1.038***	0.254	−0.067***	0.021	−0.118***	0.030	−0.191***	0.064	0.375***	0.090
College	1.822***	0.366	−0.057***	0.017	−0.124***	0.025	−0.449***	0.081	0.631***	0.085
Household size	−0.040	0.039	0.003	0.003	0.005	0.005	0.005	0.005	−0.014	0.014
Land area size (Ha)	−0.112	0.160	0.009	0.013	0.015	0.022	0.014	0.021	−0.039	0.055
Pest Management training	0.388	0.305	−0.024	0.015	−0.046	0.032	−0.072	0.074	0.143	0.118
Farming experience	0.290	0.350	−0.030	0.044	−0.042	0.054	−0.021*	0.012	0.093	0.102
Revenue from sale	0.0003	0.0006	−0.000	0.000	−0.000	0.000	−0.000	0.000	0.0001	0.0002
Embueast	−2.011***	0.456	0.504***	0.167	0.167***	0.052	−0.326***	0.118	−0.344***	0.041
Machacos	−0.461	0.298	0.049	0.041	0.067	0.046	0.029*	0.017	−0.146	0.085
Makueni	−0.685	0.459	0.089	0.086	0.102	0.071	0.007	0.055	−0.198*	0.105
Masinga	−0.675	0.458	0.089	0.088	0.101	0.071	0.002	0.060	−0.192	0.102
Mbeerenorth	−2.115***	0.384	0.539***	0.138	0.160***	0.051	−0.346***	0.096	−0.353***	0.039
Mwingi	−0.755*	0.413	0.103	0.084	0.113*	0.063	−0.004	0.061	−0.212**	0.089
Mwingicentral	0.006	0.360	−0.000	0.029	−0.001	0.049	−0.001	0.046	0.002	0.124
/cut1	−1.534	0.534								
/cut2	−0.856	0.528								
/cut3	0.780	0.533								
Log likelihood	−201.919									
Number of observations	216									
LR chi2(18)	110.25									
Prob > chi2	0.2145									

Statistically significant level: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$; (n = 216).

effect on growers' knowledge of grain legume pests. Although coefficients for the variables representing high school education and college education were positive, the marginal effect (ME) was only significant for high knowledge with ME = 0.375 and ME = 0.631 for high school and college education, respectively. Farmers with greater than five years of grain legume farming showed trends for having high level of pest knowledge (ME = 0.093) but this was not statistically significant. The coefficient representing the revenue gained from the sales of grain legumes showed trends to having a positive effect on high level of pest knowledge of grain legume pests, but again this was not statistically significant. The variables such as age (age), pest management training (pest_mgt), years of grain legume farming experience (leg_yrs) and revenue from sales of cowpea and common bean (leg_rev) showed trends to having a positive effect on the level of farmers' knowledge of grain legume pests, but they were not statistically significant. However, age (age), gender (gender), household size (hh_size), and farm size (farm_size) showed trends to having a negative relationship with the level of farmers' knowledge, but they were not statistically significant.

Farmers in Embu East and Mbere North were more knowledgeable about grain legume pests compared to Nzambani, i.e., the reference district. Although the coefficients for the variable representing Embu East, Makueni, Mbere North, and Mwingi district were negative, their marginal effect was only significant at high levels of knowledge (ME = −0.344, −0.198, −0.353, and −0.212, respectively). However, in Machakos the marginal effect was significant only at the medium level of knowledge (ME = 0.029).

5. Discussion

5.1. Socio-economic characteristics, grain legume farming experience, yields and incomes of legume farmers in eastern Kenya

Grain legumes are very important crops in Africa and our study showed that they are grown by a wide age group of both genders. This suggests that grain legumes have great potential to alleviate poverty as a cash crop (CGIAR, 2012). The majority of farmers (79.0%) had formal education but did not receive any extension services on pest management, which indicates limited knowledge on pest management. However practically all of them (97.2%) were growing grain legumes as main intercrops with maize and other cereals. Intercropping and rotation were commonly used for maintaining soil fertility, space utilization and diversification that can reduce pest damage. The majority of farmers grow grain legumes intercropped with maize and other cereals, whereas 2.8% of the respondents grew legumes as the sole crop. Similarly, most of the interviewed farmers (86.6%) practiced crop rotation as compared to continuous cropping (13.4%). Despite the relatively high number of years of grain legume farming (19 years), yields remained low in the region (400 kg/ha, with a loss of about 70–85%) compared to grain legumes yield standards (1500–3000 kg/ha). The low but highly variable yield of bean seeds reported by Kenyan' farmers may be explained as bean leaves may be also heavily consumed in African countries especially cowpea which is among the top three or four leaf vegetables in many parts of Africa (Barrett, 1990; Bittenbender et al., 1984). This fact is a key point of toxicological risk for people as the leaves receive the larger part of chemical pesticides from foliar sprays. Moreover USAID (2010) showed that despite the increase in area planted from around 130,000 ha in 2007 to about 148,000 ha in 2008, annual production of cowpea in Kenya had declined from about 83,000 metric tonnes (MT) to about 48,000 MT over the same period. There are many explanation to this situation. The average farm size (1.15 ha) is relatively small as compared to previous USAID reports (1.6 ha) in 2010, and this is believed to decline rapidly with the continuous sub-division of household farms resulting in uneconomical landholdings. Similar situations have been reported in other African regions. The financial status of smallholder farmers and the lack of financial assistance (e.g., access to loans) could also be a factor. However, the low yields observed in this study is also due to the lack of adequate pest control measures. Farmers correlated yield losses with pest attacks, with yields of cowpea and common bean of 254 kg/ha and 362 kg/ha, respectively, with a low pest pressure, and yield of 69 kg/ha and 77 kg/ha, respectively, for high levels of pest pressure. Yield losses can reach 100% if no phytosanitary measures are taken (Ekesi et al., 1998; Karungi et al., 2000; Singh and Van Emden, 1978). The grain legumes pest complex across the study districts included the legume flower thrips *Megalurothrips sjostedti*, the cowpea aphid *Aphis craccivora*, the legume pod borer *Maruca vitrata* and the pod-sucking bug *Clavigralla tomentosicollis* Stal, as has been reported elsewhere (Abate and Ampofo, 1996; Singh and Van Emden, 1978; Tamó et al., 1993).

5.2. Pest management methods practiced by legume farmers in eastern Kenya

The majority of interviewed farmers reported the effectiveness of chemical pesticides. They are using chemicals from the pyrethroid class of insecticides, such as alpha-cypermethrin or lambda-cyhalothrin, which have a broad spectrum of activity again pests. There are studies that justify reasonable use of chemical pesticides with other management methods (Cooper and Dobson, 2007). However several authors have shown negative effects on environmental quality and human health as well as on horticultural crops since they are generally not used properly by smallholder farmers (Ahouangninou et al., 2012; Ajayi et al., 2011; Ntow et al., 2006; Williamson et al., 2008). The use of chemical control alone does not guarantee effective control for all pests (Jensen, 2000; Ofuya, 1997; Toda and Morishita, 2009). They can be detrimental to beneficial fauna and cause resistance development (Ekesi et al., 1998; Oparaeke, 2006). The ineffectiveness of chemical control reported by 25% of farmers justified combination of practices such as increasing chemical concentration and frequent spraying. These practices increase the risk of human intoxication, especially when grain legume leaves are harvested with no respect of reentry period (Bon et al., 2014). Chemical alternation (with different modes of action) is recommended in IPM strategies to reduce the selection pressure on insect pest populations to slow down the development of insecticide resistance (Martin et al., 2005; Sow et al., 2015).

Farmers also use some cultural practices such as intercropping and crop rotation and majority of the farmers (77.8%) use hand tools to remove weeds, which is labor intensive. Intercropping systems can reduce pests damage and diseases by one of the plants acting as a visual barrier or repellent for a common insect pest or as an attractant for natural enemies such as predators or parasitoïds (Abate, 2000; Ampong-Nyarko et al., 1994; Karungi et al., 2000). Henriette et al. (2012) reported that crop rotation enhances pest and disease management in a sustainable way such that growers use less pesticides, thus decreasing both production costs and environmental impacts. In addition, crop rotation has a number of agronomic, economic, and environmental benefits compared to continuous cropping, such as improved soil structure with higher levels of organic matter and water supply, resulting in long term yield increase (Henriette et al., 2012).

Likewise, removal of weeds can positively influence crop yields by enhancing sprouting of crop seeds as well as reducing pest damage (Takim and Uddin, 2010). Tijani-Eniola (2001) reported that weeds can cause between 50 and 80% yield loss. Weeds can also act as reservoirs or alternate hosts for insects that further reduce yields in agricultural systems. Takim and Uddin (2010), reported that weeding greatly reduced the population densities of cowpea pests, such as thrips *M. sjostedti*, the pod borer *M. vitrata* but also useful insect such as the rove beetle (*Paederus sabaeus* Fabricius), while increasing cowpea aphid *A. Craccivora* population densities. Thrips and aphid are most important constrains to grain legume production in Eastern Kenya.

The use of biological control was very limited despite the fact that natural enemies have been widely documented for the major grain legume pests (Tamó et al., 2002). This could be due to a deficit of extension services on pest control, including the use of pesticides. Farmers did however mention the role of companion crops with repellent or toxic characteristics to disrupt the host location by the pests and improve abundance and activity of the pests' natural enemies, thereby delivering effective pest control (Khan et al., 2010).

5.3. Factors affecting farmers' knowledge of grain legume pests

Pest identification and recognition is crucial for a successful pest management program. Midega et al. (2012) reported that small farm holders have difficulties in pest recognition and the understanding of pest ecology. Similarly, Khan and Damalas (2015b) reported similar information in cotton production in the Punjab region in Pakistan. In this study, farmers were able to identify four important pests of grain legumes by describing them more than by giving the specific names of the pests. Our study showed that education can help farmers to understand and identify different pests on grain legumes. The level of farmer education as an impact on awareness and technology effectiveness (Abang et al., 2014). Educated farmers have higher score on reading labels of pesticides containers and taking precautions and proper pesticide application (Gaber and Abdel-Latif, 2012). In addition, farmers who received school education had more knowledge about the negative effects of pesticides on health and routes of contamination with pesticides. Moreover, Madisa et al. (2010) observed that educated farmers are generally more open to innovative ideas and new technologies that promote positive change. Age, pest management training and experience as well as revenue could influence farmers perception. On the other hand, age, gender, household size, and farm size do not necessarily influence the level of knowledge on pest recognition and management. Our study stresses the need for continuous training and capacity building on various aspects of grain legume farming.

The survey revealed that there was limited information available to farmers on pest control methods. Although data were not presented, 89.8% of the respondents declared never receiving any information on pesticide use and pest management, including, cultural, physical and biological methods of pest control. Those who reported receiving information on the use of pesticides mentioned various sources of information such as input suppliers (57.1%), government ministry of agriculture staff (38.9%) and fellow farmers (2.9%) and other sources e.g. media (mainly radio), farmer organizations and pesticide container labels. There is therefore a need to ramp up the capability of the farmers by providing information through appropriate channels on alternative pest control methods and by giving full attention to the poor extension system in order to enhance farmers' knowledge and pest management in grain legumes. Although this was a major concern for farmers, we have to consider that many poor farmers in Kenya cannot afford improved farming techniques. Apart from the insect pests, farmers experience many other challenges such are access to quality seed and erratic rainfalls.

Our study revealed that proximity to extension services can play a major role in farmers perception of grain legume pests and their management. Extension services may be a valuable source of information for farmers that can benefit from this service to improve their pest knowledge and management. For instance, the Kenya Agricultural and Livestock Research Organization (KALRO Embu) is closer to Embu East and Mbere North as compared to Nzambani and this may explain the difference in pest management strategies, yield and revenues.

6. Conclusions

Although chemical control remains the main control strategy of insect pests, grain legume farmers also use other cultural practices, but no biological control. The incidence of insect pests on cowpea production was well understood by farmers and our study revealed that education and proximity to extension services is crucial. It is believed that food supplies wouldn't be enough if no pesticides was applied due huge crop losses and shortfalls (Snelder et al., 2008). This situation reflects the conflict between intensive use of synthetic pesticides by smallholder farmers and both the risk of environmental degradation and sanitary risks for farmers and consumers.

Technology transfer approaches through participatory models may help farmers integrate new IPM management strategies including colored sticky traps for pest monitoring, use of entomopathogenic fungi (Ekesi et al., 1998), botanical pesticides (Oparaeke, 2006) and resistant varieties (Abudulai et al., 2006) that fits within their practice of intercropping. The role of natural enemies or companion crops needs to be researched in order to provide sustainable pest management strategies. Therefore, enhancing the performance of smallholder through promotion of sustainable farming coupled with provision of quality and timely support services, such as extension, is critical to adoption of good farming practices and future agricultural growth.

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