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Smallholder farmers' knowledge, perceptions and management of pea weevil in north and north-western Ethiopia

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ABSTRACT

Pea weevil (*Bruchus pisorum* L.) is one of the most serious insect pests of field pea (*Pisum sativum* L.) in Ethiopia. A survey of 400 farmers was conducted in four main pea-growing districts in north and north-western Ethiopia. The objectives were to assess farmers' knowledge and perceptions of pea weevil, to examine their current pest management practices and to identify challenges to pea weevil control, so that participatory integrated pest management for smallholder farmers in Ethiopia can be developed. The results revealed that most (71%) of the farmers surveyed had knowledge about pea weevil and were able to identify damaged seeds based on common visible symptoms of weevil infestation. However, most farmers did not know that pea weevil attacks plants in the field, but rather considered it a storage pest. The results also showed that farmers' cultural practices influence the incidence and spread of pea weevil and that most farmers did not check seed for pea weevil symptoms before planting. Only a minority of farmers (19%) harvested peas early and some harvested late, unintentionally promoting infestation and carryover of weevils. In addition, most farmers (74%) were not aware of the source and means of weevil spread on their farm and some did not clean up fallen and shattered peas during harvesting and threshing. The majority (63%) of the farmers surveyed relied on chemical insecticides, namely actellic dust and phostoxin, to treat harvested peas in storage. However, the results revealed a knowledge gap in that farmers were well aware of the problem of pea weevil, but lacked knowledge of cultural practices affecting pea weevil and of problems in the use of pesticides. This highlights the need for farmer training and for development of participatory integrated pest management methods for pea weevil.

1. Introduction

Field pea (*Pisum sativum* L.) is an important legume crop in Ethiopia, where it serves as an important source of dietary protein for humans. Furthermore, it improves soil fertility through its symbiotic nitrogen fixing ability (French, 2004; Messiaen et al., 2006). It is the second most important legume crop in Ethiopia, after faba bean (*Vicia faba* L.). Ethiopia is not only one of the main producers of field pea, but also one of the centres of diversity of this crop (IBC, 2008). According to a FAO report, Ethiopia produced 327,378 tonnes of field pea and ranked sixth in world field pea production in 2012 (FAOSTAT, 2012). Although there has been an increase in production of field pea in Ethiopia, the average yield is low compared with other field pea-producing countries (FAOSTAT, 2012), mainly due to low yield potential of landraces, poor management practices, insect pests and plant diseases (Ali et al., 2008; Fikere et al., 2010).

Insect pests are one of the main production constraints for field pea in Ethiopia. The pea weevil (*Bruchus pisorum* L.) is known to be an economically important pest that causes considerable crop losses in Ethiopia (Ali et al., 2008; Seyoum et al., 2012) and in most other field pea-growing countries of the world (Clement et al., 2000). Pea weevil was first reported in Ethiopia around the mid-1970s, in the northern part of the country (Abate, 2006), and then spread to other field pea-growing areas, mainly through seed exchange and trading (Teka, 2002; Ali et al., 2008). In hotspot areas of the country, up to 85% seed damage and 59% weight loss have been reported (Teka, 2002; Seyoum et al., 2012). In Ethiopia, field pea and other legume crops are grown predominantly by small-scale farmers and the damage caused by pea weevil has a bearing on the livelihood of these growers.

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Worldwide, the control of pea weevil currently relies predominantly on the use of insecticide spray in the field and on fumigation of harvested peas in storage (Horne and Bailey, 1991; Waterford and Winks, 1994; Baker, 1998; Clement et al., 2000; Seidenglanz et al., 2011). However, pesticides are unaffordable for the majority of small-scale farmers in Africa, where pesticide use is lower than in other parts of the world (Abate et al., 2000). Furthermore, due to increased concerns about the side-effects of pesticides on human health and the environment, there is growing demand to implement integrated pest management (IPM) for grain legume pests (Clement et al., 2000). IPM can significantly contribute to increasing average yield and reducing the use of pesticides (Pretty and Bharucha, 2015).

In Africa, where agriculture is mainly dominated by small-scale growers and characterised by diverse cropping systems, farmers often rely on traditional pest management practices to control insect pests (Abate et al., 2000; Abate, 2006). In order to develop an IPM programme for pea weevil that suits small-scale farmers in developing countries such as Ethiopia, information about farmers' knowledge, perceptions and management of the pest is crucial. Such information is also important in the development of participatory IPM for small-scale growers so that experiences can be shared (Norton et al., 1999). Farmers' knowledge and their pest management practices have been reported elsewhere for different cropping systems and associated pests, e.g. sorghum stem borers (*Busseola fusca* (Fuller)) and (*Chilo partellus* (Swinhoe)) (Tefera, 2004), vegetable insect pests and diseases (Obopile et al., 2008; Okonya et al., 2014), sugarcane stalk borer (*Eldana saccharina* Walker) (Cockburn et al., 2014) and cotton pests (Midega et al., 2012). However, despite its economic importance, such pertinent information is not available for pea weevil. Therefore, the objectives of the present study were to: determine farmers' knowledge and perceptions of pea weevil; examine farmers' current pest management methods; and identify challenges in pea weevil control, in order to develop participatory IPM for small-scale field pea growers in Ethiopia.

2. Materials and methods

2.1. Study sites

The study was conducted in four districts in north and northwestern Ethiopia, namely: Yilmana Densa (11°17′N, 37°43′E), Semen Achefer (11°50′N, 37°10′E), Ebinat (12°10′N, 38°05′E) and Farta (11°32′-12°03′N; 37°31′-38°43′E) (Fig. 1). These districts are among the main field pea-growing areas in the country and are hotspots for pea weevil attack (Seyoum et al., 2012). The districts are also known for growing a range of crops, including cereals, grain legumes and horticultural crops.

2.2. Data collection and sampling techniques

The data collection for the study was undertaken from October to December, 2014. It started with an informal, exploratory survey in order to get some basic preliminary information and insights on the study sites and the extent of the problems at hand. Experts in the respective District Bureau of Agriculture, development agents and some selected farmers were contacted and interviewed using a checklist.

Subsequently, a three-stage sampling procedure was used to select farm household respondents for a formal survey. In the first stage, eight potential districts were purposively selected on the basis of production of field pea and intensity of prevalence of pea weevil. The districts of Yilmana Densa, Semen Achefer, Ebinat and Farta were then selected using a random sampling technique so as to spread the selection across the districts and avoid biases. In the second stage, four *kebeles* (Peasant Associations, PAs) were purposively selected from each district using field pea production and degree of prevalence of pea weevil as criteria. The population of each PA was: Kotti 7201, Debre Mawie 9850, Agita Eyesus 11474, Diwaro 8972, Liben Danikura 8349, Denibola 6499, Sankra 17225, Yismala 9149, Gimman 9694, Debir 6483, Weniberoch 9754, Aquha 6437, Qolay Denigors 9377, Tsegur 6235, Kimir Dingay 8618 and Awizet 7820. In the third stage, 25 sample farm households were selected from each PA using a random sampling technique. Therefore, a total of 400 farmers from 16 PAs in the four districts were taken as samples for this study.

A structured questionnaire with different modules on household demographic characteristics, farm characteristics, volume of field pea produced, percentage of harvest damaged by pea weevil, knowledge and perceptions of pea weevil and pest control methods was used. The survey was administered by trained enumerators after pre-testing of the questionnaire for its validity. The household data were supplemented by information obtained from key informant interviews, focus group discussions with selected farmers and personal observations during the field survey.

2.3. Data analysis

Descriptive and econometric tools were used to analyse the data. Comparative statistical tools such as chi square (χ^2) and one-way ANOVA were used to compare the different socio-demographic and farm characteristics, knowledge on pea weevil and pest management practices of farmers across the selected districts. Many economic and agricultural publications show that logit and probit models are alternatives that can be employed to model choices which involve two completely mutually exclusive alternatives, such that when one is chosen, the other is totally left out (Gujarati and Porter, 2009). In this study, a binary logit model was used to estimate the likelihood of knowing about pea weevil. Similarly, Khan et al. (2014) used the binary logit model to determine factors influencing knowledge on Napier stunt disease, and Sharma et al. (2015) used a logit model to study factors influencing the decision to use pesticides in vegetable crops. Empirically, the model for estimating the determinants of probability of farmers' knowledge about pea weevil is described as follows (Verbeek, 2008):

$$\ln[P_x/(1-P_x)] = \beta_o + \sum \beta_i \ X_i \quad (1)$$

where P_x is the probability of an event occurring (1 if the farmer is knowledgeable about pea weevil; 0 otherwise); β_o is a constant term; βi is a coefficient associated with the explanatory variable x_i; and x_i is the explanatory variable.

As the ordinary coefficients from the logit model are not easily interpreted, marginal effects which measure the effect of a unit explanatory variable on the probability of a given outcome or dependent variable are also presented. Following Nyaupane and Gillespie (2010) and Greene (2012), the marginal effects of the continuous variables are estimated as:

$$\frac{\partial E[Y|x]}{\partial x_i} = f(\beta' x)\beta_i \quad (2)$$

where *f*(.) is the density function corresponding to the distribution function *F*(.)

Marginal effects for dummy variables are estimated using:

$$\Pr[Y=1|\overline{x}.,\ d=1] - \Pr[Y=1|\overline{x}.,\ d=0] \quad (3)$$

where *x* refers to the mean values of all continuous variables.

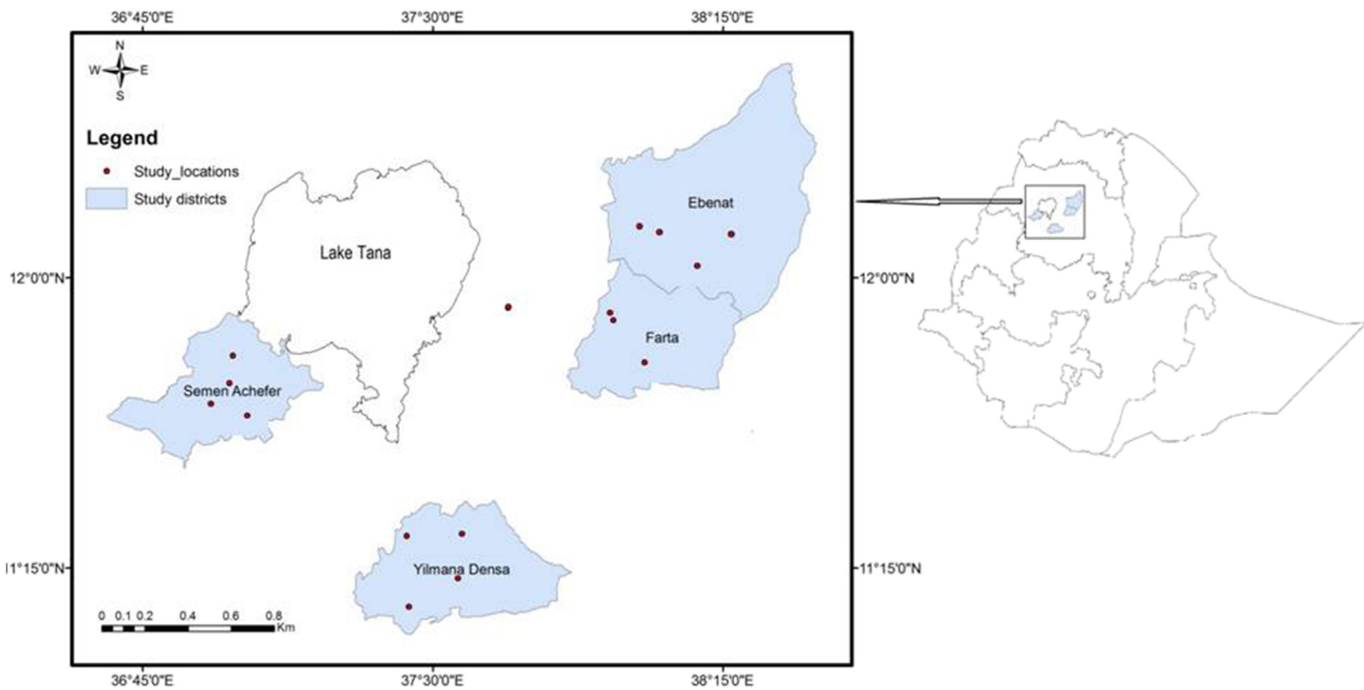

Fig. 1. Locations of the study areas in the districts of Yilmana Densa, Semen Achefer, Ebinat and Farta in north and north-western Ethiopia.

Farmers' knowledge about pea weevil was thus modelled as a dependent variable with a binary discrete choice taking 1 if the farmer was knowledgeable about pea weevil (if they knew and could properly identify the weevil and describe it) and 0 otherwise. Based on past empirical works (e.g. Midega et al., 2012; Khan et al., 2014; Sharma et al., 2015), a number of relevant independent variables which are likely to influence the likelihood of knowing about pea weevil were also identified. These variables are shown in Table 1.

3. Results

3.1. Socio-economic characteristics of the farmers

Most of the farmers (90%) surveyed in the four districts were male. The average age of the farmers varied significantly ($P < 0.01$) between survey districts, ranging from a mean of 40 years in Semen Achefer to 46 years in Farta. The mean age for all districts combined was 43 years, which was the middle age category (Table 2). The majority of the farmers (38%) had no formal education, but were able to read and write, while only about 33% had formal schooling (Table 2). The average household size of the farmers comprised about six individuals and on average the respondents had about 22 years of farming experience. The respondents in all four districts

Table 1
Description of variables used in the binary logit model.

Variable	Description	Variable type	Units
Dependent variable			
Pw_know	Farmers' knowledge of pea weevil	Dummy	1 = yes, 0 = no
Explanatory variables			
gender	Gender of the farmer	Dummy	1 = male, 0 = female
age	Age of the farmer	Years	Continuous
hh_size	The total household members	Persons	Continuous
hh_farmac	Total no. of household members involved in farm activities	Persons	Continuous
land_size	Total land area	Hectare	Continuous
land_fp	Size of area under field pea	Hectare	Continuous
farmexp	Farming experience	Years	Continuous
agriinfo	Access to agricultural information	Dummy	1 = yes, 0 = no
memcop	Membership of agricultural cooperatives	Dummy	1 = yes, 0 = no
fpyield	Yield of field pea	Kilogrammes	Continuous
fpincom	Income obtained from field pea sell	ETB	Continuous
pestprob	Pest problem	Dummy	1 = yes, 0 = no
pwfirstseen	Pea weevil first seen in the village/PA	Years	Continuous
nachefer	Semen Achefer district	Dummy	1 = yes, 0 = no
yelmadensa	Yilmana Densa district	Dummy	1 = yes, 0 = no
ebinat	Ebinat district	Dummy	1 = yes, 0 = no
farta	Farta district (reference)	Dummy	1 = yes, 0 = no

Table 2
Socio-economic characteristics of the respondents (n = 400).

Variable	District					ANOVA and Chi-square		
	Semen Achefer	Farta	Yilmana Densa	Ebinat	District mean	*df*	*F* value	χ^2 value
Gender (%)								
Male	92	94	98	77	90	3		28.724***
Female	8	6	2	23	10			
Age	40	46	44	42	43	(3,396)	4.651**	
Education level (%)						12		14.564ns
None	30	24	33	29	29			
No formal	31	47	37	36	38			
Primary	37	26	24	31	29			
Secondary	2	2	5	2	3			
Post-secondary	0	0	1	2	1			
Household size	6	6	5	6	6	(3,395)	1.676ns	
Farm experience (year)	18.4	24.6	22.4	22.1	22	(3,396)	4.985**	
Land owned (ha)	1.5	1.1	1.2	1.3	1.3	(3,393)	9.750***	
Land under field pea (ha)	0.3	0.2	0.2	0.4	0.3	(3,392)	39.520***	
Field pea yield (kg/ha)	738	852	730	843	791	(3,396)	1.421ns	
Income from field pea (ETB)	1527	1087	1114	2796	1631	(3,385)	40.287***	
Purpose of field pea production (%)						6		44.799***
Consumption	11	39	10	20	20			
Sale	13	7	18	3	10			
Consumption and sale	76	54	72	77	70			
Membership of cooperative	91	75	83	90	85	3		13.409**

Statistically significant at **P < 0.01, ***P < 0.001; ns = not significant.

were small-scale farmers who owned an average of 1.3 ha, of which the average area allocated to field pea was less than 0.5 ha. Field pea was grown both for home consumption and for sale in the local market by the majority of the farmers (70%), whereas 20% of the farmers reported that the produce was used solely for home consumption and 10% of the farmers reported they sold all their produce. Yield of field pea did not vary significantly, with a mean yield for all districts of 791 kg/ha (Table 2). Most of the farmers (85%) were members of agricultural cooperatives.

3.2. Cultural practices of field pea cultivation

Intercropping was a common cultural practice in the survey districts. On average for the four districts surveyed, 51% of respondents reported intercropping field pea, mainly with faba bean, with significantly more farmers (74%) doing so in Ebinat than in other districts. Crop rotation of field pea with cereal crops was the common cropping system practised by the majority of farmers in all survey districts (Table 3). There was considerable variation in harvesting time of field pea. Only a few (18%) farmers harvested early, while most (67%) harvested at the optimum time and about 15% harvested late. Most of the farmers (79%) across the districts surveyed reported that they cleared away leftover and fallen seeds during harvesting and threshing of the crop. In addition, more than 50% of farmers reported that they checked the seeds for pea weevil damage symptoms before planting (Table 3).

3.3. Knowledge of field pea pests

Most of the farmers (88%) reported that insect pests were the main constraint on field pea production, followed by plant diseases (31%), vertebrate pests (13%) and weeds (7%). Among insect pests, pea weevil was mentioned by the majority (83%) of the farmers as the main insect pest of field pea, followed by pea aphid (*Acyrthosiphon pisum* (Harris)) (41%) and African bollworm (*Helicoverpa armigera* (Hübner)) (10%) (Table 4).

3.4. Farmers' knowledge and perceptions of pea weevil

The majority of the farmers (71%) had knowledge about pea weevil, but there were significant differences between the districts surveyed, with the figure ranging from 50% in Farta to 90% in Ebinat (Table 5). Most of the farmers (84%) reported the occurrence of pea weevil either on their own farm or in their village. However, the majority of the farmers considered pea weevil a storage pest attacking the grains after harvest and only about 32% of the farmers were aware that pea weevil attacks peas in the field. Most farmers were able to identify damaged seeds based on common symptoms observed on infested seeds, but with significant differences between districts (Table 5). The majority of the farmers (78%) who

Table 3
Percentage of farmers reporting different farming activities in their fields in the four districts surveyed in north and north-western Ethiopia.

Farm activities	District					
	Semen Achefer	Farta	Yilmana Densa	Ebinat	District mean	χ^2 value
Intercropping	32	47	50	74	51	35.576***
Crop rotation	97	98	100	98	98	2.791ns
Time of harvest						175.937***
Early harvest	4	6	5	59	18	
Timely harvest	68	92	71	36	67	
Late harvest	28	2	24	5	15	
Clear up of leftover and fallen seeds	76	76	69	96	79	24.780***
Check damaged seeds before planting	59	63	57	55	58	1.350ns

Statistically significant at ***P < 0.001; ns = not significant.

Table 4
Percentage of farmers reporting field pea pests in their fields in the four districts surveyed in north and north-western Ethiopia.

Pest	District					
	Semen Achefer	Farta	Yilmana Densa	Ebinat	District mean	χ^2 value
Insect	94	75	85	98	88	44.265***
Pea weevil	98	67	74	95	83	91.235***
Pea aphid	40	34	43	48	41	15.742**
African bollworm	10	16	4	9	10	4.321ns
Plant disease	28	30	42	23	31	5.994ns
Weeds	4	10	1	14	7	13.369**
Vertebrate pest	13	15	9	14	13	2.189ns

Statistically significant at **P < 0.01, ***P < 0.001; ns = not significant.

Table 5
Farmers' knowledge and perceptions of pea weevil in the four districts surveyed in north and north-western Ethiopia.

Variable	District					
	Semen Achefer	Farta	Yilmana Densa	Ebinat	District mean	χ^2 value
Farmers with knowledge of pea weevil (pw)	84	50	62	90	71	51.576***
Farmers reporting pw in their farm/village	93	71	76	96	84	34.077***
Pea weevil attacking peas						
In the field	63	0	24	43	32	139.351***
In the storage	13	82	71	34	50	
Both in the field and storage	23	17	5	23	17	
Damage symptoms of pw in the seed[a]						
'Sting'	69	23	49	81	55	77.425***
'Window'	19	38	16	35	27	21.774***
'Hole'	70	68	82	91	78	19.248***
'Red seed colour'	20	25	3	1	12	39.345***
Perception of incidence of pw						42.892***
Minor	1	0	13	2	4	
Moderate	8	22	8	7	11	
Severe	91	78	79	91	85	
Percentage of harvest damaged by pw						24.053**
<25%	4	3	5	0	3	
25-50%	15	19	6	6	11	
51-75%	20	21	13	29	21	
>75%	60	56	74	65	64	
The rate of pw problem since its occurrence						10.506ns
Decreasing	17	6	13	12	12	
The same	9	13	6	5	8	
Increasing	74	81	81	83	80	
Perception of the effect of pw						
Loss of income from sale of peas	91	98	96	99	96	10.077*
Shortage of peas for home consumption	71	88	86	91	84	18.060***
Shortage of seeds for planting	76	92	92	94	88	18.926***
Perception on means of spread of pw						
Through weevil-infested seeds	23	22	1	35	20	36.569***
Due to adult weevils	2	4	3	12	5	12.385**
Other factors	2	3	1	3	2	1.178ns
Unknown	74	72	96	53	74	43.130***

Statistically significant at *P < 0.05, **P < 0.01, ***P < 0.001; ns = not significant.
[a] Sting = "a small dark spot on the seed coat, indicates the point of entrance of larvae; window = a thin circular cap, as a means of exit for future adult; hole = circular exit hole of adult weevil" (Brindley et al., 1956).

were able to identify damaged seeds did so based on the weevil exit hole, while 55% of the farmers recognised 'sting', which is the initial symptom of pea weevil infestation. It was clear that most farmers (85%) considered pea weevil a severe problem threatening field pea production and most (85%) estimated that they incurred over 50% seed damage caused by the pest. The vast majority of the farmers (96%) perceived that pea weevil was causing loss of income, shortage of grain for home consumption (84%) and shortage of seeds for planting (88%). Although most (80%) of the farmers reported that the pea weevil problem had increased since its first occurrence in their village, most (74%) did not know the source and means of pea weevil spread to their farm and village and only 20% had mentioned weevil-infested seeds as a means of spread (Table 5).

3.5. Factors determining farmers' knowledge on pea weevil

The logit coefficients and marginal effects of factors determining farmers' knowledge on pea weevil are shown in Table 6. The model was statistically significant (P < 0.01). The results revealed that farmers' knowledge of pea weevil was positively and significantly predicted by gender, farming experience and membership of co-operatives. In addition, the dummy variables representing Semen Achefer and Ebinat districts were significant and positive predictors.

3.6. Pest management practices

Most of the farmers (63%) reported that they had used insecticides for the control of pea weevil, but there were significant

Table 6
Logit results on factors determining farmers' knowledge on pea weevil.

Variable[a]	Logit coefficient		Marginal effect	
	Coef.	SE	dy/dx	SE
gender	1.638***	0.520	0.366***	0.124
age	−0.024	0.022	−0.004	0.004
hh_size	0.090	0.098	0.016	0.018
hh_farmac	−0.122	0.116	−0.022	0.021
land_size	−0.312	0.239	−0.055	0.041
land_fp	0.400	1.179	0.071	0.197
farmexp	0.040*	0.022	0.007*	0.004
agriinfo	0.008	0.527	0.001	0.094
memcop	0.720**	0.352	0.144*	0.079
fpyield	0.001	0.002	0.000	0.000
fpincom	−0.000	0.000	−6.460	0.000
pestprob	0.849	1.268	0.181	0.306
pwfirstseen	0.001	0.011	0.000	0.002
nachefer	2.127***	0.451	0.286***	0.079
yelmadensa	0.265	0.351	0.045	0.058
ebinat	2.646***	0.578	0.327***	0.093
-cons	−3.016	1.590		

[a] Description of variable is shown in Table 1. Statistically significant at *P < 0.05, **P < 0.01, ***P < 0.001, n = 357, log likelihood = −174.26908, LR $\chi 2$ (16) = 95.60, Prob > χ^2 = 0.0000, pseudo-R^2 = 0.2153.

differences between districts, ranging from 47% in Yilmana Densa to 82% in Ebinat. Of those farmers, 95% reported that they had applied grain storage pesticides, mainly phostoxin (fumigant) and actellic powder, while a very small proportion (5%) mentioned that they had sprayed insecticides in the field for control of pea weevil (Table 7). Among pesticide users, 68% said they had received advice from pesticide retailers. About 34% of all farmers surveyed reported that they had used different types of cultural practices to control weevils. Of those, 73% mentioned roasting peas. In Farta district, 39% of the farmers reported they had mixed field pea grains with tef (*Eragrostis tef* (Zucc.) Trotter) seeds in order to protect the peas from pea weevil attack during storage (Fig. 2). A few farmers (about 3%), mentioned that they sold the peas immediately after harvest to prevent pea weevil infestation, while about 27% of the farmers said they did not apply any control methods against pea weevil (Table 7).

4. Discussion

The results presented above show that pea weevil is established in the major field pea-growing districts of north and north-western Ethiopia, causing severe crop losses to small-scale field pea growers. According to Teka (2002), the pest was observed in the north-western part of the Amhara region in 1992 and farmers in Ebinat have been aware of the weevil since the mid-1980s. In the present study, farmers in Ebinat reported that they have seen the weevil in their village since the early 1990s. In addition, most (83%) considered pea weevil to be the main production constraint for field pea, which corroborates previous reports (Teka, 2002; Ali et al., 2008; Seyoum et al., 2012).

The survey results revealed that farmers in Ebinat and Semen Achefer districts had greater knowledge of pea weevil than farmers in Farta. The relatively early occurrence of the pea weevil in Ebinat district and the high infestation rate of the weevil in Ebinat and Semen Achefer (Teka, 2002; Ali et al., 2008; Seyoum et al., 2012) are probably the main explanations for this difference. Furthermore, male farmers had better knowledge about pea weevil than females, as confirmed by the logit results. This might be partly attributable to the fact that many more men than women participated in the study, but also to men being involved in farm activities and spending more time in the field than women, enabling them to gain experience and knowledge about this pest. This is consistent with Kekeunou et al. (2006) and Midega et al. (2012), who reported higher knowledge of variegated grasshopper (*Zonocerus variegatus* (L.)) and cotton pests, respectively, amongst male farmers compared with females. In addition, farming experience had a positive effect on farmers' knowledge of pea weevil. The results also revealed that farmer's knowledge of pea weevil was positively predicted by memberships of cooperatives. Cooperatives might provide an opportunity for agricultural information exchange among peers, including about pests, resulting in farmer members having better knowledge about pea weevil. Furthermore, the benefits obtained from cooperatives in terms of agricultural input use and advisory services (Abate et al., 2013) might also contribute to improving smallholder farmers' knowledge about crop pests.

Most of the farmers surveyed in this study considered pea weevil to be solely a post-harvest pest, possibly due to the fact that the majority of them identified damaged seeds by the weevil exit ‘hole’ in the seeds, which is conspicuous in the stored product. It is important to note that once ‘window’ and exit ‘hole’ symptoms are observed in the infested seeds, it is too late to apply post-harvest management practices to control the weevils. This suggests the importance of knowledge about the initial damage symptom (‘sting’) for timely application of post-harvest management practices. Furthermore, the results showed lack of awareness among farmers about the source and means of spread of pea weevil to their farm and village. This might be a barrier to farmers taking the necessary actions to prevent the spread of the weevil.

As farmers considered pea weevil a storage pest, no cultural practices were undertaken in the field to control the weevil. However, most farmers intercropped field pea with faba bean. Smallholder farmers in Africa often practise intercropping: (1) to increase productivity of farm land, (2) to minimise risks of crop failure and (3) as insurance for falling market prices (Vandermeer, 1989). Furthermore, field pea is usually grown in rotation with cereal crops such as barley (*Hordeum vulgare* L.), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), millet (*Pennisetum*

Table 7
Pest management practices used by farmers to control pea weevil in the four districts surveyed in north and north-western Ethiopia.

Pest control method	District					
	Semen Achefer	Farta	Yilmana Densa	Ebinat	District mean	χ^2 value
Cultural (in the storage)	35	40	19	42	34	14.077**
Insecticides	68	57	47	82	63	27.883***
Field spray	12	0	6	1	5	16.213*
In the storage	88	98	94	99	95	
Both	0	2	0	0	0.5	
Sell the grain immediately	4	0	7	0	3	12.994**
No control	21	29	44	15	27	23.846***
Stop growing field pea	3	1	8	0	3	17.382**

Statistically significant at *P < 0.05, **P < 0.01, ***P < 0.001.

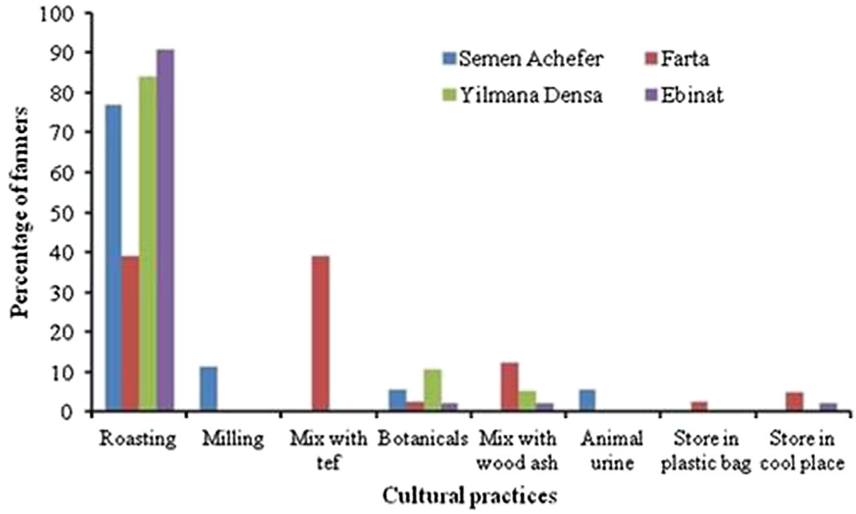

Fig. 2. Percentage of farmers reporting different cultural practices for control of pea weevil in north and north-western Ethiopia ($P < 0.001$, $df = 21$, $\chi^2 = 78.441$).

glaucum (L.) R. Br.) and tef. The farmers surveyed were well aware of the importance of crop rotation in improving soil fertility. Given the flight capacity of pea weevil, which ranges up to 5 km (Armstrong and Matthews, 2005), individual farmers' efforts alone may not be adequate to suppress the weevil, and hence cooperation among farmers is very important for cultural practices such as intercropping and crop rotation to be effective (Bajwa and Kogan, 2004).

Another cultivation practice that has an influence on pea weevil infestation is sowing. Many farmers in the study areas did not check the seed before planting and they likely sowed weevil-infested seeds, which subsequently can become a source of infestation for the next year's crop (Brindley et al., 1956; Baker, 1998). Furthermore, although early harvesting is recommended to minimise yield losses and carryover of the weevils to the next cropping season (Baker, 1998; Armstrong and Matthews, 2005), in this study only a few farmers (4–6%) in all districts except Ebinat (59%) reported that they had harvested peas early. It has been shown that larval feeding during early harvest can cause only about 26% seed weight loss and hence it is possible to prevent further seed damage by early harvesting (Baker, 1998; Armstrong and Matthews, 2005). Similarly Mihiretu and Wale (2013) showed reduced damage by pea weevil in early harvesting and threshing of peas compared with late harvesting. In addition, it was noted that farmers usually stack peas on the farm and leave them for some time before threshing, which unintentionally enhances seed damage by pea weevil.

The farmers surveyed mainly use insecticides to control pea weevil in storage. Baker (1998) showed that proper fumigation of peas as soon as the crop is harvested can prevent further damage by pea weevil, which can otherwise inflict up to 70% weight loss in infested grains. However, the present study revealed a knowledge gap in the use of insecticides. For example, the majority of farmers surveyed did not know the name of the pesticides they applied. In addition, some farmers applied non-recommended insecticides. The farmers also often complained that the insecticides they applied did not protect their crop from damage by pea weevil. This might be due to various factors, such as poor storage systems, improper application of insecticides and the use of non-recommended, expired and adulterated insecticides. Problems associated with pesticide application amongst smallholder farmers in developing countries have been reported in different cropping systems elsewhere (Williamson et al., 2008; Kamanula et al., 2011; Pretty and Bharucha, 2015; Khan et al., 2015). Such practices not only result in poor control of the pest, but also expose the farmers to pesticide risks (Williamson et al., 2008; Kesavachandran et al., 2009; Lekei et al., 2014). The lack of knowledge about pesticide use found in this survey underscores the need to train farmers in order to circumvent the problems associated with pesticide use and minimise the use of pesticides.

The traditional grain storage systems in the study areas, as in smallholder farming systems in many developing countries, largely fail to protect the grain from insect pest damage. It was noted that farmers often reuse fertiliser bags for storage and fumigation of field pea seeds. This form of storage, coupled with improper use of insecticides, further compounds the pea weevil problem, suggesting the need for improved storage facilities that fit these farmers' socio-economic conditions. One such option is the metal silo, an improved storage technology that has been proven to protect maize grains from storage pests in many countries of the world (Tefera et al., 2011). Another is hermetic plastic bags (IRRI, 2013; Vales et al., 2014), which protect grains from storage pests without insecticide application. In order to bridge the knowledge gap identified in this study and minimise the damage caused by pea weevil, it is important to provide training for local farmers.

5. Conclusions

From the present study, it is evident that pea weevil is the major biotic production constraint in the main field pea-growing areas of northern and north-western Ethiopia. The majority of the 400 farmers surveyed were aware of pea weevil and the damage it causes. However, most of them considered the pea weevil to be a storage pest. In addition, the cultural practices employed by some farmers, such as sowing weevil-infested seeds and delayed harvesting, inadvertently favour survival and carryover of the pea weevil to the next cropping season and pose a risk of severe yield losses. If proper cultural practices are implemented, they can contribute to control of pea weevil and prevent carryover to the next cropping season. Therefore, in order to bridge the knowledge gap identified in this study, it is very important to provide training for local farmers.

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References

Abate, T., van Huis, A., Ampofo, J.K.O., 2000. Pest management strategies in traditional agriculture: an African perspective. Annu. Rev. Entomol. 45, 631–659.

Abate, T., 2006. IPM in Ethiopia: the current status. In: Bekele, E., Azerefegne, F., Abate, T. (Eds.), Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia. Drylands Coordination Group (DCG) Proceedings No. 17 (02, 2006), Oslo, pp. 3–15.

Abate, G.T., Francesconi, G.N., Getnet, K., 2013. Impact of Agricultural Cooperatives on Smallholders' Technical Efficiency: Evidence from Ethiopia. Euricse Working Paper n. 50|13.

Ali, K., Chichaybelu, M., Abate, T., Tefera, T., Dawd, M., 2008. Two decades of research on insect pests of grain legumes. In: Tadesse, A. (Ed.), Increasing Crop Production Through Improved Plant Protection, vol. I. Plant Protection Society of Ethiopia (PPSE) and EIAR, Addis Ababa, Ethiopia, pp. 38–84.

Armstrong, E., Matthews, P., 2005. Managing Pea Weevil. (Pulse Point 4), third ed. GRDC project DAN463, Evaluation and management of pulses in southern NSW, New South Wales.

Bajwa, W.I., Kogan, M., 2004. Cultural practices: springboard to IPM. In: Koul, O., Dhaliwal, G.S., Cuperus, G.W. (Eds.), Integrated Pest Management: Potential, Constraints and Challenges. CAB International, Wallingford, pp. 21–38.

Baker, G., 1998. Pea Weevil. Fact Sheet. Primary Industry and Resources and the South Australian Research and Development Institute, South Australia.

Brindley, T.A., Chamberlin, J.C., Schopp, R., 1956. The Pea Weevil and Methods for Its Control. Farmers' Bulletin No. 1971. U.S. Department of Agriculture.

Clement, S.L., Wightman, J.A., Hardie, D.C., Bailey, P., Baker, G., McDonald, G., 2000. Opportunities for integrated management of insect pests of grain legumes. In: Knight, R. (Ed.), Linking Research and Marketing Opportunities for Pulses in the 21st Century. Kluwer Academic, Dordrecht, pp. 467–480.

Cockburn, J., Coetzee, H., Van den Berg, J., Conlong, D., 2014. Large-scale sugarcane farmers' knowledge and perceptions of *Eldana saccharina* Walker (Lepidoptera: Pyralidae), push-pull and integrated pest management. Crop Prot. 56, 1–9.

French, R.J., 2004. Pea agronomy. In: Wrigley, C., Corke, H., Walker, C. (Eds.), Encyclopaedia of Grain Science. Elsevier Ltd., pp. 427–437

FAOSTAT, 2012. Available online http://www.faostat.fao.org (2015-05-01).

Fikere, M., Tadesse, T., Gebeyehu, S., Hundie, B., 2010. Agronomic performances, disease reaction and yield stability of field pea (*Pisum sativum* L.) genotypes in Bale highlands, Ethiopia. Aust. J. Crop Sci. 4, 238–246.

Greene, W.H., 2012. Econometric Analysis, seventh ed. Pearson Education Inc., Boston, MA.

Gujarati, D.N., Porter, D.C., 2009. Basic Econometrics, fifth ed. McGraw-Hill Education (India) Pvt Limited.

Horne, J., Bailey, P., 1991. *Bruchus pisorum* L. (Coleoptera: Bruchidae) control by knockdown pyrethroid in field peas. Crop Prot. 10, 53–56.

IBC (Institute of Biodiversity Conservation), 2008. Ethiopia: Second Country Report on the State of PGRFA to FAO. IBC, Addis Ababa.

IRRI., 2013. Grain Storage and Pest Management. International Rice Research Institute (IRRI), Postharvest Unit, CESD.

Kekeunou, S., Weise, S., Messi, J., Tamò, M., 2006. Farmers' perception on the importance of variegated grasshopper (*Zonocerus variegatus* (L.)) in the agricultural production systems of the humid forest zone of Southern Cameroon. J. Ethnobiol. Ethnomed. 2, 17. http://dx.doi.org/10.1186/1746-4269-2-17.

Khan, Z.R., Midega, C.A.O., Nyang'au, M.I., Murage, A., Pittchar, J., Agutu, L., Amudavi, D.M., Pickett, J.A., 2014. Farmers' knowledge and perceptions of the stunting disease of Napier grass in western Kenya. Plant Pathol. 63, 1426–1435.

Khan, M., Mahmood, H.Z., Damalas, C.A., 2015. Pesticide use and risk perceptions among farmers in the cotton belt of Punjab, Pakistan. Crop Prot. 67, 184–190.

Kamanula, J., Sileshi, G.W., Belmain, S.R., Sola, P., Mvumi, B.M., Nyirenda, G.K.C., Nyirenda, S.P., Stevenson, P.C., 2011. Farmers' insect pest management practices and pesticidal plant use in the protection of stored maize and beans in Southern Africa. Int. J. Pest Manag. 57, 41–49.

Kesavachandran, C.N., Fareed, M., Pathak, M.K., Bihari, V., Mathur, N., Srivastava, A.K., 2009. Adverse health effects of pesticides in agrarian populations of developing countries. In: Whitacre, D.M. (Ed.), Reviews of Environmental Contamination and Toxicology, vol. 200. Springer Science, pp. 33–52.

Lekei, E.E., Ngowi, A.V., London, L., 2014. Farmers' knowledge, practices and injuries associated with pesticide exposure in rural farming villages in Tanzania. BMC Public Health 2014 (14), 389. http://dx.doi.org/10.1186/1471-2458-14-389.

Messiaen, C.M., Seif, A.A., Jarso, M., Keneni, G., 2006. In: Brink, M., Belay, G. (Eds.), *Pisum sativum* L.. PROTA (Plant Resources of Tropical Africa), Wageningen. Record from PROTA4U. http://www.prota4u.org/search.asp (accessed 18.11.13.).

Mihiretu, E., Wale, M., 2013. Effect of harvesting and threshing time and grain fumigation of field peas (*Pisum sativum* L.) on pea weevil (*Bruchus pisorum* L.) (Coleoptera: Bruchidae) development and damage. ETH J. Sci. Technol. 6, 13–24.

Midega, C.A.O., Nyang'au, I.M., Pittchar, J., Birkett, M.A., Pickett, J.A., Borges, M., Khan, Z.R., 2012. Farmers' perceptions of cotton pests and their management in western Kenya. Crop Prot. 42, 193–201.

Norton, G.W., Rajotte, E.G., Gapud, V., 1999. Participatory research in integrated pest management: lessons from the IPM CRSP. Agric. Hum. Values 16, 431–439.

Nyaupane, N., Gillespie, J., 2010. Factors Influencing Producers' Marketing Decisions in The Louisiana Crawfish Industry. Selected paper presented at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 6-9, 2010.

Obopile, M., Munthali, D.C., Matilo, B., 2008. Farmers' knowledge, perceptions and management of vegetable pests and diseases in Botswana. Crop Prot. 27, 1220–1224.

Okonya, J.S., Mwanga, R.O.M., Syndikus, K., Kroschel, J., 2014. Insect pests of sweet potato in Uganda: farmers' perceptions of their importance and control practices. SpringerPlus 2014 (3), 303. http://dx.doi.org/10.1186/2193-1801-3-303.

Pretty, J., Bharucha, Z.P., 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects 2015 (6), 152–182. http://dx.doi.org/10.3390/insects6010152.

Seyoum, E., Damte, T., Bejiga, G., Tesfaye, A., 2012. The status of pea weevil, *Bruchus pisorum* (Coleoptera: Chrysomelidae) in Ethiopia. In: Mulatu, B. (Ed.), Invasive Plant Pests Threatening Ethiopian Agriculture. Proceedings of the 17th Annual Conference. Plant Protection Society of Ethiopia, 26-27 November 2010, Addis Ababa, pp. 52–66.

Seidenglanz, M., Rotrekel, J., Poslusna, J., Kolarik, P., 2011. Ovicidal effects of thiacloprid, acetamiprid, lambda-cyhalothrin and alpha-cypermethrin on *Bruchus pisorum* L. (Coleoptera: Chrysomelidae) eggs. Plant Prot. Sci. 47, 109–114.

Sharma, R., Peshin, R., Shankar, U., Kaul, V., Sharma, S., 2015. Impact evaluation indicators of an integrated pest management program in vegetable crops in the subtropical region of Jammu and Kashmir, India. Crop Prot. 67, 191–199.

Tefera, T., Kanampiu, F., De Groote, H., Hellin, J., Mugo, S., Kimenju, S., Beyene, Y., Boddupalli, P.M., Shiferaw, B., Banziger, M., 2011. The metal silo: an effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. Crop Prot. 30, 240–245.

Tefera, T., 2004. Farmers' perceptions of sorghum stem-borer and farm management practices in eastern Ethiopia. Int. J. Pest Manag. 50, 35–40.

Teka, W., 2002. The importance and distribution of pea weevil (*Bruchus pisorum*) in the Amhara region. In: Proceedings of a National Workshop on the Management of Pea Weevil, *Bruchus pisorum*. 25-27 November 2002, Bahir Dar, Ethiopia, pp. 30–36.

Vales, M.I., Ranga Rao, G.V., Sudini, H., Patil, S.B., Murdock, L.L., 2014. Effective and economic storage of pigeonpea seed in triple layer plastic bags. J. Stored Prod. Res. 58, 29–38.

Verbeek, M., 2008. A Guide to Modern Econometrics, third ed. John Wiley & Sons, Chichester, UK.

Vandermeer, J.H., 1989. The Ecology of Intercropping Systems. Cambridge Press, Cambridge.

Waterford, C.J., Winks, R.G., 1994. Response of the pea weevil *Bruchus pisorum* L. to phosphine. In: Highley, E., Wright, E.J., Banks, H.J., Champ, B.R. (Eds.), Stored Product Protection Proceedings of the 6th International Working Conference on Stored-product Protection, vol. I, pp. 217–220. Canberra, Australia, 17-23 April 1994. CAB International, UK.

Williamson, S., Ball, A., Pretty, J., 2008. Trends in pesticide use and drivers for safer pest management in four African countries. Crop Prot. 27, 1327–1334.