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Farmers' perspectives of rodent damage and management from the highlands of Tigray, Northern Ethiopian

Meheretu Yonas [a,b,*], Kiros Welegerima [a], Seppe Deckers [c], Dirk Raes [c], Rhodes Makundi [d], Herwig Leirs [b,e]

[a] Mekelle University, Department of Biology, P. O. box 3102 Mekelle, Ethiopia
[b] University of Antwerp, Evolutionary Ecology Group, Groenenborgerlaan 171, Antwerpen 2020, Belgium
[c] Division of Soil and Water Management, K.U. Leuven, Celestijnenlaan 200E, 3001 Heverlee, Belgium
[d] Sokoine University of Agriculture, Pest Management Center, P. O. Box 3110, Morogoro, Tanzania
[e] Danish Pest Infestation Laboratory, Lyngby, Denmark

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ABSTRACT

A farmers' knowledge, attitude and practice (KAP) survey was conducted in the highlands of Tigray, northern Ethiopia, to better understand rodent damage and rodent management from the farmers' perspective. Farmers ($n = 191$) from Dogu'a Temben district, were interviewed using a semi-structured questionnaire. The large majority of the farmers stated that rodents are the main pests in crop fields (92.1%) and storage (88.5%). The farmers (64.2%) reported they experienced 100–500 kg ha^{-1} damage in crop fields, which is equivalent to 8.9–44.7% loss in annual production. There was some overlap between the most common crops grown in the highlands and the most common crops susceptible to rodent attack. Farmers identified barley as the crop most susceptible to rodent attack (76.4%) and the booting stage as the crop developmental stage with the highest rodent abundance and damage. Rodenticide application was the most commonly practiced management strategy in crop fields (51.8%); in storage, farmers mainly keep domestic cats around granaries (80.6%). We recommend a reduction in reliance on chemical rodenticide in crop fields and a shift to a more sustainable rodent management approach to reduce rodent numbers and damage.

1. Introduction

Rodents are responsible for substantial damage to food and cash crops world wide. They adversely affect rural communities by damaging agricultural crops in the field and by eating and contaminating stored grain. In some cases, the damage can be so enormous that it not only threatens individual farmers, but also national and international food security (Leirs, 2003; Meerburg et al., 2009).

Rodents are one of the major causes of pre-harvest losses in cereal crops in Africa (Makundi et al., 1999) and have been ranked the number one crop pest in Eastern Africa (Makundi et al., 2003). Annual losses due to rodents in several countries are economically unacceptable. On average, in Tanzania, rodents are responsible for losses amounting to 15% of the total production of cereals (Makundi et al., 1991), losses which could feed over 2 million people in Tanzania annually (Leirs, 2003). Ethiopia experiences chronic rodent pest problems, including attacks on enset (*Ensete ventricosum* (Welw.) Cheesman) by mole rats (*Tachyoryctes splendens* Rüppell) to high losses of about 26% in maize crop (Bekele et al., 2003).

In Ethiopia, 84 species of rodents have been reported; about a dozen are significant agricultural pests (Bekele and Leirs, 1997; Bekele et al., 2003). However, there have been few attempts to quantify estimates of crop damage and economic loss due to rodents. The impact of rodents in the highlands of Tigray, northern Ethiopia, is particularly poorly documented. Recent studies have demonstrated the presence of several different species in the crop fields (D'aes, 2006; Workneh et al., 2004; Nyssen et al., 2007).

In the highlands of Tigray region (province), soil erosion and vegetation loss are of major agricultural concern. Hence, over the last few decades, massive agronomic and physical soil and water conservation and rehabilitation programs have been initiated by governmental and non-governmental organizations in and outside crop fields. The programs include the building of stone bunds, aforestation, agroforestry and establishment of exclosures (guarded areas where grazing and farming are not allowed) (Nyssen et al., 2001; Desta et al., 2005; Vancampenhout et al., 2006; Mekuria

* Corresponding author. Tel.: +251 914 721856; fax: +251 344 409304.
E-mail address: meheretu@yahoo.com (M. Yonas).

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et al., 2009). According to the 2002 annual report of the Regional Bureau of Agriculture and Natural Resource (RBoANR), 522,600 ha of land has been covered by different soil and water conservation measures between 1991 and 2002, especially stone bunds (RBoANR, 2002). The conservation and rehabilitation programs are expected to continue until all treatable farm lands and erosion threatened mountain slopes are covered.

These massive conservation and rehabilitation programs have already demonstrated several advantages, including significant reduction in water runoff and soil erosion, increase in soil moisture and increase in crop yields (Vancampenhout et al., 2006; Menale et al., 2007; Nyssen et al., 2007). However, farmers and experts claim that the systems (especially the stone bunds) have created good habitats for rodents (Herweg, 1993; Belay and Edwards, 2002; Rämi, 2002; D'aes, 2006).

The livelihood of farmers in the highlands of Tigray is based mainly on small scale subsistence agriculture, with a farm size 1 ha on average (Mitiku et al., 2001). The average family size is 6 persons. Grassland, rangeland and exclosures are communally owned (Mekuria et al., 2009). The main crops grown are barley (*Hodeum vulgare* L.), wheat (*Triticum* species), tef (*Eragrostis tef* (Zucc.) Trotter) and pulses. The livestock comprise cattle, such as cow and oxen, sheep, goats, donkeys and mules.

Farming is done by traditional technology, including ploughing with animal traction and predominantly rain dependent. Harvest is by hand mowing after which crops are left to dry in small heaps in the fields for few days. Dried crops are then threshed in one or two places. Threshing (by animal trampling) takes place on a circular flat surface polished with a thin coat of dung and surrounded by stones. After threshing, the farmers carry the grains to the villages and usually store in granaries made of bamboo or dung. Some farmers store grains in hide or jute sacks. The whole process of mowing, threshing, and carrying the grains to the villages usually requires organized labor from the community. Therefore, the process is sometimes delayed when labor becomes scarce.

The aim of this paper is to report on the knowledge, attitude and practices (KAP) of farmers in the highlands of Tigray, regarding rodent damage and rodent management. The information obtained from the study will be combined later with ongoing rodent ecology research to design more efficient intervention programs tailored to the needs and problem areas identified by the survey.

2. Methods

2.1. Study area and interview

The study was conducted in Hagere Selam area (13° 38′ 54″ N, 39° 10′ 25″ E) (Fig. 1), Dogu'a Temben *Woreda* (district), Tigray region, northern Ethiopia. Northern Ethiopia has a tropical monsoon climate with wide topographically–induced variation in climatic factors. The morphology of Dogu'a Temben is typical for the northern Ethiopian highlands (Nyssen et al., 2008). The mean altitude of the area is about 2250 m a.s.l. It has an average annual rainfall of 778 mm. The main rainy season runs from mid June to mid September. The typical land use in the area is rangeland and exclosures on the steep slopes and crop land in the flat and lesser slopes. The vegetation is largely dominated by *Acacia etbaica* Schweinf and *Euclea schimperi* (DC., A.) Dandy. Dogu'a Temben district was previously described as one of the rodent prone areas in the highlands (D'aes, 2006; Fredu et al., 2006; Nyssen et al., 2007).

A total of 10 hamlets (kushets) were selected from 5 villages (tabias) (2 from each village) across Dogu'a Temben district in consultation with crop protection experts from Agriculture and Rural Development Office of the district. Two of the sub-villages are located within the area range of the ongoing rodent ecology research project being conducted by the same group of researchers.

Twenty households were randomly selected from each of the 10 hamlets, and only household heads were interviewed (191 male, 9 female, all farmers). The 10 sub-villages were: Adikolakul and Hechi from Ayinberkekin village; May Mereb and Guderuo from Mahbere Silassie; Maekel Geza and Zala from Melfa; Harena and Dinglat from Michael Abiy; and Tensehe and Meheno from Selam.

A semi-structured questionnaire previously used for the same purpose in central Ethiopia, Tanzania, and South–East Asia (Makundi et al., 2003; Brown et al., 2008) was used as starting format and tailored to the situation of the highlands. The questionnaire was composed of four parts (socio-demographic profile, agricultural practices, rodent damage, and rodent management). Information was collected through interviews using local language. Interviewers were trained ahead and the questions and the approach were pre-tested twice. The interviews were conducted in January and February, 2009.

2.2. Data analysis

Descriptive statistics were generated by the software SPSS 12.0 (SPSS, 2003). Multiple correspondence analyses were performed to examine associations between the frequencies of rodent damage in crop fields, crop developmental stages with high rodent abundance, crop developmental stages with high rodent damage and perceived crop damage, using the CORRESP Procedure of SAS software version 9.01 (SAS, 2003).

3. Results

3.1. Profile of respondents

Out of the 200 household heads, 9 were female household heads. Therefore, we did not include the responses of the female households in the analysis as their number was not large enough to check for gender variation/similarity in response. Accordingly, the distribution of the respondents in the 5 villages was 36 from Ayinberkekin, 35 from Mahbere Silassie, 40 each from Melfa, Michael Abiy and Selam.

Profiles of the 191 respondents are summarized in Table 1. The average age of the respondents was 47 years (±0.91 SE, range 25–81). The average family size was 6.06 (±0.14 SE, range 2–12). The majority of the respondents (57.1%) had no formal education. The respondents have spent few years to more than 40 years on farming. Farming is mainly rain dependent and happens once in a year. The farmers' own small pieces of farmland, 2.69 plots (±0.07 SE, range 1–5) on average per household. The average sum of plots was 0.86 ha (±0.04 SE, range 0.2–3.5), and the average annual crop yield per household was 964 kg ha^{-1} (±52 SE, range 200–4800). Perceived crop damage and type of management was not significantly explained by village, age, family size, and education. The main crops grown in the farm were wheat (*Triticum species*), barley (*H. vulgare* L.), a mixture of wheat and barley, and pulses such as grass pea (*Lathyrus sativus* L.), horse bean (*Vicia faba* L.), *and* lentil (*Lens culinaris* Medik).

3.2. Pest and crop damage

The number one crop pest identified by the respondents, both in the crop fields (92.1%) and storage (88.5%) was rodents. The rest of the pests were soil nematodes (3.7%), monkey (1.1%) and others (such as beetles) (3.1%) in crop fields, and weevils (9.4) and termites (1.6) in storage. When asked through a set of four consecutive questions to describe the frequency of rodent occurrence and

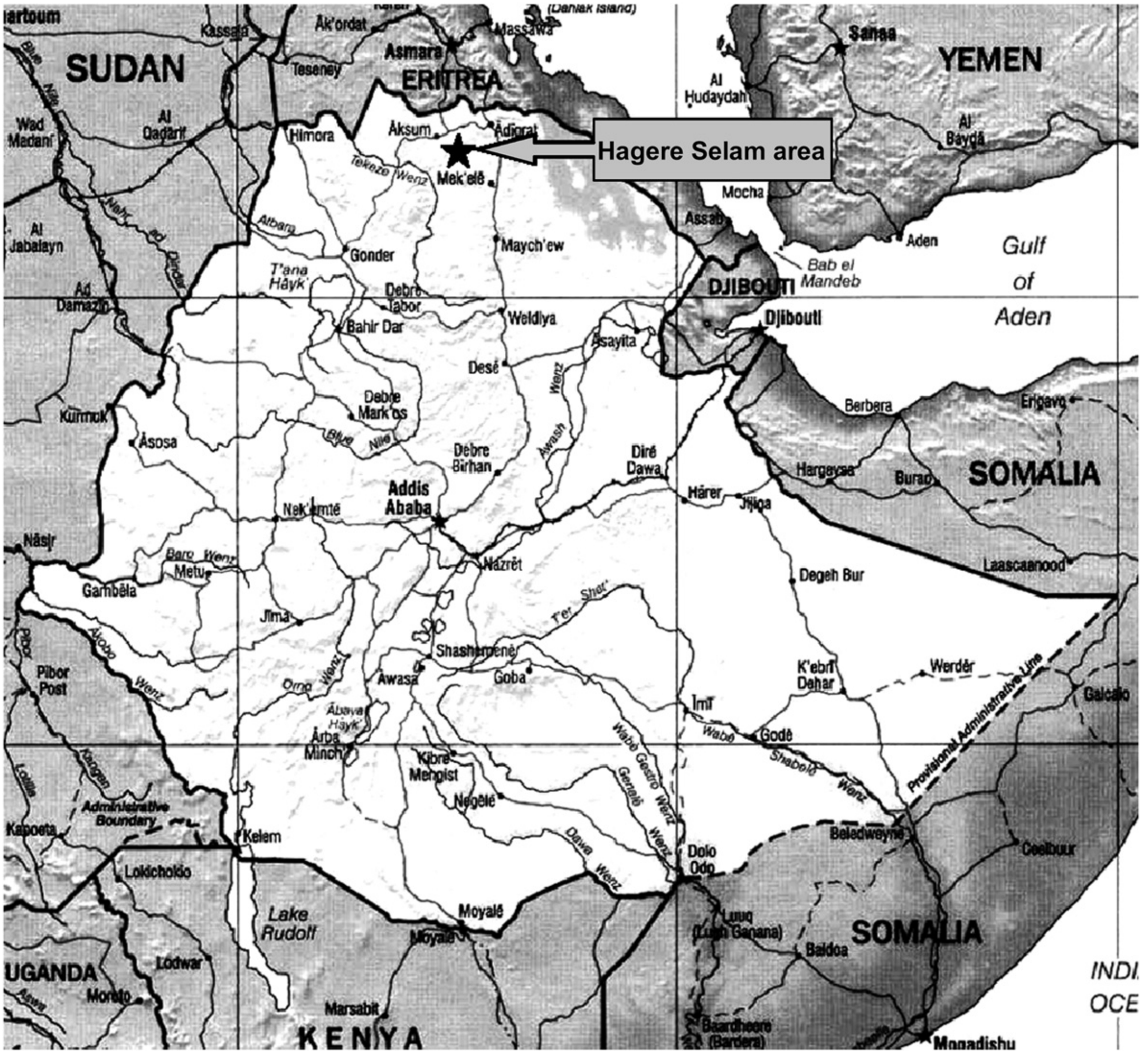

Fig. 1. The star on the map indicates the approximate position of the survey area around Hagere Selam, in the Dogu'a Temben district of Tigray province, Ethiopia.

damage in crop fields and storage, 80.6% believed that frequency of rodent occurrence in crop fields was '*regular*' and '*frequent*' (every one to two years) and 75.9% believed frequency of occurrence was '*regular*' and '*frequent*' in storage. 80.1% of the respondents also believed that frequency of crop damage was '*regular*' and '*frequent*' in crop fields, and 70.6% believed frequency of crop damage was '*regular*' and '*frequent*' in storage (Table 2).

When asked to compare the amount of damage in crop fields with storage, 95.3% of the respondents claimed that crop damage was higher in the crop fields than in storage, 3.1% believed the damage was the same (equal), and the rest (1.6%) believed damage was higher in storage. In some years, 64.2% of the respondents estimated crop damage in their fields to be 100–500 kg ha^{-1}, 11.6% estimated <100 kg ha^{-1}, 7.9% estimated >500 kg ha^{-1}, and it was difficult to estimate crop damage in the fields for 16.3% of the respondents (Fig. 2). The farmers identified barley as the most susceptible crop to rodent attack (76.4%), followed by wheat (15.7) and the mixture of wheat and barley cultivated (4.7%) (Table 3).

The booting stage was indicated as the crop developmental stage coinciding with high rodent abundance (90.1%), followed by germination and maturation stages (14.7% each). Rodent damage was also indicated as most critical (higher) at booting stage (96.3%), followed by germination (11.5%) and maturation (10.5%) stages (Fig. 3). August was identified as the month in which crop damage in the fields was critical by 40.8% of the respondents, followed by August to September (13.1%), July to August (6.8%), July to September (4.7%) and the rest other months.

The two-dimensional multiple correspondence analysis plot in Fig. 4 shows that the plot scores (responses) for categories C (Crop developmental stage with high rodent abundance) and D (Crop developmental stage with high rodent damage) are dispersed across the 4 quadrants of the plane and are relatively far from the origin. In fact, dimension 1 separates scores for single crop developmental stage (C1 = germination (g), C2 = booting (b), C3 = maturation (m)) from scores for multiple crop developmental stages (C4 = g and b, C5 = b and m, C7 = g, b, and m). The top-left quadrant of the plot shows that categories C3 (high rodent abundance during maturation) and D3 (high rodent damage during maturation) are associated. Proceeding anticlockwise, association is evident between categories C5 (high rodent abundance during booting and maturation stages) and D5 (high rodent damage during booting and maturation stages). The bottom-right quadrant especially shows association between categories C4 (high rodent abundance during germination and booting stages) and D4 (high rodent damage during germination and booting stages). One might also consider associations between C2 and D2, at the top-left quadrant of the plot, representing the association between 'high rodent abundance during booting stage' and 'high rodent damage

Table 1
Overview of respondents' profile by village.

Tabia (village)		Age (years)	Family size	No. of farm plots	Total Size of farm (ha)	Annual yield (Kg/ha)
Ayninberkekin	Mean	45.67	6.61	2.86	0.96	1110
	SE	1.66	0.36	0.19	0.08	100
	Min	30	3	1	0.5	300
	Max	66	12	5	2	3000
Mahbere Silassie	Mean	48	6.66	2.77	0.85	1203
	SE	2.08	0.29	0.15	0.11	175
	Min	30	2	1	0.25	400
	Max	81	10	5	3.5	4800
Melfa	Mean	47.15	5.98	2.62	0.87	989
	SE	2.18	0.28	0.16	0.09	116
	Min	30	2	1	0.2	300
	Max	77	11	5	2.5	4000
Michael Abiy	Mean	48.8	5.83	2.68	0.90	663
	SE	1.75	0.32	0.17	0.08	70
	Min	30	2	1	0.25	200
	Max	72	8	5	2.5	2000
Selam	Mean	45.4	5.38	2.55	0.74	928
	SE	2.35	0.31	0.14	0.06	94
	Min	25	2	1	0.25	200
	Max	78	9	4	2.25	2800
Overall	Mean	47	6.06	2.69	0.86	964
	SE	0.91	0.14	0.07	0.04	52
	Min	25	2	1	0.2	200
	Max	81	12	5	3.5	4800

during booting stage', respectively. These interpretations are based mainly on points found in approximately the same direction from the origin in the same space (quadrant) (Greenacre, 1984).

Dimension 2 separates scores of B3 and E2 from scores of B4 and E3, i.e. between perceived damage and frequency of damage in crop fields. Hence, there are associations between B3 and E2 (frequency of rodent damage in the fields was *frequent* and perceived damage was $<$100 kg ha^{-1}), as well as B4 and E3 (frequency of rodent damage in the fields was *regular* and perceived damage was 100–500 kg ha^{-1}). Weak associations were observed with the rest of the categories.

Almost all the farmers (97.4%) have stone bunds in their crop fields. 78.3% of them indicated that stone bunds have been built 15–25 years ago. When asked about significance of having stone bunds in crop fields, 83.8% of them indicated that stone bunds are important in reducing soil erosion. 82.7% of them also claimed that overall crop production has increased since the stone bunds were built. However, 78% of the farmers mentioned that overall crop damage due to rodents in crop fields has increased since the stone bunds were built in the crop fields.

3.3. Rodent management

Farmers employed different methods (signs) to assess crop damage by rodents in the field and during storage. They used signs

Table 2
Farmers' perception concerning frequency of rodent occurrence and damage in crop fields and storage.

	Occurrence in fields		Occurrence in storage		Damage in fields		Damage in storage	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Rare	3	1.6	7	3.7	3	1.6	14	7.3
Irregular	34	17.8	39	20.4	35	18.3	42	22
Frequent	60	31.4	72	37.7	50	26.2	67	35
Regular	94	49.2	73	38.2	103	53.9	68	35.6
Total	191	100	191	100	191	100	191	100

*Rare = 5 and more years; Irregular = 3–4 years; Frequent = every 2 years; Regular = every year.

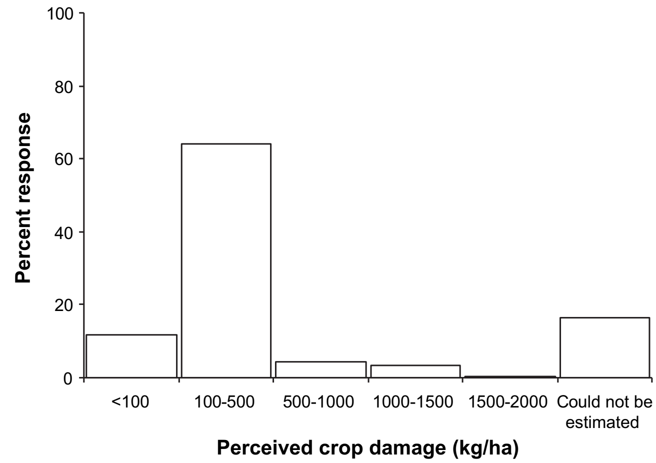

Fig. 2. Perceived crop damage in the fields as evaluated by respondents (n = 191).

such as stems cut of standing crops (92.1%) and rodent tracks and runways (79%) in crop fields. In storage, the assessment involved hearing sounds made by the rodents (81.7), observation of damaged seeds (78%), and damaged seed stores (75.4%) (multiple response was allowed).

Different management practices were employed by the farmers to reduce rodent numbers and damage both in crop fields and storage. In crop fields, poisoning was the most common management practiced (51.8%) followed by field sanitation (29.3%) and trapping (16.8%). However, only 24.2% of the farmers practiced rodent management together with their farm neighbours. In storage, the most common management practice (80.6%) was keeping domestic cats around granaries, followed by trapping (15.7%) and poisoning (3.7%).

The farmers initiated rodent management after noticing damaged crops in the fields (76.4%), after noticing rodent movement (42.4%), as part of routine farming practice (3.14%), and when instructed by extension staff (1.1%) (multiple response allowed). 67% of the farmers pointed out that they engaged in rodent management in crop fields mainly in August, while 20% did the same in September, 10.3% between June–July, and the rest 2.7% did it after September. 90.6% of the respondents indicated that they prefer to initiate rodent management when the crops are at booting stage and 80.1% also pointed out booting stage as suitable for effective rodent management (Fig. 5).

3.4. Rodenticide

The large majority of farmers (93.2%) applied rodenticide (zinc phosphide) to manage rodents in crop fields; 51.8% three times or more per cropping season, 28.5% once and 13% twice. However, about 80% of them preferred to apply rodenticide three times or more per cropping season for maximum result. The farmers (86.9%)

Table 3
Respondents (n = 191) answers to crops grown in the highlands and crops susceptible to rodent attack.

		Wheat	Barley	Mixture of wheat and barley	Teff	Pulse
Crops grown in the	Freq.	100	67	16	0	8
Highlands	%	52.4	35.1	8.4	0	4.2
Crops susceptible to rodent	Freq.	146	30	9	5	1
Attack	%	76.4	15.7	4.7	2.6	0.5

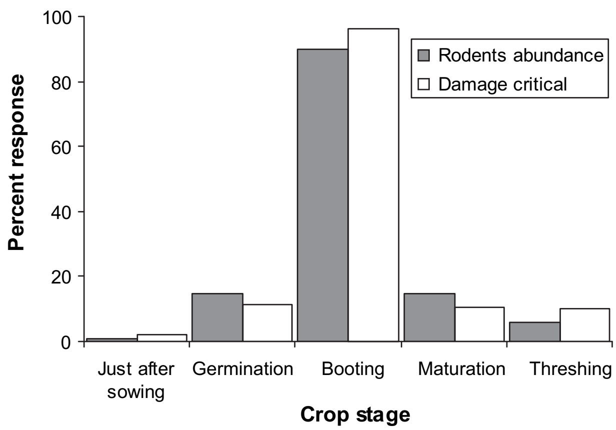

Fig. 3. Rodent abundance and damage in relation to crop developmental stages as evaluated by respondents (multiple responses allowed; $n = 191$).

said they decided to buy rodenticide after noticing rodent movement in the fields, and 5.2% of them never bought rodenticide at all. The district agricultural office was the main provider of purchased or free rodenticide (88.5%), followed by local market (53.9%) (multiple response allowed). When asked to rate the effectiveness of the rodenticide they have applied in crop fields, 52.9% replied that the rodenticide was '*very good*', 35% said '*excellent*', 6.3% rated it '*good*', where as for 5.8% of them it was difficult to rate. The respondents (76.4%) or members of their household have not been trained on how to apply (use) rodenticides.

4. Discussion

4.1. Pest

It appears that rodents are perceived by farmers as the main pest problem in crop fields and storage in the highlands of Tigray, northern Ethiopia. Makundi et al. (2003) also reported that farmers in central Ethiopia described rodents as the number one pest in maize fields. There were times in which rodents occurred every cropping season and times when they occurred rarely (once in five years or more). It was not possible to verify the claim of the farmers due to lack of information on distribution and abundance of rodents in the area. In a preliminary investigation conducted near Hagere Selam in 2005, a total of 191 rodents and insectivores (mainly multimammate rat (*Mastomys awashensis* Lavrenchenko, Likhnova, and Baskevich) (60%) and grass rat (*Arvicantis niloticus* Desmarest) (31%)) were trapped at a density of 4–24 per trapping session per field plot of 60 m × 60 m (D'aes, 2006).

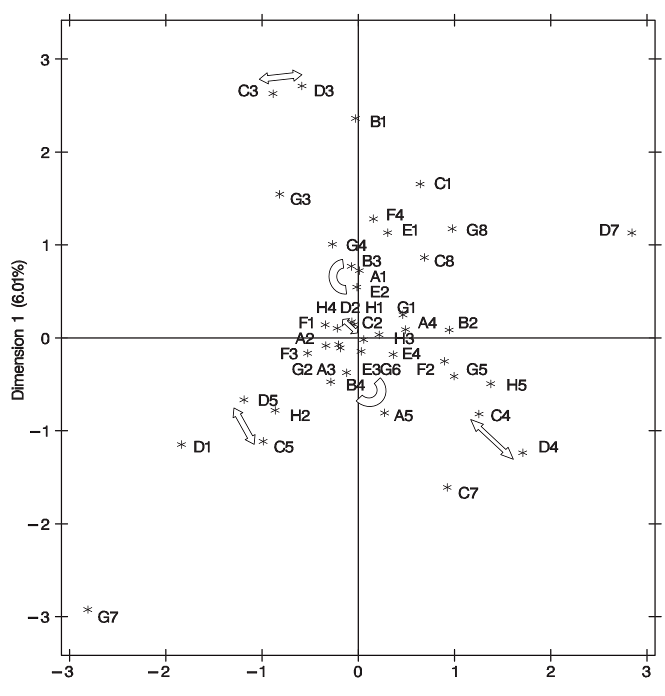

Fig. 4. Two-dimensional multiple correspondence analysis plot indicating associations between certain categories. Categories with relatively better associations are shown in arrows.

A = Years spent farming	B = Frequency of rodent damage in the fields	C = Crop developmental stage at high rodent abundance	D = Crop developmental stage at high rodent damage	E = Perceived crop damage in the fields	F = The no. 1 rodent management strategy in crop fields	G = Crop developmental stage at which rodent management is effective	H = How effective is the chemical rodenticide applied in the crop fields
A1 = 1–10	B1 = Rare	C1 = Germination (*g*)	D1 = Germination	E1 = Could not be estimated	F1 = Poisoning	G1 = Germination	H1 = Do not know
A2 = 11–20	B2 = Irregular	C2 = Booting (*b*)	D2 = Booting	E2 = <100 kg ha^{-1}	F2 = Field sanitation	G2 = Booting	H2 = Good
A3 = 21–30	B3 = Frequent	C3 = Maturation (*m*)	D3 = Maturation	E3 = 100–500 kg ha^{-1}	F3 = Trapping	G3 = Maturation	H3 = Very good
A4 = 31–40	B4 = Regular	C4 = *g* and *b*	D4 = *g* and *b*	E4 = >500 kg ha^{-1}	F4 = Missing value	G4 = Missing value	H4 = Excellent
A5 = >40		C5 = b and m	D5 = *b* and *m*			G5 = g and b	H5 = Missing value
		C7 = *g*, *b*, and *m*	D7 = *g*, *b*, and *m*			G6 = *b* and *m*	
		C8 = Missing value				G7 = *g* and *m*	
						G8 = *g*, *b*, and *m*	

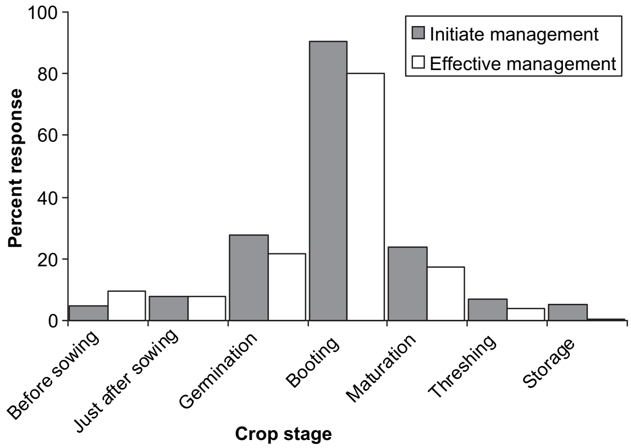

Fig. 5. Crop developmental stages preferred for initiation and for effective rodent management as perceived by respondents (Multiple responses were allowed in both cases; $n = 191$).

4.2. Damage

Farmers reported damage caused by rodents to both standing crops and stored grains. The results suggest that frequency of the damage ranges from every year to once in five years or more and the farmers were more concerned about the damage in the fields than in storage. However, during the pilot survey of the current study, the farmers were unable to estimate post-harvest damage. They estimated stored grain damage by merging it with animal feed (straw), storage materials and other household properties. Hence, later in the survey they were asked to estimate damage for pre-harvest only. Nevertheless, since the houses of the farmers are located in the middle of the farm or close to bushes and the grains are stored in granaries made of materials such as bamboo, dung, hide and jute, which can easily be attacked, a certain level of damage is anticipated. The most serious damage would be the loss of seeds for the next planting (Fiedler and Fall, 1994).

The amount of crop damage in fields estimated by the large majority of the farmers was alarming. The figure might seem small but for such a subsistence and small-holding farming community a 8.9–44.7% loss in annual production is hard to tolerate. Our figures are similar to central Ethiopia, where rodents have been documented to consume up to 26% of the maize crop in some years (Bekele and Leirs, 1997; Bekele et al., 2003).

There was some overlap between the most common crops cultivated in the highlands and the most susceptible crops to rodent attack. Wheat and barley were the two most preferred crops for cultivation but they were also suggested as the two most susceptible crops to rodent attack. In addition to being staple crops in the highlands (Bishaw, 2004; Birhanu et al., 2005), other possible explanation as to why the farmers kept growing mainly wheat and barley is that seed and varietal selection among Ethiopian highland farmers growing wheat and barely depends not only on tolerance to pests but also on environmental factors, previous experience and varietal characteristics such as grain yield, grain color, grain size, marketability and food quality (Bishaw, 2004; Fetien et al., 2008).

Farmers have identified critical crop developmental stages as far as rodent abundance and damage were concerned. The booting stage was identified as the stage where rodent abundance and damage was high. This perception may well be correct, but there are some caveats. First, it might be that the farmers tend to associate damage with a high population of rodents or vice versa (See Figs. 3 and 4). Secondly, although damage and economic losses are often difficult to estimate because of complex patterns of growth and recovery of plants in relation to the developmental stage when damage occurs (Fiedler and Fall, 1994), some crops are more damaged at a certain crop developmental stage than others. For instance, rodent damage to cereal crops such as wheat at later stages of crop development inflicted more significant loss on the overall production in Australia than damage at early stages of crop development (Brown et al., 2007). Similarly, an important part of rodent damage in maize fields in central Ethiopia was reported to be after the seedling stage (Bekele et al., 2003). Workneh et al. (2004) reported intense rodent attacks during the fruiting stage in irrigated fields in northern Ethiopia. Mulungu et al. (2005, 2006) reported that in Tanzania the damage after the seedling stage will have a significant impact on the potential yield of maize crops since farmers can not replant the seeds after the rainy season advanced. Further more, the chance of later stage regeneration for crops like wheat and barley will not be the same as the earlier stages of development.

In addition to the crop developmental stage, the farmers also identified 'August' as the month in which high crop damage occurred. 'August' coincides with the peak period of flowering and fruiting stages of the crops (between August and early September) (Berg, 1992; Pender and Berhanu, 2007).

The large majority of the farmers showed strong attitudes and knowledge of stone bunds, including their benefit for holding soil and increasing crop production. The result was in agreement with several on farm and survey studies conducted in the highlands (Berhanu et al., 1998; Vancampenhout et al., 2006; Menale et al., 2007; Pender and Berhanu, 2007; Nyssen et al., 2007). Information on claims that the stone bunds are creating habitats for rodents is rare. Belay and Edwards (2002) acknowledged the importance of stone bunds made for soil and water conservation in crop fields in Tigray, yet they also described them as breeding and hiding places for rodents, from where the rodents come out and feed on crops and emerging shoots of planted tree seedlings. Rämi (2002) reported an increase in rodent population of epidemic proportion in northern Gonder, northern Ethiopia, after years of stone bund construction in crop fields. We plan to assess the relation between stone bunds and rodent dynamics and crop damage in the future.

4.3. Management

It was evident from the result that rodent management was symptomatic and reactive. The large majority of farmers initiated rodent management after noticing damaged crops and rodent movement in the fields. Multiple rodent management strategies were practiced by the farmers. Poisoning was the most common in crop fields, even though supply of rodenticides is low in Ethiopia. We found that farmers bought rodenticide from the local market or sometimes received it free of charge (or at a reduced price) from a district agricultural office. Even so, repeated application of rodenticide was considered by the farmers as the best method to reduce rodent numbers and damage. Most farmers had no knowledge about the correct application of rodenticides (e.g. amount per ha, when and where to apply), most tried one or two applications which did not bring the desired reduction in rodent numbers and damage. It could also be that the rodenticides are weak. According to Haylamichael and Dalvie (2009), a 2005 inventory revealed the presence of 121 t of pesticides in the Tigray region, many of which were of poor quality, improperly packed, improperly labelled and/or banned.

Only about one-third of the farmers considered field sanitation as a first choice for rodent management. It is therefore doubtful whether the farmers realize the importance of field sanitation in reducing rodent numbers and crop damage. Rodents respond to reduction in vegetation cover with reduced spatial activity and increased perceived predation risk (Jacob, 2008). Reduction in food and shelter, including removal of grasses, weeds and undesirable vegetation in the fields and adjacent areas, will have an impact on the rodent populations (Jacob, 2008). Trapping was practiced less than poisoning and field sanitation in the fields. This could have been because of low cost-effectiveness (a trap costs about US$ 0.6 in local markets). Further more, traps left in the field could be removed by people or by non-target animals. Farmers can usually tolerate a certain level of crop damage (Brown et al., 2007). They decide to take action when the damage is beyond the acceptable level. They try to predict the probability of damage depending on observation and experience. Selection of the type of management against anticipated crop damage is believed to be the result of many factors including type of pest and crop, economic and social conditions and management skills and knowledge (Gray et al., 2009). Understanding of the level of crop damage which is unacceptable for farmers and which causes them to take management action remains an area for future research. It is generally believed that perceived economic injury levels will aid in deciding whether there is a necessity of suppressing the pest population (Wilson and Tisdell, 2001). Further more, economic injury levels for subsistence farmers are generally low leading to the use of poison for a quick reduction in pest infestation and damage level.

The farmers have knowledge of the potential role predators have in managing rodents. They described domestic and wild cats, a variety of avian predator, snakes, jackal, and mongoose as rodent predators. However, they did not report any practice to attract predators to the crop fields. On the other hand, a large majority of the farmers kept cats at home to manage rodents around granaries. The farmers believed that rodent management initiated at booting stage and in August rewarded a maximum result. This coincides with the time of high rodent damage, and with the time of flowering and fruiting stage of the main crops. One might assume that the farmers properly identified when management would be most effective. However, this sort of symptomatic treatment usually remains less rewarding (Stenseth et al., 2003). Rodent management should be initiated before economic damage can be inflicted. Since long-term population reduction is impractical, there is a need to research a particular period in the cropping season where management would be initiated before chronic damage occurs (Sultana and Jaeger, 1992; Leirs et al., 1997). Cooperative rodent management was less common. It was uncertain if the farmers understood the importance of managing rodents together. For instance, the remarkable damage estimated by the farmers in crop fields during booting stage could be reduced by cooperative rodent management before the onset of the breeding season (Singleton et al., 2005; Brown et al., 2007). Synchronized planting and harvesting could also be employed because rodents are reported to migrate from early planted fields to later planted fields and from early harvested fields to not harvested fields in search of food and cover (Sultana and Jaeger, 1992; Leirs et al., 1997; Cavia et al., 2005).

We conclude that rodents were perceived as the main crop pest in the highlands of Tigray. However, the frequency of occurrence and damage by rodents ranged from rare to every cropping season. Farmers were more concerned with crop damage in the fields than in storage. There was a certain overlap between the most common crops cultivated in the highlands and the most susceptible crops for rodent attack. Farmers identified the booting stage as the stage where rodent damage and abundance was high. The farmers also identified 'August' as the month of high crop damage. The majority of the farmers showed strong attitude and knowledge towards the benefits of stone bunds, though most of them also believed that the stone bunds were acting as habitats for the rodents and that damage had increased since the stone bunds were built in crop fields. Rodent management in the highlands was symptomatic and involved the use of rodenticide. Trapping, attracting predators, field sanitation involving reduction in vegetation cover and elimination of potential rodent shelter and cooperative rodent management were less common.

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References

Bekele, A., Leirs, H., 1997. Population ecology of rodents of maize fields and grasslands in central Ethiopia. Belgian Journal of Zoology 127, 39–48.
Bekele, A., Leirs, H., Verhagen, R., 2003. Composition of rodents and damage estimates on maize farms at Ziway, Ethiopia. In: Singleton, D.R., Hinds, L.A., Krebs, C.J., Spratt, D.M. (Eds.), Rats, Mice and People: Rodent Biology and Management. ACIAR Monograph No. 96, p. 564.
Belay, M., Edwards, S., 2002. Healing the earth for sustainable agriculture: An Ethiopian story. Third World Resurgence magazine Issue No. 145–146.
Berg, T., 1992. Indigenous knowledge and plant breeding in Tigray, Ethiopia. Forum for Development Studies 1, 13–22.
Berhanu, G., Swinton, S.M., Yibebe, T., 1998. Effects of stone terraces on crop yields & farm profitability: results of on-farm research in Tigray, Northern Ethiopia. Soil and Water Conservation 54 (3), 568–573.
Birhanu, B., Fekadu, A., Berhane, L., 2005. Food barley in Ethiopia. In: Stefania, G., Macpherson, H.G. (Eds.), Food Barley: Importance, Uses and Local Knowledge. Proceedings of the International Workshop on Food Barley Improvement. ICARDA, Hammamet, Tunisia Aleppo, Syria.
Bishaw, Z., 2004. Wheat and barley seed systems in Ethiopia and Syria. PhD Dissertation, Wageningen University, The Netherlands.
Brown, P.R., Yee, N., Singleton, G.R., Kenney, A.J., Htwe, N.M., Myint, M., Aye, T., 2008. Farmers' knowledge, attitudes, and practices for rodent management in Myanmar. International Journal of Pest Management 54 (1), 69–76.
Brown, P.R., Huth, N.I., Banks, P.B., Singleton, G.R., 2007. Relationship between abundance of rodents and damage to agricultural crops. Agriculture, Ecosystems & Environment 120, 405–415.
Cavia, R., Gómez Villafañe, I.E., Cittadino, E.A., Bilenca, D.N., Mariela, H., Miño, M.H., Busch, M., 2005. Effects of cereal harvest on abundance and spatial distribution of the rodent *Akodon azarae* in central Argentina. Agriculture, Ecosystems & Environment 107 (Issue 1), 95–99.
D'aes, M., 2006. Impact of stone bund building on rat population and damages in the Northern Ethiopian Highlands. MSc thesis, Department of Biology, University of Antwerp, Belgium.
Desta, G., Poesen, J., Nyssen, J., Deckers, J., Mitiku, H., Govers, G., Moeyersons, J., 2005. Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray highlands, Northern Ethiopia. Soil Use and Management 21, 287–297.
Fetien, A., Waters-Bayer, A., Bjørnstad, Å, 2008. Farmers' seed management and innovation in varietal selection: implications for barley breeding in Tigray, Northern Ethiopia. AMBIO: Journal of the Human Environment 37 (4), 312–320.
Fiedler, L.A., Fall, M.W., 1994. Rodent control practice: tropical field crops. In: Buckle, A.P., Smith, R.H. (Eds.), Rodent Pests and Their Control. CAB International, UK.
Fredu, N., Zaid, N., Kidanemariam, G., Abebe, E., Mihret, B., Nyssen, J., Bedru, B., Deckers, J., Tollens, E., 2006. Tigray Livelihood Papers: Participatory Rural Appraisal Report of Selected Villages in Tigray. VLIR–Mekelle University IUC Program, Ethiopia.
Gray, M.E., Ratcliffe, S.T., Rice, M.E., 2009. The IPM paradigm: concepts, strategies and tactics. In: Radcliffe, E.B., Hutchison, W.D., Cancelado, R.E. (Eds.), Integrated Pest Management – Concepts, Tactics, Strategies and Case Studies. Cambridge University Press.
Greenacre, M.J., 1984. Theory and Applications of Correspondence Analysis. Academic Press, London.
Haylamichael, I.D., Dalvie, M.A., 2009. Disposal of obsolete pesticides, the case of Ethiopia. Environment International 35, 667–673.
Herweg, K., 1993. Problems of acceptance and adaptation of soil conservation in Ethiopia. In: Baum, E., Wolff, P., Zöbisch, M.A. (Eds.), Acceptance of Soil and Water Conservation Strategies and Technologies. Topics in Applied Resource Management, vol. 3, pp. 391–411.
Jacob, J., 2008. Response of small rodents to manipulations of vegetation height in agro-ecosystems. Integrative Zoology 3, 3–10.
Leirs, H., 2003. Management of rodents in crops: the pied piper and his orchestra. In: Singleton, D.R., Hinds, L.A., Krebs, C.J., Spratt, D.M. (Eds.), Rats, Mice and People: Rodent Biology and Management. ACIAR Monograph No. 96, p. 564.

Leirs, H., Verhagen, R., Sabuni, C.A., Mwanjabe, P., Verheyen, W.N., 1997. Spatial dynamics of *Mastomys natalensis* in a field fallow mosaic in Tanzania. Belgian Journal of Zoology 127, 29–38.
Makundi, R.H., Mbise, T.J., Kilonzo, B.S., 1991. Observations on the role of rodents in crop losses in Tanzania and control strategies. Tropical Agriculture & Veterinary Medicine 29, 465–474.
Makundi, R.H., Bekele, A., Leirs, H., Massawe, A.W., Mulungu, L.S., Rwamugira, W., 2003. Farmer's perception of rodents as crop pests: knowledge, attitude and practice in rodent pest management in Tanzania and Ethiopia. Belgian Journal of Zoology 135, 153–157.
Makundi, R.H., Oguge, N., Mwanjabe, P.S., 1999. Rodent Pest Management in East Africa. ACIAR Monograph no.59, Canberra, Australia.
Meerburg, B.G., Singlton, G.R., Leirs, H., 2009. The year of the rat ends-time to fight hunger! Pest Management Science 65, 351–352.
Mekuria, W., Veldkamp, E., Mitiku, H., Gebrehiwot, K., Muys, B., Nyssen, J., 2009. Effectiveness of exclosures to control soil erosion and local community perception on soil erosion in Tigray, Ethiopia. African Journal of Agricultural Research 4 (4), 365–377.
Menale, K., Pender, J., Mahmud, Y., Kohlin, G., Bluffstone, R., Elias, M., 2007. Impact of Soil Conservation on Crop Production in the Northern Ethiopian Highlands. International Food Policy Research Institute (IFPRI) Discussion Paper 00733, Washington DC, USA.
Mitiku, H., Eyasu, Y., Girmay, T., 2001. Land Tenure and Plot Size Determination Issues in Small Scale Irrigation Development Schemes in Tigray, Ethiopia: A Survey Study in Seven Traditional and Introduced Irrigation Schemes. Mekelle University, Ethiopia.
Mulungu, L.S., Makundi, R.H., Massawe, A.W., Machang'u, R., Ngowo, V., Leirs, H., 2005. Spatial patterns and distribution of damage in maize fields due to *Mastomys natalensis* in Tanzania. Belgian Journal of Zoology 135, 183–185.
Mulungu, L.S., Makundi, R.H., Massawe, A.W., 2006. Characteristics of rodent damage to major crops in Tanzania and crop loss assessment techniques. In: Makundi, R.H. (Ed.), Management of Selected Drop Pests in Tanzania. Tanzanian Publishing House Limited, Dar Es Salaam.
Nyssen, J., Mitiku, H., Poesen, J., Deckers, J., Moeyersons, J., 2001. Removal of rock fragments and its effect on soil loss and crop yield, Tigray, Ethiopia. Soil Use & Management 17, 179–187.
Nyssen, J., Poesen, J., Desta, G., Vancampenhout, K., D'aes, M., Gebremedhin, Y., Govers, G., Leirs, H., Moeyersons, J., Naudts, J., Nigussie, H., Mitiku, H., Deckers, J., 2007. Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia. Soil & Tillage Research 94, 151–163.
Nyssen, J., Poesen, J., Moeyersons, J., Mitiku, H., Deckers, J., 2008. Dynamics of soil erosion rates and controlling factors in the Northern Ethiopian highlands – towards a sediment budget. Earth Surface Processes and Landforms 33, 695–711.
Pender, J., Berhanu, G., 2007. Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigray, Ethiopia. Journal of African Economies 17, 395–450.
Rämi, H., 2002. Food aid is not development. Case studies from North and South Gondar. UN-Emergencies Unit for Ethiopia.
RBoANR, 2002. Annual Summary Report – Soil and Water Conservation in Tigray. Bureau of Agriculture and Natural Resource Development, Mekelle, Ethiopia.
SAS® Institute, 2003. GLM: A Guide to Statistical and Data Analysis, Version 9.1. SAS Institute, Cary.
Singleton, G.R., SudarmajiJacob, J., Krebs, C.J., 2005. Integrated management to reduce rodent damage to lowland rice crops in Indonesia. Agriculture, Ecosystems & Environment 107, 75–82.
SPSS®, 2003. 12.0 Brief Guide. SPSS Inc, Chicago USA.
Stenseth, N.C., Leirs, H., Skonhoft, A., Davis, S.A., Pech, R.P., Andreassen, H.P., Singleton, G.R., Lima, M., Machangu, R.M., Makundi, R.H., Zhang, Z., Brown, P., Shi, D., Wan, X., 2003. Mice, rats and people: the bio-economics of agricultural rodent pests. Frontiers in Ecology and the Environment 1, 367–375.
Sultana, P., Jaeger, M.M., 1992. Control Strategies to Reduce Pre-Harvest Rat Damage in Bangladesh. Proceedings of 15th Vertebrate Pest Conference. University of Nebraska, USA.
Vancampenhout, K., Nyssen, J., Gebremichael, D., Deckers, J., Poesen, J., Mitiku, H., Moeyersons, J., 2006. Stone bunds for soil conservation in the northern Ethiopian highlands: impacts on soil fertility and crop yield. Soil & Tillage Research 90, 1–15.
Wilson, C., Tisdell, C., 2001. Why farmers continue to use pesticides despite environmental, health and sustainability costs. Ecological Economics 39, 449–462.
Workneh, G., Bekele, A., Gurja, B., Balakrishnan, M., 2004. Microhabitat choice and diet of rodents in Maynugus irrigation field, northern Ethiopia. African Journal of Ecology 42, 315–321.