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Farmers' insect pest management practices and pesticidal plant use in the protection of stored maize and beans in Southern Africa

John Kamanula[a], Gudeta W. Sileshi[b]*, Steven R. Belmain[c], Phosiso Sola[d], Brighton M. Mvumi[e], Greenwell K.C. Nyirenda[f], Stephen P. Nyirenda[g] and Philip C. Stevenson[c,h]

[a]*Department of Chemistry, Mzuzu University, Private Bag 201, Luwinga, Mzuzu 2, Malawi;* [b]*World Agroforestry Centre (ICRAF), Southern Africa Programme, Chitedze Agricultural Research Station, PO Box 30798, Lilongwe, Malawi;* [c]*Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK;* [d]*Southern Alliance for Indigenous Resources, PO Box BE 398, Belvedere, Harare, Zimbabwe;* [e]*Department of Soil Science & Agricultural Engineering, Faculty of Agriculture, University of Zimbabwe, PO Box MP167, Mount Pleasant, Harare, Zimbabwe;* [f]*Bunda College, University of Malawi, PO Box 219, Lilongwe, Malawi;* [g]*Department of Agricultural Research Services, PO Box 59, Mzuzu, Malawi;* [h]*Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, UK*

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Storage losses due to pests threaten livelihoods of farmers across Africa. Synthetic pesticides provide effective control when used correctly but resource-poor farmers cannot afford them. A survey of farmer ethno-ecological knowledge of pests of stored maize and bean, and their pest management practices including pesticidal plant use, was conducted in eastern Zambia and northern Malawi. Almost all respondents reported serious pest damage, with bruchids (*Callosobruchus maculatus*) and grain weevils (*Sitophilus* spp.) being major pests in beans and maize, respectively. The larger grain borer (*Prostephanus truncatus*) was reported more widely in Malawi. In Zambia, 50% of farmers used synthetic pesticides during storage, while nearly all did so in Malawi. Despite differences in storage methods between Malawi and Zambia, farmers in both countries were familiar with pesticidal plants, where *Tephrosia vogelii* was the most frequently reported. Surprisingly few farmers actually used pesticidal plants, highlighting a promotion opportunity. Our results provide a foundation for optimizing the use of pesticidal plants and enhancing their value to resource-poor farmers, across Africa.

Keywords: *Callosobruchus*; ethno-ecology; pesticidal plants; *Prostephanus*; *Sitophilus*; *Tephrosia*

1. Introduction

Post-harvest losses are recognized as being one of the critical constraints upon food security among resource-poor farmers across Africa (Owusu 2001; Owusu et al. 2007). Without chemical treatment, household-level losses of 40–100% have been reported in Malawi (Denning et al. 2009). These negate much of the productivity gain made through other agricultural innovations. Therefore, safeguarding crops from such losses is an important step towards ensuring food security. Increasing severity of post-harvest problems is largely due to both the increased use of high-yielding varieties which are susceptible to storage pests and the recent arrival of more damaging and invasive alien pests such as the larger grain borer (LGB), *Prostephanus truncatus* (Phiri and Otieno 2008). In addition to LGB, the most important stored products pests in Africa are grain weevils (*Sitophilus* spp.) and the Angoumois Grain Moth (*Sitotroga cerealella*) on cereals, and bruchids (*Acanthoscelides, Zabrotes* and *Callosobruchus*) on legumes (Abate et al. 2000). The use of synthetic insecticides for grain protection in traditional farm stores in Africa has been partially successful (Ogendo et al. 2004). However, the subsistence nature of agriculture, the poor dissemination of information, and the high cost and erratic supply of synthetic pesticides have emerged as reasons for farmers' reluctance to adopting synthetic pesticides (Tembo and Murfitt 1995; Belmain and Stevenson 2001; Ogendo et al. 2004). These problems, and the possibility of misuse of pesticides, and the accompanying undesired effects, demand a vigorous search for alternative pest control practices (Owusu et al. 2007).

Traditionally, farmers have used various forms of cultural practices and herbal products for the control of post-harvest insect pests, and local communities still continue to use an array of insecticidal plants for the control of specific pests (Abate et al. 2000). Ethno-ecology or traditional ecological knowledge (Berkes 2008) is important for the identification of indigenous practices and for the formulation of sustainable pest management strategies relevant to local conditions (Altieri 1993; Sileshi et al. 2008, 2009). Ethno-botanical research has documented traditional uses of various plants in folk medicine and protection of agricultural crops against pre-harvest and post-harvest pests

*Corresponding author. Email: sgwelde@yahoo.com

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(Lehman et al. 2007). Inferences from indigenous traditional practices have uncovered plant chemicals that are useful in pest management, for example, azadirachtin (from neem), rotenone (from *Derris* spp.) and pyrethrum (Casida 1973; Taylor 2005). Farmers' indigenous knowledge will provide a foundation for optimizing existing practices or identifying novel environmentally benign and appropriate management strategies.

Unfortunately, indigenous practices have been dismissed by some researchers in the absence of sufficient work to demonstrate their potential (Sileshi et al. 2008, 2009). This is because the performance of indigenous practices is often judged against insecticidal control, which often gives an immediate result with almost total impact. For a farmer who does not have access to synthetic products, even low efficacy (~50% control) can still be considered effective. So, instead of dismissing such practices as ineffective and unsuitable, their rationale and shortcomings need to be seen as a means for generating contextual and site-specific knowledge. In this way, limitations of indigenous practices can be identified and solutions with local relevance may be generated. This emphasizes the point that ethno-ecological knowledge is best employed as a complement to, rather than a substitute for, scientific knowledge (Sileshi et al. 2009). Research and development in IPM for use by subsistence African farmers requires incorporation of indigenous knowledge about natural products and their local use.

The aims of the study were to: (1) assess farmers' knowledge and perceptions of pests of stored maize and beans; (2) identify farmers' indigenous pest management practices; and (3) assess the extent of pesticidal plant use by farmers' for the control of pests of stored maize and beans in northern Malawi and eastern Zambia. Maize and beans were chosen for this study because they are the most important cereal and legume crops, respectively, in southern Africa. Maize accounts for more than 60% of the cropped area in Malawi and Zambia and is almost as dominant in Kenya and Tanzania. Beans are the major source of dietary protein across Africa (Broughton et al. 2003) and they provide an additional source of income, especially for women farmers who produce the crop in Malawi (Chirwa 2002).

2. Materials and methods

2.1. The study area

The study was conducted in two districts of northern Malawi and 3 districts of eastern Zambia. The sites in northern Malawi were Jenda (12°22' S, 33°33' E) in Champhira Extension Planning Area (EPA) of Mzimba district and Nchenachena EPA (10°45' S, 33°57' E) in Rhumphi district. The sites in eastern Zambia were Chadiza (14°03'S, 32°26' E) in Chadiza district, Mugabi (13°38' S, 32°39' E) in Chipata district and Katete (14°03' S, 32°02' E) in Katete district (Figure 1). These locations were specifically chosen because farmers grow maize and beans widely. In addition, the sites in the two countries were chosen to facilitate transfer of knowledge and experiences among the beneficiary through a common language. The majority of the people in the study area in Malawi belong to the Tumbuka and Ngoni ethnic groups, while those in eastern Zambia belong to the Ngoni and Chewa ethnic groups. All of the respondents could speak Chinyanja or Chichewa, which are closely related languages belonging to the Bantu group of languages spoken in southern Africa.

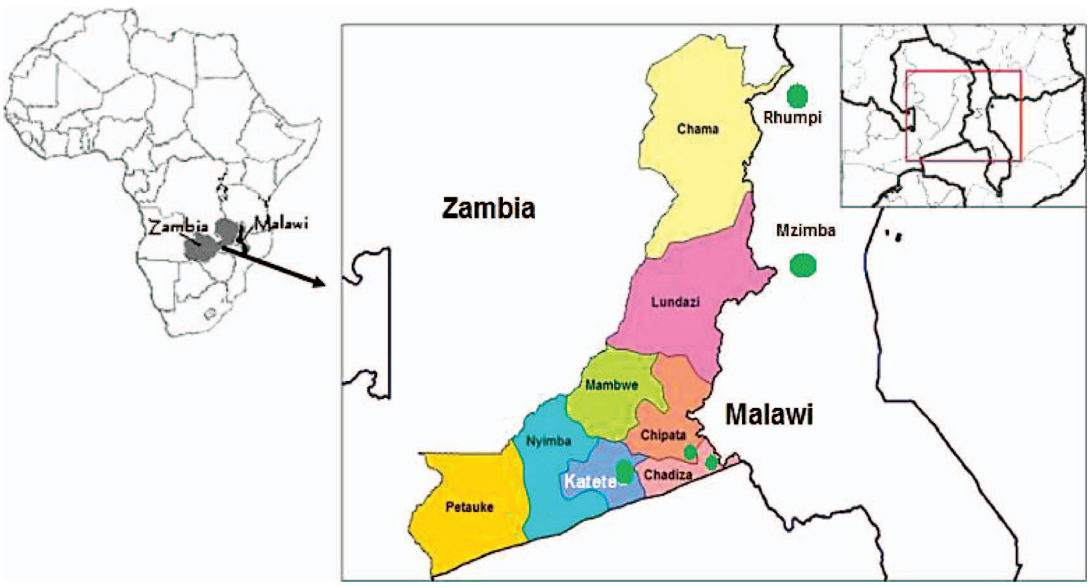

Figure 1. Map of the study sites in Zambia (i.e. Chadiza, Katete and Chipata districts) and Malawi (Mzimba and Rumphi districts).

2.2. Data collection and analyses

Data were collected through household surveys conducted in November and December 2007 in northern Malawi and eastern Zambia, respectively. Semi-structured questionnaires were administered to households that were randomly selected from a list of households held by the extension officers. In all, 167 farmers (60% men and 40% women) were interviewed in northern Malawi, while in eastern Zambia 91 farmers (83.5% men and 16.5% women) were interviewed.

The qualitative and quantitative data were summarized as contingency tables, and analysed using the chi-squared test. A generalized linear model assuming binomial/multinomial error distribution of farmer responses was used to characterize respondents' knowledge of pesticidal plants and the use of these plants for pest control purposes. It was hypothesized that farmer's awareness and use of pesticidal plants is a function of farmer-specific explanatory variables such as age, sex, education level and years of experience in farming. Parameters of the logit linear model were estimated using the LOGISTIC procedure of SAS (2003). The model was run after combining the data for the two countries, as initial analysis disaggregated by country showed quasi-complete separation of data points.

3. Results

3.1. Demographic characteristics of respondents

Most of the respondents (>60%) were male, and over 79% of them were older than 25 years of age in both northern Malawi and eastern Zambia (Table 1). The majority of respondents in northern Malawi (94%) and eastern Zambia (77%) had received formal education. Respondents were predominantly married (>85%), with single, widowed and divorced respondents accounting for less than 15% in eastern Zambia and northern Malawi (Table 1). About 60% of the households in northern Malawi were medium (4–6 people) to large (>6 people per household in size). In eastern Zambia, 84% of the households were medium to large.

A large proportion (>63%) of the respondents had long experience (>5 years) in farming (Table 2). The majority of the respondents in northern Malawi (55%) and eastern Zambia (77%) farmed more than 1.0 ha

Table 1. Distribution of respondents according to demographic characteristics in Malawi and Zambia.

Variable	Category	Malawi (n = 167)	Zambia (n = 91)
Gender	Female	39.9	16.5
	Male	60.1	83.5
Age	Young (<25 years)	21.1	12.1
	Middle aged (25–40 years)	44.9	42.9
	Old (>40 years)	34.1	45.1
Education level	Illiterate	6.0	23.1
	Primary (up to SD 8)	58.7	58.2
	Secondary (>SD 8)	33.5	18.7
	Tertiary (Post secondary)	1.8	–
Marital status	Divorcee/widowed	8.4	3.3
	Married	85.7	95.6
	Single	10 (6.0)	1.1
Household size	Small (<4 people)	39.5	16.5
	Medium (4–6 people)	39.5	30.8
	Large (>6 people)	21.0	52.8

Note: Figures are percentages of respondents and the significance of difference between categories.

Table 2. Distribution of respondents according to farming experience, land holding size, form of land acquisition and perception of land tenure and land holding in Malawi and Zambia.

Variable	Category	Malawi (n = 167)	Zambia (n = 91)
Farming experience	Short (<5 years)	36.8	30.8
	Long (>5 years)	63.2	69.2
Land holding	Small (<0.4 ha)	3.1	–
	Medium (0.4–1 ha)	42.3	23.3
	Large (>1 ha)	54.6	76.7
Form of land acquisition	Given by chief	5.4	17.6
	Inherited	91.7	76.9
	Lease-hold/rent	3.0	2.2
	Private	–	3.3
Preferred land tenure	Customary land	96.4	60.4
	Private/purchased	1.8	38.5
	Lease-hold/rent	1.8	1.1

Note: Figures are percentages of respondents and the significance of difference between categories.

while small land holdings (<0.4 ha) were less common in eastern Zambia than in northern Malawi. Over 91 and 76% of the respondents in northern Malawi and eastern Zambia, respectively, had inherited land. Those who purchased, leased or rented land constituted a small proportion (<4%) of the respondents (Table 2).

3.2. *Maize and bean production and mode of storage*

Maize was grown by all of the respondents, in both eastern Zambia and northern Malawi (Table 2). Beans were grown by 94% of the respondents in northern Malawi and 48.4% in eastern Zambia. Several varieties of maize and bean were mentioned by respondents in northern Malawi and eastern Zambia. Improved varieties accounted for over 55% of the maize grown in both countries. Local maize varieties accounted for 37 and 43% of all varieties in northern Malawi and eastern Zambia, respectively (Table 3). There were several minor varieties, each accounting for less than 5% of the maize varieties grown. Among the bean varieties, a local landrace accounted for 16%, while two improved varieties (Maluwa and Nyauzembe) accounted each for 12% of the varieties grown in northern Malawi. Similarly, in eastern Zambia, a local landrace (red beans) accounted for about 19%, while two improved varieties (Kabulangeti and Lyambai) each accounted for about 14% (Table 3). The rest of the varieties constituted less than 10% each.

The main seed sources of maize (62.1%) and beans (55.1%) were shops in northern Malawi because most of the seed used was hybrid. Own seed accounted for about 30% for beans and maize, indicating that farmers store seed for later use. Other sources included family/friends, coupons from an input subsidy programme, and clubs, which accounted for less than 10% of the seed sources. In eastern Zambia, own seed accounted for 49% of the maize seed followed by shops (40%), cooperatives (6%), friends (4%) and non-governmental organizations (NGOs). In the case of beans, the major sources of seeds were shops (60%) and friends (40%).

Figure 2 presents the facilities used for storing maize and beans in the two countries. In northern Malawi, sacks were the major storage facility for both maize (54%) and beans (97%). In northern Malawi, farmers believe that shelled maize kept in sacks is less susceptible to insect attack. In eastern Zambia, the majority of farmers stored unshelled maize in granaries (81%) and beans in sacks (82%).

3.3. *Farmers' knowledge of storage pests and their management practices*

In the study areas, respondents mentioned experiencing pest damage on stored maize and beans. In northern Malawi, all respondents experienced pest damage on maize and 93% experienced damage on beans.

Table 3. Maize and bean varieties mentioned by farmers in northern Malawi and eastern Zambia.

Maize varieties				Bean varieties			
Malawi	Percent	Zambia	Percent	Malawi	Percent	Zambia	Percent
Hybrid*	38.1	Local	43.4	Local	16.1	Red beans	18.6
Local	37.3	MRI 634	9.3	Maluwa	12.4	Lyambai	14
MH 18	4.8	Hybrid	8.5	Nyauzembe	11.7	Kabulangeti	13.9
Kanyani	2.4	SC	6.2	Napilira	10.9	Local	9.3
OPV	2.4	MRI	4.6	Kalima	10.2	PAN 148	9.3
SC 403	1.6	MRI 604	4.6	Dwarf	7.3	Solwezi	7
SC 715	1.6	SC 531	3.9	Mixed	7.3	Red giant	4.7
DK 8031	2.0	Pannar	3.1	Saba	7.3	Sweet beans	4.7
DK 8033	1.2	MM 604	2.3	Jandalala	3.6	White beans	4.7
PAN 67	1.2	PAN 53	2.3	Sugar beans	3.6	Bonanza	2.3
Mkango	0.8	PAN 67	2.3	Zoyera	2.2	Carioca	2.3
MZ 520	0.8	Pioneer	2.3	Sweet beans	1.5	Lundazi	2.3
DK 8051	0.4	K0833	0.8	Nanyati	1.5	Lukupa	2.3
DK 8073	0.4	MM 603	0.8	Khalatsonga	0.7	Nyatakala	2.3
Composite	0.4	PAN 6777	0.8	Masusu	0.7	Nyenyati	2.3
MH 17	0.4	PAN MR1	0.8	Sapasika	0.7		
MH 33	0.4	Pool 16	0.8	Senjere	0.7		
MZ 21	0.4	SC 267	0.8	Kachikwama	0.7		
PAN 77	0.4	SC 513	0.8				
SC 407	0.4	SC 627	0.8				
SC 512	0.4	SC 621	0.8				
SC 627	0.4						
SC 713	0.4						
UCA	0.4						
ZM 521	0.4						
ZM 627	0.4						

Note: *A total of 38.1% farmers mentioned 'hybrid' without specifying the variety.

Similarly, in eastern Zambia, 95 and 100% of the respondents mentioned experiencing pest damage to stored maize and beans, respectively. A small proportion of the respondents (<5%) were unaware of storage pests (Table 4).

Sitophilus spp. and LGB were the topmost pests of stored maize in the study areas (Table 4). Zambian respondents mentioned *Sitophilus* spp. with greater frequency (59%) compared with LGB (36%). Among the pest of stored beans mentioned by respondents in northern Malawi, bruchids accounted for the largest proportion (71%) followed by *Sitophilus* spp. (15%) and *Tribolium* (7%). On the other hand, the major pests of stored beans mentioned by respondents in eastern Zambia were *Sitophilus* spp. (65%), bruchids (16%), *Tribolium* (8%) and LGB (5%).

The majority of respondents in northern Malawi (94%) and eastern Zambia (60%) said they had taken actions to control storage pests of maize and beans. Farmers pest control actions in northern Malawi were dominated by the use of synthetic pesticides ($\chi^2 = 289.3$; $P < 0.001$) compared to the use of resistant varieties, cultural practices and pesticidal plants (Figure 3a). Similarly in eastern Zambia, a significant majority ($\chi^2 = 80.0$; $P < 0.001$) used synthetic pesticides (Figure 3b). Actellic (Pirimiphos-methyl) and its cocktails were the most frequently mentioned synthetic pesticides in eastern Zambia (54%) and northern Malawi (96%). These included Actellic Super dust (Pirimiphos-methyl 1.6% + Permethrin 0.3%) and Shumba Super (fenitrothion 1.0% + deltamethrin 0.13%) in northern Malawi, and Actellic Chirindamatura dust (Pirimiphos-methyl 1.6% + deltamethrin 0.13%) and Actellic Super (40% Pirimiphos-methyl + 10% permethrin) in eastern Zambia. Respondents also mentioned several pesticides of minor use (Figure 3c, d).

About 15% of the respondents in both countries had used cultural practices including application of wood ash, drying grain and smoking seeds. Some 16%

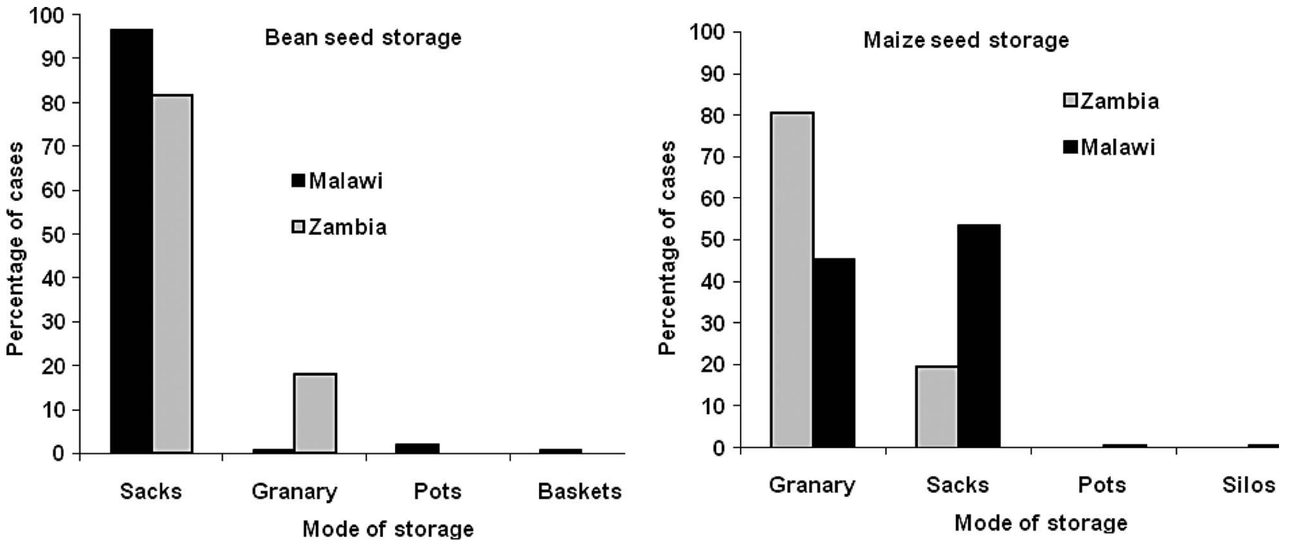

Figure 2. Percentages of farmers using various facilities for maize and bean storage in northern Malawi and eastern Zambia.

Table 4. Major pests of stored maize and beans mentioned by respondents in northern Malawi and eastern Zambia.

Country	Pests of maize	Percent	Pest of beans	Percent
Malawi	*Sitophilus* spp.	46.1	Bruchids	70.9
	Larger grain borer	46.1	*Sitophilus* spp.	14.6
	Bruchids	3.4	*Tribolium* spp.	6.8
	Don't know	0.6	Don't know	3.9
	Missing (not answered)	3.9	Rats	2.9
	–	–	Moths	1.0
Zambia	*Sitophilus* spp.	59.3	*Sitophilus* spp.	64.9
	Larger grain borer	36.0	Bruchids	16.2
	Moths	3.5	*Tribolium* spp.	8.1
	Tribolium spp.	1.2	Larger grain borer	5.4
	–	–	Moths	5.4

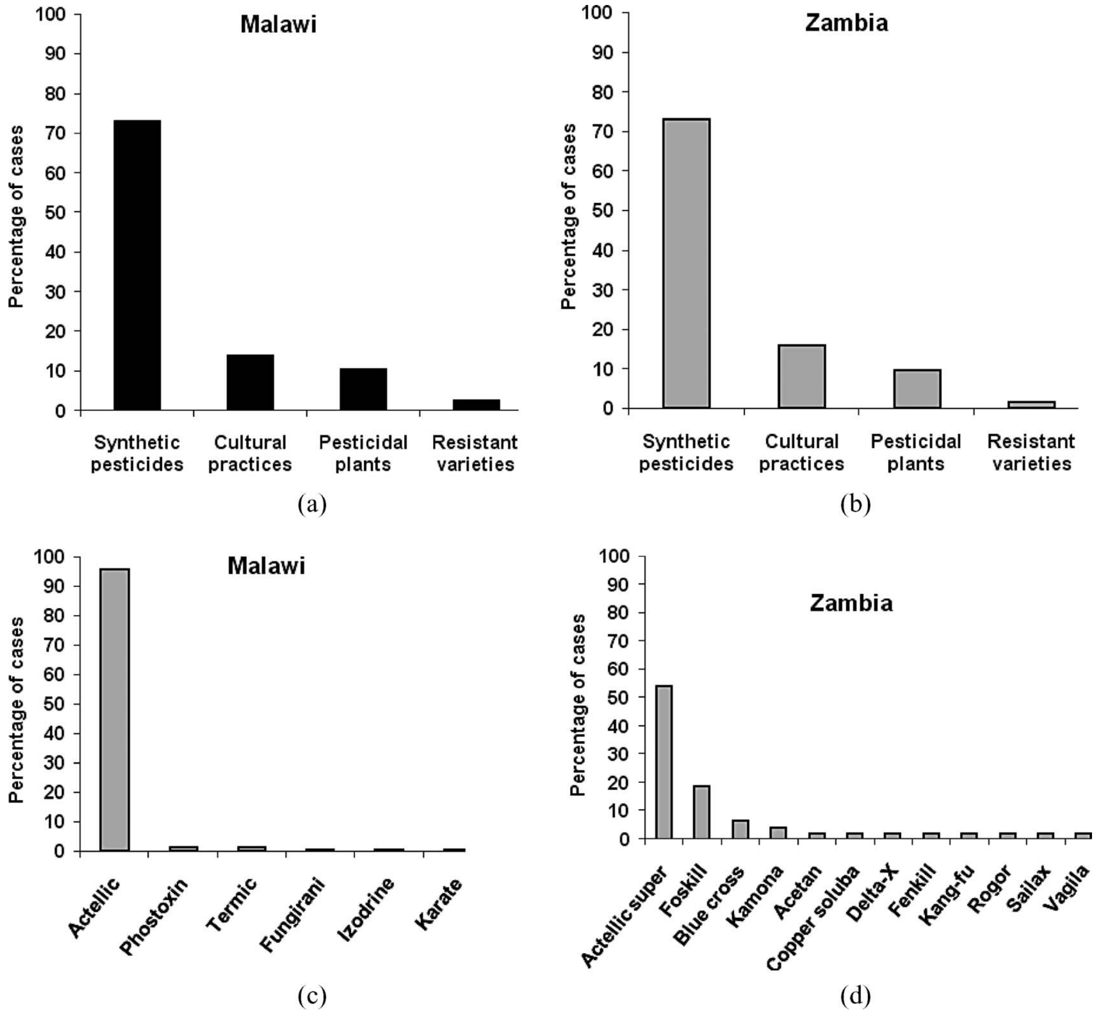

Figure 3. Pest management practices (a, b) and synthetic pesticides (c, d) used by respondents in northern Malawi and eastern Zambia.

of the respondents in northern Malawi had used wood ash. The majority (57%) of those who applied ash used it for controlling pests of beans while 36% used it to control pests of stored maize. Out of the 91 respondents in eastern Zambia, only one person mentioned using ash for control of LGB. Four farmers in northern Malawi had also applied paraffin to stored beans.

Most of the respondents in northern Malawi (61%) and eastern Zambia (89%) were knowledgeable about the use of pesticidal plants in controlling pests of stored maize and beans. Parents or friends were the major source of information about pesticidal plants to 76% of the respondents in northern Malawi, while extension officers and researchers accounted for only 39% and 27%, respectively. In eastern Zambia, extension (39%) and parents or friends (25%) were the main sources of information for pesticidal plants. Other sources accounted for less than 2%.

Despite the majority being aware of pesticidal plants, a small proportion of the respondents in northern Malawi (22%) and eastern Zambia (9.9%) had actually used them. Those who used pesticidal plants mentioned having used two or more of them. Among the plant species that respondents had used, tephrosia (*Tephrosia vogelii*, Fabaceae) was known by the majority of respondents in northern Malawi (86%) and eastern Zambia (62%). However, only 18% in northern Malawi and 6% in eastern Zambia had actually used it. When those respondents who used pesticidal plants were considered separately (Figure 4), tephrosia accounted for 68 and 63% of all pesticidal plants used in northern Malawi and eastern Zambia, respectively.

According to the logit-linear model (Table 5), the significant factors associated with knowledge of pesticidal plants were respondents' gender ($\chi^2 = 4.5$; $P = 0.035$), level of education ($\chi^2 = 12.5$; $P = 0.002$), age and farming experience ($\chi^2 = 9.6$; $P = 0.002$), where the model gave 61% correct classification (25.8% discordant). Slightly more women (77%) were knowledgeable about pesticidal plants than men

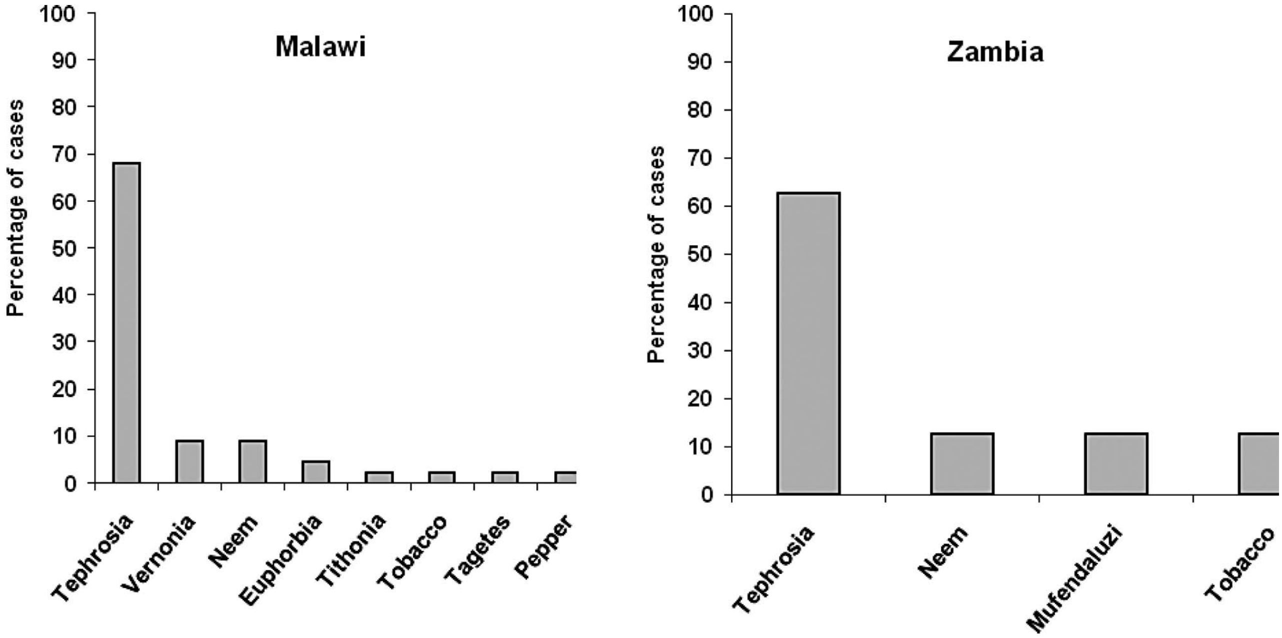

Figure 4. Pesticidal plants used by farmers in northern Malawi and eastern Zambia.

Table 5. Association of respondents' knowledge and use of pesticidal plants with sex, and education and farming experience in the study areas (Malawi and Zambia data combined).

	Variable	Category	Estimate	χ^2	Probability
Knowledge	Intercept		−0.69 (0.18)	14.1	0.0002
	Gender	Female	−0.35 (0.16)	4.5	0.0346
	Education	None	0.98 (0.29)	11.4	0.0007
		Primary	−0.19 (0.20)	0.9	0.3485
	Experience	Long	−0.47 (0.15)	9.6	0.0020
Use	Intercept		−0.35 (0.20)	3.0	0.0826
	Gender	Female	−0.33 (0.17)	3.9	0.0484
	Education	None	1.31 (0.35)	13.7	0.0002
		Primary	−0.52 (0.23)	5.3	0.0216

(68%). A large proportion of those with secondary education (78%) were knowledgeable compared to those with primary education (71%) and illiterate respondents (48.3%). The majority of respondents that had greater than 5 years of farming experience (76%) were more knowledgeable than those with shorter experience (61%). Actual use of pesticidal plants was significantly associated only with gender ($\chi^2 = 3.9$; $P = 0.049$) and education level ($\chi^2 = 13.8$; $P < 0.001$), where the model gave 53% correct classification (23% discordant). Parameters of the significant explanatory variables are presented in Table 5.

3.4. *Farmers' constraints*

Although farmers were knowledgeable about pests of stored maize and beans, some of their perceptions did not agree with scientific perceptions. For example, farmers in eastern Zambia mentioned *Sitophilus* spp. as a pest of stored beans while other farmers mentioned bruchids as pests of maize. Farmers also seemed to apply insecticides not recommended for control of pests of stored products (Figure 3). A significantly ($\chi^2 = 91.6$; $P < 0.001$) large proportion of respondents (64%) in northern Malawi regarded synthetic pesticides as expensive, 33% regarded them as affordable while the remaining 3% were not sure. In eastern Zambia, a significant ($\chi^2 = 21.9$; $P < 0.001$) proportion (55%) regarded pesticides as expensive, while 15% regarded them as affordable, and the remaining 30% were not sure. Availability of pesticidal plants was also another constraint for farmers. Respondents that stated pesticidal plants to be scarce accounted for 42% in northern Malawi and 39% in eastern Zambia. About 62% of the respondents in northern Malawi and 13% in eastern Zambia stated pesticidal plants to be abundant in their area.

4. Discussion

From the demographic characteristics (Table 1), it can be seen that the respondents involved in the survey represent typical farmers in terms of gender, age, education level, farming experience and resource endowment. Therefore, we believe the sample is representative of the knowledge, attitudes and pest control practices of the general population in the study areas. The fact that grain weevils and LGB were identified by farmers as the main pests of stored maize is consistent with research findings. Although LGB is a recent introduction to Malawi (since 1991) and Zambia (since 1993) and its outbreaks are sporadic in nature (Farrell 2000), farmers are aware of this pest. LGB is an invasive alien species that was introduced into Africa in the late 1970s, originating from Central America (Golob and Hodges 1982). It is a devastating beetle pest, often reducing maize kernels to dust in a relatively short time, especially when stored on cobs. In Tanzania, Hodges et al. (1983) recorded losses as high as 34% on maize cobs infested with LGB after storage for only 3–6 months.

Although farmers are knowledgeable about pests of stored maize and beans, gaps in their knowledge were also noted. The mention of *Sitophilus* spp. as pests of beans and bruchids as pests of maize could be an error in identification on the part of farmers. Misidentification is indicative of farmers' limited knowledge of pest species, and this highlights the need for farmer training regarding constraints and solutions. Most farmers in the study areas applied synthetic insecticides, mainly Actellic and its cocktails. Among the insecticides listed in Figure 3c, d, Actellic, Phostoxin and Foskill are registered in most countries as grain storage pesticides. Phostoxin and Foskill are fumigants. The rest of the insecticides (Figure 3c, d) are recommended for field or vegetable crops. Therefore, their use by farmers to protect stored commodities in the study area is indicative of knowledge gaps in the selection and use of pesticides. Although synthetic pesticides are a vital component of the control of stored maize and beans, their high cost, inaccessibility for resource-poor farmers, their misuse and the accompanying undesired effects could have negative impacts (Ogendo et al. 2004; 2007). Phiri and Otieno (2008) further indicated that adulterated insecticides are often sold to farmers without the farmers' knowledge. Insecticides are mixed with maize flour making them very difficult to distinguish from the actual insecticides. The authors also report a tendency in northern Malawi, particularly for vendors, to sell expired insecticides from neighbouring Mozambique.

Only a small proportion of farmers (39%) had heard about pesticidal plants from extension staff and researchers; this highlights a need for their promotion in both countries. The fact that parents and friends were the major sources of information to farmers also highlights the value of indigenous knowledge systems regarding pesticidal plants and the shortfall of the extension services.

Farmers used various cultural practices and herbal products (e.g. ash) to control pests in storage. In both countries farmers have also used pesticidal plants, mainly *Tephrosia* spp., *Azadirachta indica* (neem), *Vernonia* spp. (Asteraceae) and other species as a means of indigenous pest management. The reporting of *Vernonia* spp. identifies a potentially important new research area; there is a need to better understand its mode of action. The farmers' indigenous knowledge and widespread use of *Tephrosia* spp. as a grain protectant in Zambia and Malawi is supported by research conducted elsewhere. All parts of *Tephrosia vogelii* are used in tropical Africa for numerous ethno-medical and traditional veterinary practices (Dzenda et al. 2007). *Tephrosia* has been shown to have toxic and repellent effects against certain insect pests of stored grains (Ogendo et al. 2003). Studies from Kenya showed that tephrosia leaf powder was as effective as the synthetic insecticide (Actellic Super), without affecting grain colour, odour and germination (Ogendo et al. 2004).

Farmers' indigenous use of pesticidal plants has often not been considered to have real value since the plants' effectiveness has been so unfavourably compared with synthetic pesticides. However, to many farmers even moderate efficacy is of great importance since the alternative to their use may be crop loss and food shortage. These moderate efficacies could be optimized through better understanding of the mechanisms involved. Farmers may also use ineffective control practices, either due to lack of knowledge of the pests in question or out of desperation. Effective use of pesticidal plants may be achieved by ensuring correct time of harvest, storage and application rates.

Our results serve as a starting point for rationalized use of pesticidal plants for insect pest management through constructive collaboration between scientists and farmers in southern South Africa. Scientists can now develop guidelines to ensure efficacious use of the pesticidal plants widely used by farmers. Some plants are required in large quantities, so cultivation may be an important consideration to increase their availability. Researchers can also develop guidelines for the propagation and cultivation of those plant species. This would have a positive impact on the availability of such plants, and encourage more farmers to use them.

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