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Indigenous pest management knowledge of Eritrean farmers and their application in pest and disease management

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Abstract

The incorporation of traditional indigenous knowledge is crucial in the agricultural production systems. To ensure the preservation of these practices for future use, there is a necessity for comprehensive documentation. This research aimed at exploring and documenting the indigenous technical knowledge (ITK) practices employed by local farmers in agricultural production and assessing their scientific rationality. A sample of 62 farmers from Gash Barka and Debub regions of Eritrea were randomly selected for the study of which 72% were males, within the age of 61-70. Data collection involved interviews and focus group discussions (FDGs). The identified ITKs underwent scientific validation by experts from the Departments of Plant Health, Hamelmalo Agricultural College, Eritrea and CABI, Nairobi. Among the 62 interviewed farmers, the primary crops cultivated were cereals such as sorghum (84%), teff (77%), and wheat (76%), along with legumes like chickpea (60%), peas (52%), and groundnut (32%). Farmers reported several storage pests such as grain weevils, red flour beetle, confused flour beetle, pulse beetle. In the field, farmers identified major field pests, including the fall armyworm sorghum shoot fly, locusts, and stem borers, as major challenges. Indigenous pest control methods used by farmers ranged from animal by-products to plant components like neem (*Azadirachta indica*), red pepper, and physical strategies were deemed rational by experts. The most frequently cited ITKs, with a relative frequency of 1.0, were pre-storage drying of grains, weeding, and ploughing. The study concludes that the application of ITKs carries significant implications for pest and disease management, and their integration into an integrated pest management system is recommended.

Key words: *Cereals; Field pests; Legumes; Pests and Diseases; Storage pests*

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Introduction

Agriculture is the backbone of the economy of Eritrea and the development of this country largely depends on the development of this sector which contributes about 17% of the GDP (Okumu *et al*., 2023). Eighty percent of the population depend on agriculture and its associated fields (Sati, 2008) and in spite of the limited area for agricultural production, Eritrea has a wide range of agro-climatic conditions related with altitude which goes from below sea level to 3100 m. These areas are characterized by traditional production system of wheat, barley, sorghum, finger millet, maize and taff, peas, beans, chick pea and linseed crops (Okumu *et al*., 2023). Pests and diseases constraint production of crops, for instance in a survey by Roden *et al*. (2007) downy mildew was recognized as a serious problem affecting pearl millet. Others also indicated striga (*Striga hemontheca*) (*Metselem*), *amaranth* spp (*Hamliagdhi*), *Setaria homonyma* (*Abertata*) and birds (*Quelea quelea*) as major constraint to crop production.

Traditionally, farmers have strategies that they use to manage pests and diseases that are considered ecologically sustainable that were developed long ago through generations (Chhetry and Belbahri, 2009; Singh *et al*., 2021). These practices are indigenous methods of cultivating crops using self-reliance locally available resources without external inputs. However, these practices that were once prevalent in the indigenous societies are now vanishing but can be retrieved in some tribal dominated regions. Eritrea is rich in traditional farming systems because of diversity in agro-ecological habitats occupied by diverse ethnic groups who have been practicing age-old farming. Therefore, indigenous knowledge is the knowledge of indigenous people settled in a particular geographical region having their own language, culture, tradition, beliefs, rites and rituals (Shakrawar *et al*., 2018). Indigenous knowledge is based on necessities and observations of a particular group to provide solution to immediate problem such as pest and diseases. Indigenous knowledge also called traditional knowledge is dynamic, community generated, culture and traditional based, not documented and critical for local problems (Sharma *et al*., 2020). The indigenous knowledge is shaped by indigenous creativity, innovativeness, and contact with other knowledge systems (Eyong, 2007; Bruchac, 2014; Buthelezi *et al*., 2024). These practices have been used for a period of time through one generation to another and validated to establish them as practical and successful (Mosime, 2018; Ubisi *et al*., 2019).

In Eritrea the production of crops varies from highland regions to lowland regions. Therefore, production practices and the indigenous knowledge not only vary among the zones but also among the ethnic groups (FAO, 2016). Among the communities, use of plant and animal products contributes indigenous knowledge in management of pests and diseases. For instance, farmers treat seeds by soaking them in cattle urine or cattle manure for 24 hours, and then dried before sowing (Roden *et al*., 2007). Other practices include the storage of seed in an indoor rack suspended beneath the roof beams where it is well ventilated and safe from rodents. Others apply ash in order to limit insect infestation and damage to the seed. These practices are socially desired, affordable, and sustainable and involve minimum risk to farmers (Bruchac, 2014). These practices are potential for strengthening sustainable agricultural production, however, despite their importance; ITK practices appear neglected and often regarded as unscientific which is not justifiable. This study was designed to document indigenous technological practices used by traditional Eritrean farmers to manage pests and diseases. This study documents and analyzes indigenous technological knowledge used by farmers for pests and disease management across different regions thus generating structured knowledge base that can support the integration of local practices into modern sustainable pest management strategies.

Materials and methods

Study Site and sample population

The survey was conducted in the indigenous community's inhabitant in the two administrative regions locally known as 'Zoba' in Eritrea which were Zoba Debub and Gash Barka. Five villages were randomly selected from each Zoba. The targeted study sample for this study was 62 farmers, determined using Yamane's formula for sample size determination using a 10% margin of error (+/- 5%) at 95% confidence level and the total population of farmers in the study areas.

$$n = \frac{N}{1+N(e)2} \quad (1)$$

where N= Population size, n = sample size and e = margin of error

Farmer's knowledge on pests and diseases

A structured questionnaire was administered to individual farmers in the selected villages for quantitative data collection, while semi structured questionnaires were used during open interviews to obtain more detailed qualitative responses. The survey was conducted in the local dialect by native speakers between July and September, 2023. All the activities were carried out with informed consent from the farmers. Farmers were selected using a stratified sampling techniques in which sub zoba (region) constituted a stratum and participants were selected systematically from the list of farmers in each region. Active participation was ensured through open interactions. Field visits were also conducted to find out the existence of these technologies. The questionnaire covered demographic information about the respondent such as gender, age, level of education, agricultural production practices such as crop varieties, the yield obtained, external inputs used, main pests and diseases and management practices, farmers' knowledge, on pests and diseases, and indigenous practices for controlling pests and diseases.

Documentation and Scientific rationality of ITKs

During the survey a portable notebook was used to record all the information during the interview and then organized them into an Excel sheet (Microsoft Corporation, http://www. microsoft.com) in a synthesized format. The information on ITK was collected through informal interactions and participatory manner by engaging the local moderator with knowledge in vernacular language. Direct observation was also used to record the image of the prevailing technologies in the field with the permissions of the farmers. The practices identified by the farmers had been passed on from their progenitors and practiced for years together were noted and considered indigenous pest management practices. Each practice was identified and its rationality identified by experts mainly drawn from the Department of Plant Health and Agronomy of the Hamelmalo Agricultural College. The standard of evidence to consider a practice to be rational was based on the opinion and scientific justification explained by the panel of experts, and literature (Rathore *et al.*, 2021). In this context we considered the rationality as being the extent to which an indigenous practice has the feature of being described on scientific grounds based on their applications and use for an extended period of time. The ITKs were compared with some of the indigenous technologies that have been reported to work elsewhere

Data analysis

Data analysis on the survey was performed using the statistical software; SPSS 20. Once the field survey was completed, data was input in the SPSS for analysis. Descriptive statistical analysis including frequency distribution, means and standard error were done to summarize the characteristics of respondents and describe the distribution of the survey variables. For the identified indigenous technical knowledge (ITKs), the frequency of citation (FC) and relative frequency of citation (RFC) were calculated following the formula by Tardio and Pardo-de-Santayan (2008) to determine the relative importance and level of agreement among the farmers regarding each ITK. The FC represents the number of respondents who mentioned a particular ITK while RFC is a quantitative index used to assess the relative importance of each knowledge practice in the study population based on the citations by the respondents. The RFC ranged from 0 to 1, where 0 indicates that no respondents mentioned the ITK and 1 indicates that all respondents cited the ITK. This method compares the relative prominence of different ITKs within the sample population.

$$\text{Relative Frequency of Citation (RFU)} = \frac{FC}{N} \quad (2)$$

where FC: number of informants who mentioned use of the particular ITK practice and N: total number of respondents who took part in the survey. A generalized linear model assuming multinomial error distribution of farmer responses was used to characterize respondents' awareness of indigenous technologies and their use in pest control.

Results

Demographic characteristics of the respondents

In the current study, it was observed that majority of the farmers were males, accounting for 72% of the 62 interviewed farmers (Table 1). Regarding age demographics, the study included farmers age between 30 to 70 years. Among the 62 respondents, 44% were within the 61 -70 years age group, approximately 11% were older than 70 years, and only 4% were below 40 years of age. Of the 62 farmers interviewed, 48% had attained primary education level, around 32% had no formal education while only 16% of the 62 respondents had secondary level of education. Regarding land ownership, majority 72%, of the 62 respondents owned land parcels ranging from 3-6 acres which they were producing their crops on.

Table 1

Demographic characteristics of respondents from Debub and Gash Barka regions of Eritrea

Baseline Characteristics	Category	Frequency (n=62)	Respondents (%)	X^2	P Value
Sex	Male	45.0	72.6	12.65	0.0004
	Female	17.0	27.4		
Age (Years)	Below 40	3.0	4.8	29.9	<0.0001
	41-50	8.0	12.9		
	51-60	17.0	27.4		
	61-70	27.0	43.5		
	Above 70	7.0	11.3		
Education	None	21.0	33.9	27.4	<0.0001
	Primary	29.0	46.8		
	Secondary	10.0	16.1		
	College	2.0	3.2		
Marital Status	Single	0.0	0.0	124.0	<0.0001
	Married	62.0	100.0		
	Divorced	0.0	0.0		
Land Size (Acre)	Less than 3	9.0	14.5	43.0	<0.0001
	Between 3-6	45.0	72.6		
	Above 6	8.0	12.9		

n- number of participants in the study

Sources of seeds and Common crops planted by the farmers

Among the respondents, 76% of the 62 interviewed farmers relied on their own seeds for planting while a few depended on markets as their source of seeds (Figure 1). About 20% of the 62 farmers obtained their seeds from neighboring farmers. Notably, the farming landscape revolves around cereal crops as majority (76%, n=62) grow cereals crops (Table 2). Among the 62 farmers surveyed, the most commonly grown cereals include sorghum (84%), taff (77.3%), wheat (76.3%), Maize (48%) and pearl millet (44%). Concurrently, leguminous crops also play significant roles, with chick pea (60%), peas (52%), beans and groundnuts (32%) as the most important legume crops grown by the farmers in the study areas.

Figure 1

Sources of Planting Materials for Farmers in Debub and Gash Barka regions of Eritrea

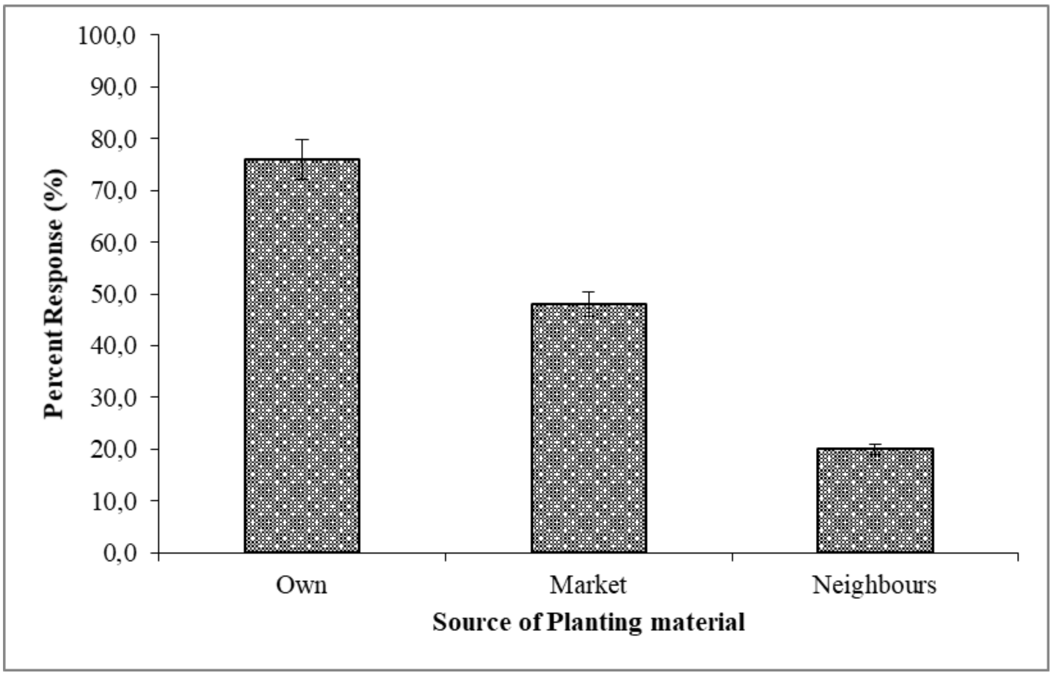


Table 2

Major Food Crops Grown by Farmers in Eritrea

Crops	Frequency (n=62)	Respondents (%)
Cereals		
Sorghum	21.0	84.0
Teff	19.0	76.0
Wheat	17.0	68.0
Barley	16.0	64.0
Maize	12.0	48.0
Pearl Millet	12.0	48.0
Sesame	8.0	32.0
Pearl Millet	12.0	48.0
Legumes		
Peas	13.0	52.0
Beans	8.0	32.0
Groundnuts	6.0	24.0
Cowpea	3.0	12.0
Fenugreek	2.0	8.0
Flax	1.0	4.0
Vetch	1.0	4.0
Vegetables		
Pumpkin	2.0	8.0

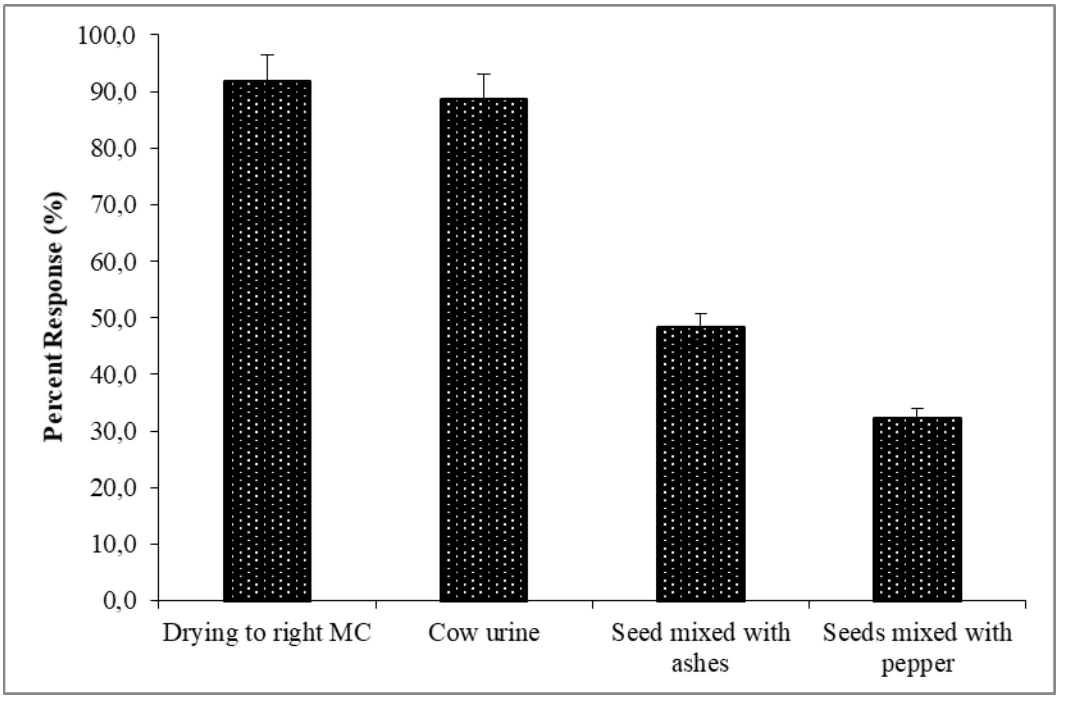
n- number of participants in the study

Seed treatment methods before storage

Farmers use various methods to treat their grains before storage (Figure 2). Almost all (92%) of the 62 farmers interviewed dried their grains to the right moisture content prior storage, while 88%, (n=62) of the farmers treated their seeds with cow urine by soaking them for 24 hours before storage. Additionally, alternative methods such as dusting seeds or grains with ash and pepper were utilized by the farmers.

Figure 2

Seed Treatment Methods Practiced by the Farmers from Debub and Gash Barka regions of Eritrea. MC – moisture content



Farmers' knowledge of field and storage pests and diseases

Farmers provided the name of pests and diseases that damage their crops in the field in their local dialect (Table 3). The identification of these pests and diseases were often based on the observed damages and losses inflicted on the crops. Among the insects, fall armyworm (*Spodoptera frugiperda*), stem borer (*Busseola fusca*), sorghum shoot fly (*Atherigona soccata*), cutworms (*Agriotis* sp) and locusts were commonly mentioned by the farmers. Approximately 74% (n=62) of the farmers identified birds, particularly *Quelea quelea* (qetel) as a significant threat to cereals during grain ripening stages, while rodents were reported as a menace in stores. In the stores, weevils (*Sitophilus granaris*), rice weevils (*Sitophylus oryzae*) lesser grain borer (*Rhyzopethra dominica*), flour beetles (*Tribolium* spp), and grain moth (*Sitotrega cerelella*) were identified as significant threat to grains. Additionally, in legumes, bean bruchid (*Callosobruchus chinensis)* was identified as a problem. Among the 62 farmers surveyed, 74% encountered problems with grain weevils, while 56%, 64%, and 58% reported problems with lesser grain borers (LGB), flour beetles, and grain moths, and maize weevils, respectively (Table 4).

Table 3

Status of Various Field and Storage Pests Mentioned by the Farmers from Debub and Gash Barka regions of Eritrea

Insect pests	Scientific name	Percentage (62)	Status
Storage			
Weevils	*Sitophilus granaris* L	74.2	Major
Rice weevils	*Sitophylus oryzae* L	14.6	Major
Lesser grain borer	*Rhyzopethra dominica*	56.3	Major
Grain moth	*Sitotrega cerelella*	64.2	Major
Maize weevil	*Sitophylis zeamais* L	58.2	Major
Granary weevil	*Sitophylus granarius*	51.2	Major
Rust red grain beetle	*Cryptolestes ferruginus*	23.2	Minor
Bean bruchid	*Callosobruchus chinensis L*	11.4	Minor
Red Flour beetle	*Tribolium castaneum*	18.2	Minor
Rodents		33.7	Major
Field			
Fall armyworm	*Spodoptera frugiperda*	76.3	Major
Sorghum shoot fly	*Atherigona soccata*	36.4	Major
Locust	*Schistocerca gregaria*	32.6	Minor
Stem borers	*Busceola fusca*	29.4	Minor
Birds	*Quelea quelea*	76.2	Major

Table 4

Logit-Linear Model Results on Determinants of Farmers Use of Indigenous Technical Knowledge

Management Method		B	Std. Error	Wald X^2	Sig.
Ash	Intercept	-16.778	3.770	19.809	.000
	Gender	16.717	1.421	138.325	.000
	Age	.355	.812	.191	.662
	Education	-.501	.588	.727	.394
	Land size	-.434	1.047	.172	.678
	Crops	.291	.589	.244	.621
	Planting materials	-.186	.502	.138	.711
neem	Intercept	-23.132	5.908	15.328	.000
	Gender	19.771	1.685	137.613	.000
	Age	.429	1.424	.091	.763
	Education	-.202	.721	.079	.779
	Land size	.031	1.272	.001	.980
	Crops	-.559	1.130	.244	.621
	Planting materials	.872	.554	2.477	.116
drying	Intercept	16.511	5530.127	.000	.998
	Gender	-.080	5348.155	.000	1.000
	Age	-2.187	1.335	2.686	.101
	Education	.153	.699	.048	.826
	Land size	.555	1.349	.169	.681
	Crops	.395	.908	.189	.663
	Planting materials	-13.718	1406.957	.000	.992
Cowdung and urine	Intercept	-11.566	5.633	4.216	.040
	Gender	20.656	2.596	63.329	.000
	Age	-1.515	1.668	.825	.364
	Education	-.770	.979	.618	.432
	Land size	-1.868	1.515	1.519	.218
	Crops	-2.486	2.257	1.214	.271
	Planting materials	.598	.814	.539	.463
Biopesticides	Intercept	-14.503	2.664	29.639	.000
	Gender	16.882	0.000		
	Age	-.941	.669	1.983	.159
	Education	.038	.458	.007	.934
	Land size	.523	.789	.440	.507
	Crops	-.113	.484	.055	.815
	Planting materials	-.216	.390	.306	.580

Indigenous pest management practices and their rationality

Our findings reveal profound understanding among farmers regarding the appropriate sustainable use of available resources in pest management. A total of 16 ITKs were documented as commonly practiced by the locals, all of which were considered scientifically rational by the experts (Table 5). Among these practices, some of the most-cited ITK practices with relative frequency of citation (RFC) values ranging from 0.28 to 1.0 were practices such as hand weeding and pre-storage seed drying against stored product pests. Additionally, farmers used animal products such as cow urine (0.92), ash (0.8), pepper (0.48), crop protection (0.48), and neem (0.32). Fallow farming where fields are left uncultivated for extended period of time of about 1 - 3 years after harvest was common among the surveyed farmers. Nearly all the management strategies practiced by farmers as strategies were considered scientifically rational by the experts except use of water soaking and roasting where experts had different opinions as they lacked a scientific rationale for their usage.

Logit-linear model on determinants of farmers' knowledge

Table 5 shows the significant predictors in the logit-linear model relating knowledge and use of indigenous technical knowledge. Respondent's knowledge was described by models with gender, age, education level, land size and crops planted. The significant determinants of use of ITKs were gender (P=0.00) for instance more male respondents were reported to apply the indigenous technologies than their female counterparts while the farmers with small landholdings were more inclined to use ITKs than those with large land sizes.

Discussion

General characteristics of respondents

The demographic information provided a background detail on the respondents' age, gender, educational level, marital status, and land size from which they practiced farming and the common crops they grow. According to Ngxabi *et al*. (2023) demographic information is a baseline for determining factors influencing indigenous knowledge in crop production system. In the current study, the majority of the farmers were male indicating that farming is an old practice dominated by the male in the Eritrean society. The current outcome mirrors those reported by Mihale *et al*. (2009) where 76% of the respondents were males. This outcome, however, contradicts those reported by Ngxabi *et al*. (2023) where majority (76%) of respondents were females. According to the authors agriculture is labor intensive and traditionally such activities are carried out by women. However, every society allocate different roles to each gender and in this case, traditionally men participate more in agricultural activities than the women. Therefore, it is critical that we investigate the role of gender as the fundamental value of ITK.

The majority of the farmers (44%) fell within the 61-70 age bracket and only 4% were below the age of 40 years. The findings align with those reported by Rigg *et al.* (2020) where older farmers had more positive attitude towards ITK practices. Age, as highlighted by Deng and Nina (2020) and Kuyu and Bereka (2020), is one of the key parameters in preservation of ITK technologies as it is an indication of experience and accumulation of indigenous knowledge among farmers (Rathore *et al*., 2021). In this work, the older farmers were more knowledgeable in ITKs than young farmers and this is because younger farmers were not interested in the indigenous practices as they prefer conventional pest control methods while others may only be interested in other commercial enterprises (Kitheka and Muli, 2022). Generally, a wealth of ITKs is generally found among the older generation (Lwoga *et al*., 2020; McGinnis, *et al*., 2020). Majority of farmers had primary education level while around 32% had no formal education. Education is recognized as an important component of human capital that can improve farmers' capacity to recognize, engage with, and implement innovations in their farms, and thus positively impacting the adoption of indigenous pest management practices (Rathore *et al*., 2021).

Sources of seeds and common crops planted by the farmers

The majority of the farmers rely on their own seeds for planting, with only a few depending on markets as source of seeds. The result here is supported by those of Roden *et al*. (2007) and

Okumu *et al*. (2017) were majority of farmers, after harvesting prepared seeds from their own farms as planting material. Accordingly, after harvest, the farmers select the best seeds, treat them traditionally by mixing them with ash and store them in small sacks and shelve them within the roof beams of their home. This method exposes the seed to dry smoky environments, effectively protecting them from rodents, moths and fungi (Roden *et al*., 2007; Gupta and Kumar, 2020).

Cereal crops were grown by all the farmers followed by legumes, an outcome that aligns with those of Mihale *et al.* (2009) where majority of the farmers were engaged in production of cereal crops. Among the cereals grown, sorghum, teff and wheat were grown by majority while chick pea, peas, beans and groundnuts were the most important legume crops. These results closely mirror those reported Roden *et al*. (2007) which identified pearl millet, groundnuts, sorghum, and chickpea as the primary crops in these areas. In this study, sorghum ranked first because of its cultural importance and its ability to withstand drought while chick pea (*Cicer arietinum* L.) ranked first as it is one of the most important crops mostly grown in dry lands (Nene *et al*., 2012). Generally, small scale are farmers associated with adoption ITKs than commercial farmers (Rathore *et al*., 2021; Naharki and Jaishi, 2020).

Seed treatment methods before storage

Farmers used various methods to treat their grains before storage. Nearly all the farmers dried their grains to the appropriate moisture content prior to storage while others treated their seeds with cow urine by soaking them for 24 hours before storage. Other methods used include dusting seeds or grains with ash and pepper. Drying seeds to the right moisture content creates a barrier that inhibits the growth and proliferation of pest and other post-harvest microorganisms; further, it also enhances the shelf life of the agricultural produce. The use of cow urine was reported by Roden *et al*. (2007) where farmers soaked their seeds in cattle urine for 24 hours which is then dried as this helped in repelling storage pests.

Farmers' knowledge of field and storage pests and diseases

Farmers named the pests and diseases that were common in their local dialect. According to Midega *et al.* (2012) the description by local farmers using the local dialect helps researchers and extension officers working with the rural communities appreciate local knowledge. Farmers identified these pests by describing their damages and losses. For instance, a farmer revealed a pest attacking maize crops causing defoliation and cob damage. This narrative fit the description of fall armyworm. The occurrences of field pest infestations align with findings documented by Mihale *et al*. (2009), according to the authors, crops were predominantly attacked by field pests, particularly during the vegetative or productive stages, leading to significant losses. Occurrence of fall armyworm has been reported in Eritrea and various neighbouring countries causing significant yield losses. The occurrence of fall armyworm and native lepidopteran stem borers in these areas are a serious threat to food security and may contribute to income loss for smallholder farmers. Birds, specifically *Quelea quelea* was reported to cause significant losses to cereals during grain ripening stages, while rodents were reported as a menace in stores. These findings align with the results presented by Singh *et al*. (2021), who highlighted birds as a major issue during grain ripening and rodents in stored goods. Storage pests like grain weevils, lesser grain borers (LGB), flour beetles, and grain moths, and maize weevils constitute a challenge to farmers, as highlighted by Adugna and Ahmad, (2019) in Anseba region of Eritrea. These pests affect quality and quantity of cereals implying that the crops are preferentially stored as main food types in the area.

Indigenous pest management practices and their rationality

According to Signh *et al*., (2021) there is a pressing need for investigation, and documentation of indigenous technologies. Our findings reveal that the farmers were aware of the sustainable use of available resources in pest management. Primarily, most of the ITKs were used in protection of stored products as many farmers stored their produce for future consumption. This is also because of the absolute nature of the losses that occur in storage are more compared to the field environment. This underscores farmers' motivation to devise appropriate storage structures and effective control measures. For instance, farmers used various storage methods such as Koffo made from a mixture of mud and cow dung and Guffet made from palm leaves.

A total of 16 ITKs were documented, all of which were considered scientifically rational by the experts. Notably, the five most-cited ITK practices had RFC values ranging from 0.28 to 1.0. The highly cited practices were hand weeding and seed drying before storage against stored product pests, which suggests that they performed better and were considered more effective. This outcome mirrors results reported by Singh *et al*. (2021) and; Chauhan and Ghafar (2022) where majority of the farmers indicated sun drying as most preferred indigenous technology. Weeding not only prevents yield loss due to weed competition but also maintains purity and quality of grains while reducing buildup of weed seeds in the soil. Manual weeding is also considered part of an integrated weed management and it is ecologically sound, provides clean and thorough weeding and it is a good resource for poor farmers where labour is available at low wages (Riemens *et al*., 2022). Sun drying as highlighted by Asemu *et al.* (2020) decreases moisture content of crops creating a barrier for storage pests to gain entry. Drying inhibits growth and proliferation of pest and other post-harvest microorganisms, further; it enhances the shelf life of the agricultural produce. Farmers noted that such harvested, preserved grains and seeds are vital for the next season sowing which is also an important source of healthy, disease free or non-infested planting materials. Healthy or disease-free seeds are collected before general harvest for next sowing.

Additionally, farmers used animal derived products and plants such as cow urine and ash. Studies have shown that storage in wood ash is very effective if the ratio of ash to grains is at least 3 parts ash to 4 parts of grain and the mixture thoroughly mixed and stored in a container make seeds inconsumable to the pests. Under these conditions, these treatments render the seeds unpalatable and in accessible to pests, with effectiveness comparable to inorganic pesticides (Mkenda *et al.*, 2015). Inorganic pesticides are designed for a high efficiency when compared to traditional pesticides. Traditional pesticides are slower and may require repeated application and depends on preparation, concentration and environmental conditions. According to Boruah *et al*. (2020) dusting crops with ash early in the morning sticks on the plant leaves due to dewdrops thus reducing the contact area between pests and plant parts therefore discourage pest build up. Further ash acts as a poison especially to aphids and other soft bodied insects and kill them by abrasion. Singh *et al*. (2021) indicated that ash application causes abrasion of mouth parts thereby repelling the insects. Adugna (2006) reported that ash treatment reduces storage losses by 30%. The use of cow urine has been used as pesticide as it reduces pest and disease infestation in the soil (Roden *et al*., 2007).

A good number of farmers also applied neem and pepper. Farmers use these pesticidal plants in their crude form as they are harvested locally and require limited processing that is feasible and economically-viable. For example, neem leaves are air dried, grinded and the resulting powder is thoroughly mixed with grains before and after packing (Mihale *et al*., 2009). Neem (*Azadirachta indica*) contains the active ingredient azadirachtin, which cause delay in insect development, mating, acts as a repellent, is antifungal, and inhibits insect feeding (Grzywacz *et al*., 2014). Red pepper fruits are grinded and mixed with the grains. Pepper is also soaked in water and left for two days and then filtered. The filtrate is then sprayed as an aqueous solution to crops at a rate of two (2) litres per acre (Mihale *et al*., 2009). Chili is known to contain capsaicin component that is insecticidal and effectively suppresses store pest problems (Singh *et al*., 2021). Use of plants and animal parts and products are the important components of indigenous knowledge in the management of pest and diseases of crops. Neem seed powder, which act as repellent generally used in storage, mixture of fresh cow dung is used or smeared in granary walls and floor.

Farmers also practiced crop rotation as an indigenous technology against pests and diseases and mostly rotated cereals with legumes. According to Dury *et al.* (2012) crop rotation is an important technique that has been used for centuries and involves farming various plants on a piece of land. Researchers have indicated that use of crop rotation increases occurrence of beneficial species and interactions, breaks the cycle of pathogens, and reduces weed populations as compared to mono-cropping which has been reported to cause changes in soil ecosystem, increase pathogen load (Imoro *et al*., 2021). Inclusion of legumes in a rotation system provides symbiotically fixed nitrogen, maintains water status, and reduces pathogen burden (Imoro *et al*., 2021). Thus, it is fair to say that this practice improves soil health and productivity by changing the structure and the aggregation of soil, soil organic carbon, cycling of nutrients, and pest and disease control. All the farmers practiced fallow farming, after harvesting period is over. Farmers left their farms fallow for more 1-3 years which is intended to break the life cycle of various pests and diseases and allow soil to regenerate without the need to apply fertilizers (Habiyaremye and Korina, 2021). Ploughing was practiced by all the farmers at pre-planting stage. Farmers in the study used traditionally made animal drawn plough just a few weeks before sowing to give time for the weeds and other crop residues to decompose and also expose pupae and other pests residing in the soil to desiccation (Nicolas and Cabarogial, 2015). Nearly all the practices followed by the farmers as strategies for managing pests and diseases were considered scientifically rational by the experts except use of water and soaking and roasting where experts had different opinions as they lacked a scientific rationale for their usage. Similar findings were reported by other scientists in that most of the indigenous practices used by the farmers were considered rational by the scientists (Rathore *et al*., 2021).

Logit-linear model on determinants of farmers' knowledge

Significant predictors in the logit-linear model related to knowledge and use of indigenous technical knowledge. Respondent's knowledge was described by models with gender, age, education level, land size and crops planted. The significant determinants of use of ITKs were gender (P=0.00) for instance more male respondents were reported to apply the indigenous technologies than their female counterparts while the farmers with small landholdings were more inclined to use ITKs than those with large land sizes.

Conclusion

The study revealed that pests were identified as the primary constraint to crop production in the surveyed areas. Nonetheless, farmers employed diverse indigenous technologies to address the challenges posed by these pests. A majority of the farmers recognized the importance Indigenous Technological Knowledge (ITK) and its transmission across generations. Despite ongoing advancements in technology, the significance and efficacy of ITKs cannot be disregarded. Moreover, it is practically difficult to ignore the value of ITKs in pest management. The present study documented 16 ITKs in Eritrea, the majority of which were found to be scientifically sound and have extensive applications in the farmers' fields. These practices are popular and are used among a good number of older people; therefore, documenting of ITK is an essential undertaking. Subsequently, the most promising practices can be integrated into novel integrated pest management strategies to promote sustainable crop production.

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