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Farmers' Knowledge and Perception on Beans Postharvest Constraints and Their Mitigation Methods in the Humid Rainforest and Highland Ecozones of Cameroon

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Authors' contributions

This work was carried out in collaboration between both authors. Author NNN designed the study, wrote the experiment procedures and the first draft of the manuscript. Author HAA performed the studies supervised by author NNN. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: This study sought to assess farmers' awareness and knowledge about bean postharvest constraints and their indigenous methods to mitigate them. Cameroon.
Study Design: Random interviewing of bean farmers.
Place and Duration of study: Interviewed farmers of the highland savanna and humid rainforest ecological zones which are two agro-ecological zones of Cameroon respectively from January 2017 to October 2018**.**
Methodology: A structured questionnaire was randomly distributed to 519 bean farmers in order to document their perceptions on various constraints hampering beans postharvest handling/storage and their indigenous methods of mitigating these constraints. Of these, 356 were from the highland savanna and 163 from the humid rainforest ecozones
Results: Most postharvest losses in beans are caused by insects and mold/rot. Insect pests were reported by 251 (69.5%) of farmers in the highland savanna and 134 (84.8%) in the humid rain forest, while mold/rot was reported by 108 (29.9%) of the farmers in the highland savanna and 11

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(6.9%) in the humid rainforest. Farmers in both agro-ecological zones lacked adequate storage facilities, as reported by 147 (40.7%) in the highland savanna and 43% (275) in the humid rainforest. Most farmers in the highland savanna 118 (39.20%) and humid rainforest 67 (43.22%) stored bean grains for 1-3 months, though farmers in the highland savanna generally stored beans longer than those in the humid rainforest. The insect infestations were controlled mainly by using conventional pesticides and local plant materials while mold was mainly managed by proper drying of the produce.

Conclusions: To mitigate these constraints, an integrated approach of storing appropriately dried insect-free grains in moisture proof storage containers/facilities and judicious use of synthetic pesticides and/or proven effective botanicals should be adopted. Thus, farmers should be trained on good bean preservation methods and effective plant-based products.

Keywords: Beans; postharvest; constraints; humid rainforest; highland savanna; agro-ecologies.

1. INTRODUCTION

Food and nutrition insecurity is a major challenge to smallholder farmers and the developing world in general. Boosting agricultural productivity and food availability therefore, in a bid to alleviate this situation, is a major priority in these developing nations. One logical way of boosting food availability, without extending the available arable cropland nor depleting water resources, is through appropriate postharvest protection of various food sources, especially cereals and grain legume crops. Dried grain legumes, particularly the common beans (*Phaseolus vulgaris*), are of major importance to the livelihoods of millions in the developing countries. Beans are the third most important food grain legume after soybean and peanut worldwide; it is of high nutritional and economic value to humans and also serve as feed to livestock [1]. Beans are one of the most common foods in schools due to its high nutritional quality in terms of percentage protein. Its high mineral content, especially iron and zinc, are advantageous in regions with high prevalence of micronutrient deficiencies such as anemia due to iron deficiency [2]. The consumption of common beans has also been reported to reduce colon and breast cancer and heart diseases [3]. Immature bean pods are eaten fresh and can be easily preserved by freezing, canning or dehydrating. Mature beans are eaten boiled, baked, fried, or ground into flour. Bean crop residues, such as dried pods and stems (straw) and processing by-products (discarded pods, pod extremities), can also be used as fodder [4,5]. Common bean also improve soil fertility through fixation of atmospheric nitrogen in symbiosis with rhizobia [6,7]. Dry beans also serve as an important source of income for smallholder farmers in Cameroon and hence play a key role in mitigating wide spread rural poverty in the country [8]. In view of the tremendous importance of beans as a source of human food, livestock feed and income to the smallholder farmers, its increased production and safe storage is vital in maintaining its high quality supplies. A crucial pre-requisite for this safe storage, is the proper identification of the various harvest/post-harvest factors hampering adequate safe storage of beans to ensure a sufficient and high quality supply of this vital protein-rich food resource. Consequently, this study was conducted to document bean farmers' knowledge and perceptions on their postharvest constraints and their indigenous methods of mitigating these problems.

2. MATERIALS AND METHODS

2.1 Study Site

The survey was conducted in Buea in the humid rainforest and Dschang in the western highland savanna agro ecological zones of Cameroon. Buea is located at 4^0 08'036" N, and 9^o25' 826" E, and 573 m above sea levels. It is at the east slope of Mount Cameroon, with an annual rainfall of about 4,090 mm, rich volcanic rocky soils and a temperature range of 20 -27^{0}C. It has an equatorial climate with a rainy season from March to mid-November and a dry season from mid-November to March. Dschang is located at 05^{0}26' 666" N, and 01^{0}03' 798" E on an altitude of 3000 m above sea level; it has temperature range between of between 19.5^{0}C - 25.0^{0}C and an annual rainfall between 1100 mm-2000 mm. It has a dry season from November to March and rainy season from March to November.

2.2 Survey

A semi structured questionnaire was distributed to 519 male and female bean farmers comprising of 356 in Dschang and 163 in Buea. Farmers were interviewed separately within their farming areas or residence. Participants in the study were selected on the basis that they had been involved in beans cultivation for at least one year and were willing to participate in the survey. Interviews were done in English or local language (Pidgin) in Buea and French in Dschang. Interviews were done with the assistance of local agricultural extension workers.

The questionnaires were developed in English and later translated into the French language for the farmers in the francophone region of Dschang. The questions sought to know: (a) how long they stored beans (b) where and how they dried beans (c) how they stored the harvested beans (d) the various storage facilities used (e) their perceptions on the causes of post-harvest losses (f) how they mitigated or controlled stored insect pests (g) what they did with the beans damaged by post-harvest factors.

2.3 Data Analysis

Data collected were keyed into Microsoft Excel 2016 spreadsheet and analyzed using statistical packages for social sciences (SPSS) software, version 17.0. Analysis of variance (ANOVA) was performed at 95% confidence level to compare the results. Means were separated using Tukey's HSD $P < 0.05$. Frequency distribution and percentages were used to present the findings.

3. RESULTS

3.1 How Long farmers Store Beans

Most respondents in the humid rainforest 67 (43.22%) and western highland savanna 118 (39.20%) stored bean grains for 1-3 months; generally farmers in the highland savanna stored beans for longer periods than those in the humid rainforest (Table 1), but the difference was not statistically significant ($P > .05$).

3.2 How Farmers Dried Beans

Majority of the farmers in the highland savanna 234 (64.8%) and humid rainforest 112 (70.9%) dried beans on tarpaulin; a few farmers 30 (18.99%) in the humid rainforest and 31 (8.59%) in the highland savanna dried beans on the bare ground. A few farmers in the highland savanna also dried beans by tying together the stems of bean plants with the pods and suspending the tied plants on the rafter of the verandas which also served as storage sites (Fig. 1).

3.3 Areas where Farmers Dry Beans

Irrespective of the region, most farmers preferred to dry their beans at home compared to the field; a lower percentage of the farmers in the highland savanna (64.5%) dried beans at home compared to 82.3% in the humid rainforest (Fig. 2).

3.4 Farmers' Perceptions of what Caused Bean Post-Harvest Losses

Most farmers 251 (69.5%) in the highland savanna and 134 (84.8%) in the humid rainforest, reported that insects were the main causes of their post-harvest losses, followed by mold/rot, 108 (26.2%) in the highland savanna and grain losses during harvesting and storage 11 (6.8%) in the South west (Table 2).

3.5 Farmers' Knowledge of Field-to-Storage Insects

Most farmers in the highland savanna 341 (92.6%) and 133 (96.3%) in the humid rainforest were aware that insects could be transferred from the field into stores, though the identity of the insects was not precise.

Among the farmers who knew that insects could be carried from field into stores, the most frequently mentioned pests were weevils, 34 (24.6%) in the humid rainforest and 180 (58.6%) in the highland savanna. This was followed by caterpillars, 23 (16.7), in the humid rain forest and 55 (16.1%) in the highland savanna. Furthermore, 19 (13.8%) of the farmers mentioned grasshoppers in the humid rain forest while 51 (16.6%) of those in the highland savanna reported crickets (Table 3) as a problem in storage areas.

3.6 Where Insects Attacked Beans along the Value Chain

In the highland savanna 208 (57.6%) and in the humid rainforest 131 (82.9%) of the farmers reported that insects attacked their beans both in the field and in storage. Very few participants in the humid rainforest, 8 (0.6%) stated that insects attacked their beans only in the field (Fig. 3).

Table 1. Number and percentage of farmers storing beans for different durations in the various regions of the study

Duration(months)	Numbers and percentage n (%)				
	1-3	4-6	7-9	10-12	>12
Humid rainforest	67 (43.22)	45 (29.03)	9 (5.80)	33 (21.29)	1 (0.64)
Highland savanna	118 (39.20)	96 (31.89)	26 (8.63)	59 (19.60)	2 (0.66)

χ^2: 10.371, df: 13, P = .663

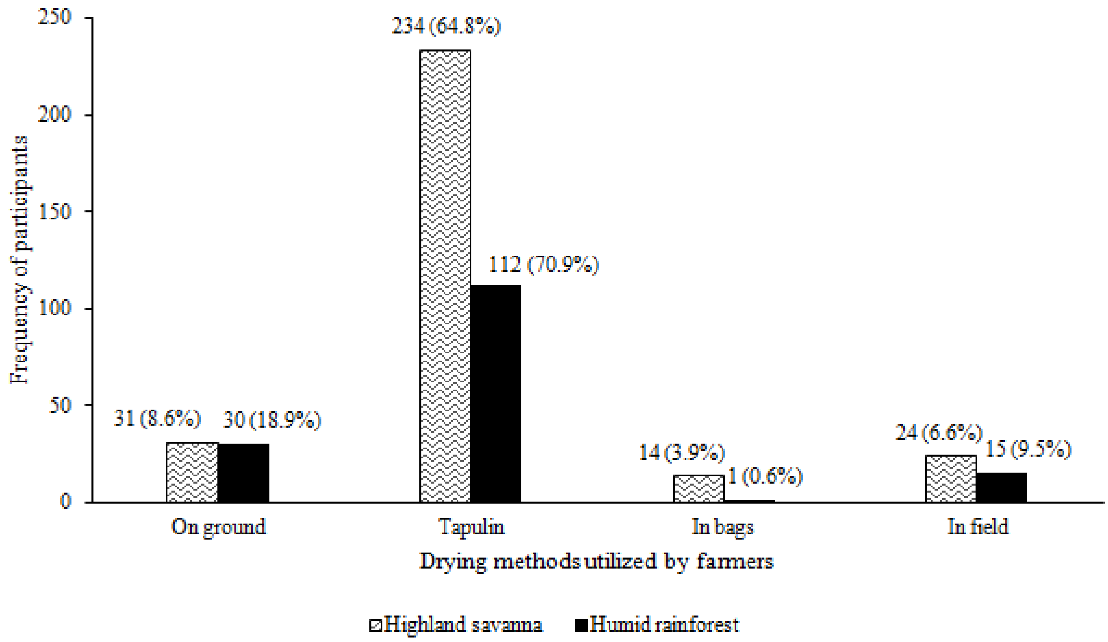

Fig. 1. Different methods of drying beans used by farmers in the humid rainforest and highland savanna agro ecological zones

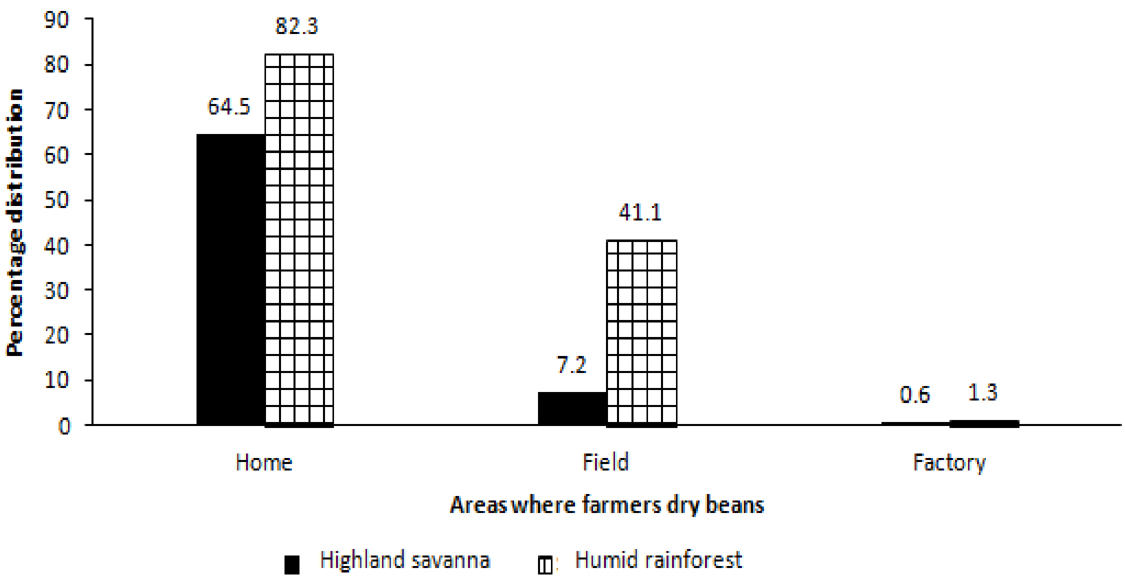

Fig. 2. Different places where farmers dried harvested beans

Table 2. Participants' perceptions of what caused post-harvest loss of beans

Causes	Highland savanna N (%)	Humid rainforest N (%)
Heavy rainfall	17 (4.7)	0 (0.0)
Diseases	15 (4.1)	0 (0.0)
Mold/rot	108 (26.2)	5(1.3)
Insects	**251 (69.5)**	**134 (84.8)**
Rodents	3 (0.8)	0 (0.0)
Water penetration	12 (3.3)	10 (6.3)
Grains losses during harvesting and threshing	5 (1.4)	11 (6.9)

χ^2: 163.794, df: 42, P= .000

Table 3. Participants' perceptions of the pests that were transferred from field to storage

Pests	Humid rainforest n (%)	Highland savanna n (%)
Beetles	13 (9.4)	6 (1.9)
Weevils	34 (24.6)	180 (58.6)
Caterpillars	23 (16.7)	55 (16.1)
Crickets	16 (11.6)	51 (16.6)
Grasshoppers	19 (13.8)	11 (3.6)
Maggots	12 (8.7)	6 (1.9)
Moths	6 (4.3)	10 (3.3)
Snails	10 (7.2)	22 (7.2)
Total	**133 (96.3)**	**341 (92.6)**

χ^2:63.549, df: 17, P= .000

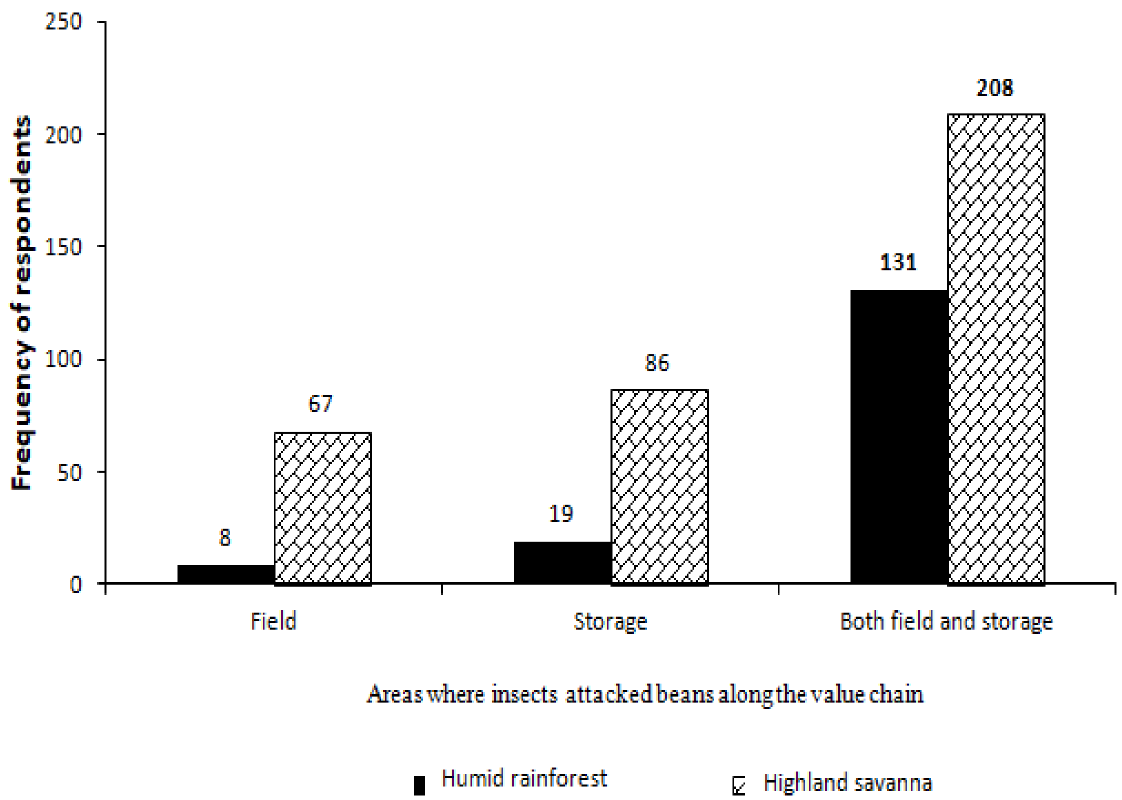

Fig. 3. Farmers perceptions about where insect are serious in the bean value chain

3.7 Farmers' Methods of Controlling Insects in Storage

Regardless of the region, the pesticide most widely used in combating insects in stored beans was Poudrox (organophosphate/pyrethoid) with the active ingredient malathion 50g/kg.. In the highlands savanna, 38 of the respondents (41.75%) indicated that they used this pesticide, compared to 31 (59.61%) in the humid rainforest. . Only 5 (5.49% and9.61% respectively), used Cypercal® (active ingredient Cypermethrine) in the highland savanna and humid rainforest respectively.

Overall, a wider variety of insecticides were used on the stored beans in the highland savanna than in the humid rain forest, but the percentages were very low (Table 4).

3.8 Local Plants used by Farmers to Control Bean Storage Pests

Amongst the plants used, cypress (Cupressus sp) was the most frequently reported both in the highland savanna 34 (52.31%) and humid rain forest 6(66.67%). Most farmers who used local plants in both regions reported that these were used in order to repel pests as reported by 44(67.69%) in the highland savanna and 5(55.56%) in the humid rain forest followed by 10 (15.38) of the farmers in the highland savanna and 2 (22.22) in the humid rainforest who reported that they use local plants because of its long preservation. Meanwhile 8 (12.31) of the farmers in the highland savanna and only 1 (11.11) in the humid rainforest attest that local plants are cheap to get. (Table 5).

3.9 How Farmers used the Local Plants to Control Stored Beans Insect Pests

For cypress, most of the farmers harvested the branches with leaves, adding these to the storage container together with the beans, as reported by 30 (88.23%) of the farmers in the highland savanna and 6 (100.0%) in the humid rainforest. The majority of farmers that used bush pepper in the highland savanna 4 (66.67%), reported using ground pepper corns and mixing it with the bean, while 2 (66.67%) in the humid rainforest mixed the whole pepper corns with the stored beans (Table 6).

3.10 Farmers' Beans Post-Harvest Storage Facilities

The majority of farmers in the highland savanna 147 (40.7%) stored their beans in bags, compared to 43 (27.2%) of the respondents in the humid rain forest. This was followed by storage in sealed containers, as reported by 122 (33.8%) of the respondents in the highland savanna and 58 (36.7%) in the humid rainforest. Storage in barns was more popular in the highland savanna than in the humid rainforest, few farmers in either ecozone stored beans on the floor.

Most of the beans was stored as threshed grains, as reported by 269 (74.5%) and 132 (83.5%) of the respondents in the highland savanna and humid rain forest respectively. Relatively very few farmers stored their beans in the unthreshed forms that is the beans are still in the pods (Fig. 4).

3.11 Non-Conventional Methods used by Farmers to Control Mold in Stored Beans

Generally, most of the farmers 288 (99.96%) in the highland savanna and 120 (75.94%) in the humid rainforest used non-conventional methods to control mold in storage. Sun-drying of beans was the most popular method used by 163 (54.15%) in the highland savanna and 60 (50.00%) in the humid rainforest. This was followed by applying wood ash to grain as reported by 85 (28.24%) of the farmers in the highland savanna and 26 (21.67%) in the humid rainforest. Other methods like applying country onion, dry pepper or groundnut oil, or kitchen/poultry wastes, were used by farmers in the highland savanna but not by those in the humid rainforest (Table 7).

3.12 Limitations of using Non-Conventional Methods to Control Mold

For the farmers who used country onion, 4 (57.1%) of them in the highland savanna reported that its effects do not last long while for pepper 4 (50.0%) mentioned that it is costly and another 4 (50%) stated limited availability of the dry pepper. Short duration of sunlight during the rainy season was the main reason mentioned by farmers who exposed their beans to sunlight as reported by 49 (81.7%) in the humid rainforest and 60 (36.8%) in the highland savanna. Most of those who applied wood ash 50 (58.8%) in the highland savanna and 19 (73.1%) in the humid mentioned the huge quantities needed as a limitation (Table 8).

Table 4. Conventional pesticides used by farmers to control storage insect pests

Name	Class	Family/Type	Active Ingredient	Highland savanna n (%)	Humid rainforest n (%)
Poudrox	Organophosphate/pyrethoid	Contact insecticide	Malathion 50g/kg	38 (41.75)	31 (59.61)
Actellic® Gold DP	Organophosphate/pyrethroid	Insecticide	Pirimiphos-methyl+thiamethoxan	0 (0.0)	7 (13.46)
Cigogne	Pyrethoid	Insecticide	Cypertmethrine	4 (4.39)	0 (0.0)
Cypermethrine	Pyrethoid	Insecticide	Cypermethrine	6 (6.59)	0 (0.0)
Cypercal®	Pyrethoid	Insecticide	Cypermethrine	5 (5.49)	5 (9.61)
Dursband	Organophosphate	Insecticide	Chlorpyrifos	12 (13.18)	0 (0.0)
Pyriforce EC	Organophosphate	Insecticide	Chlorpyriphos-ethyl 600g/L;EC	11 (12.08)	0 (0.0)
Parastar 40 EC	Neonicotinod + pyrethoid	Insecticide	20g/L Imidachlopride +20g/L Lambdacyhalothrine	4 (4.39)	0 (0.0)
Manizang	Organophosphate	Contact fungicide	50g Fungicao 72	2 (2.19)	0 (0.0)
Mocap	Organophosphate	Nematocide/insecticide granules	Terbufos	0 (0.0)	1 (1.92)
Antouka® Super	Organophosphate	Insecticide powder	Pirimiphos-Methyl 16g/kg +Permethrine 3g/kg; DP	9 (9.89)	0 (0.0)

Table 5. Most frequently used Local plants by farmers to control stored bean pests

Common names of Plants used	Highland savanna n (%)	Humid rainforest n (%)
Cypress (*Cupressus sp*)	34 (52.31)	6 (66.67)
Bush pepper plant (*Piper guineense*)	6 (9.23)	3 (33.33)
Masepo (*Ocimum sp*)	8 (12.31)	0 (0.0)
Sunflower (*Helianthus sp*)	7 (10.77)	0 (0.0)
Tobacco plant (*Nicotiana tabacum)*	5 (7.69)	0 (0.0)
White pepper plant (*Piper nigum*)	5 (7.69)	0 (0.0)
Reason for using plants		
Drive pests (repelling odor)	44 (67.69)	5 (55.55)
Easy accessibility	2 (3.07)	0 (0.0)
They are more effective	1 (1.54)	1 (11.11)
They are cheap	8 (12.31)	1 (11.11)
Long preservation	10 (15.38)	2 (22.22)

χ^2:13.692, df: 2, P = .001

Table 6. Various methods how farmers used local plants to control stored beans insect pests

Plant Type	Description	Highland savanna n (%)	Humid rainforest n (%)
Cypress(*Cupressus sp*)	Harvest and put inside the container for beans	30 (88.23)	6 (100.0)
	Grind and sprinkle on beans	3(8.82)	0 (0.0)
	Grind and mix with beans	1(2.94)	0 (0.0)
Bush pepper plant (*Piper guineense*)	Mix peppercorns with beans during storage	2 (33.33)	2 (66.67)
	Grind bush pepper corns and mix with beans	4 (66.67)	1(33.33)
Masepo (*Ocimum sp*)	Harvest and put inside the container of beans	6 (75.0)	0 (0.0)
	Grind and sprinkle on beans	2 (25.07)	0 (0.0)
Sunflower (*Helianthus sp*)	Grind and sprinkle on beans	7 (100.0)	0 (0.0)
Tobacco plant (*Nicotiana tabacum*)	Mash, dry and mix with beans	5 (100.0)	0 (0.0)
White pepper (*Piper nigrum*)	Mix pepper grains with beans during storage	1(20.0)	0 (0.0)
	Grind and sprinkle on beans	3 (60.0)	0 (0.0)
	Grind and mix with beans	1 (1.20.0)	0 (0.0)

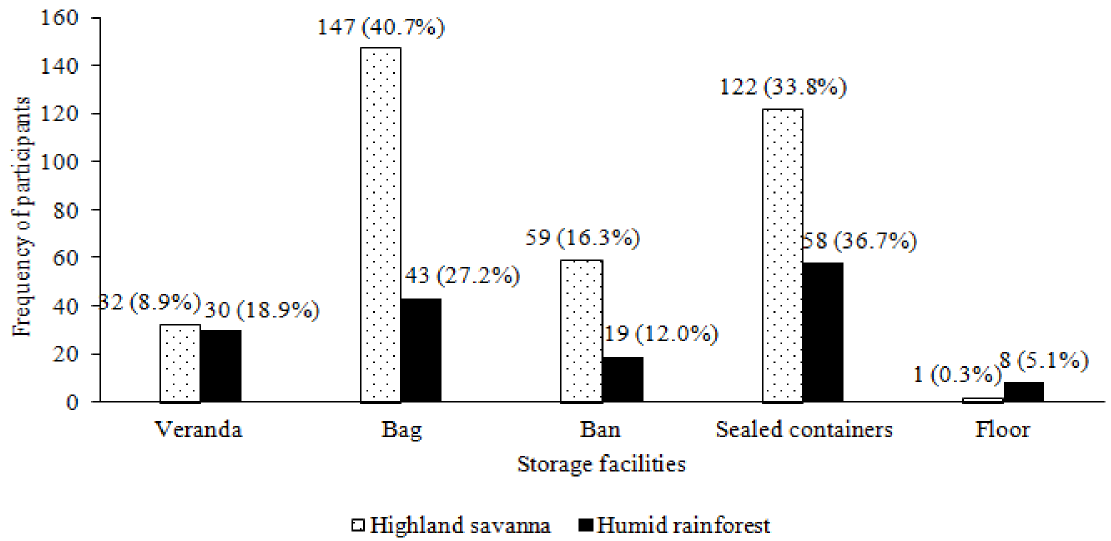

Fig. 4. Different bean storage facilities used by participants in the study areas

Table 7. Non-conventional methods used by participants to control mold on stored beans

	Methods used	Highland savanna n (%)	Humid rainforest n (%)
Yes			
	Country onion (*Afrostyrax sp*)	7 (2.33)	0 (0.0)
	Dry pepper (*Piper guineense*)	8 (2.66)	0 (0.0)
	Sun-drying	163 (54.15)	60 (50.00)
	Groundnut oil	5 (1.73)	0 (0.0)
	Use kitchen and poultry wastes	9 (2.99)	0 (0.0)
	Apply wood ash	85 (28.24)	26 (21.67)
	Keep beans in sealed containers	11 (3.65)	34 (28.33)
	Total	**288 (99.96)**	**120 (75.94)**

Table 8. Limitations of the various non-conventional methods used by farmers against mold

Methods used	Limitations	Humid rainforest (%)	Highland savanna (%)
Use of country onion (*Afrostyrax sp.*)	Limited availability	0 (0.0)	1 (14.3)
	Costly (high cost)	0 (0.0)	2 (28.6)
	Short protective period	0 (0.0)	4 (57.1)
Use of dry pepper (*Piper guineense*)	Limited availability	0 (0.0)	4 (50.0)
	Costly (high cost)	0 (0.0)	4 (50.0)
Expose beans to sunlight (solarization of beans)	Costly (high cost)	0 (0.0)	3 (1.8)
	Short protective period	0 (0.0)	1 (0.6)
	Lack of adequate drying facility	11 (18.3)	60 (36.8)
	Lack of adequate storage facility	0 (0.0)	18 (11.0)
	Insufficient sunlight during rains	49 (81.7)	60 (36.8)
Use of vegetable oil	Costly (high coat)	0 (0.0)	1 (20.0)
	Short protective period	0 (0.0)	4 (80.0)
Use of kitchen/poultry waste	Short protective period	0 (0.0)	9 (100.0)
Use of wood ash	Limited availability	19 (73.1)	50 (58.8)
	Short protective period	0 (0.0)	30 (35.3)
	Lack of storage space	2 (7.7)	0 (0.0)
	Easily blown off by wind	5(19.2)	5 (5.9)
Store beans in sealed containers	Limited availability	11 (32.4)	7 (63.6)
	Costly (high cost)	6 (17.6)	4 (36.4)
	Lack of adequate drying facility	7 (20.6)	0 (0.0)
	Lack of storage space	10 (29.4)	0 (0.0)

χ^2:1514.457, df: 280, P < .001

3.13 Why Farmers Wished to Improve on Their Beans Storage Methods

Farmers in both ecozones wanted to learn how to improve on their beans storage methods. Most of them in the highland savanna 237 (65.65%), indicated that they wanted to learn improved beans storage methods in order to prolong the shelf life of their beans. In the humid rainforest, 94 (59.5%) of the farmers wanted to learn about improved storage methods to prolong the shelf life and also increase their profit from beans sold during offseason (Table 9).

3.14 Insects that Emerged from Beans Purchased from Farmers

Two stored bean insect pest species, *Acanthoscelodes obtectus* and *Zabrotes subfasciatus* emerged from the bean samples purchased from beans farmers in the areas surveyed. The numbers of *Acanthoscelodes obtectus* were at least double those of *Zabrotes subfasciatus* from each ecozone (Fig. 5). Generally, the numbers of insects that emerged from beans in the highland savanna were significantly lower than those from the humid rainforest (P<0.05), irrespective of the insect species (Fig. 5).

4. DISCUSSION

Postharvest handling and storage is a major activity in the bean value chain. However, if not properly implemented, it can lead to considerable losses and also contamination of the produce. Previous studies by [9,10,11] showed that postharvest practices can have a great influence on fungi infestation and resultant contamination of beans with mycotoxins.

The study also found that major losses occurred during the bean handling and storage stages which concurs with previous reports [12-18] who observed that 15-25% loss of maize grain in developing countries occurred during storage.

Farmers in both ecological zones were of the view that insects caused more damage on their stored beans than rot/mold and these insect attacks also increased mold problems. This is understandable because storage fungi normally accompany or are exacerbated by insect infestation [19]. This is partly due to the generation of metabolic heat and water by insects in stored foods which increase the water activity and temperature of the commodity to levels suitable for fungal growth and multiplication [20, 21]. Also, insect damage causes openings in the seed, thus exposing the flesh to fungal infections.

Most of the farmers dried their beans on the bare ground which further predisposed the grain to mold contamination from ground surfaces and hence mycotoxin production. The traditional drying techniques on the bare ground are as expected, a major source of fungal contamination since these microorganism are ubiquitous [22]. More farmers in the highland savanna used tarpaulins to dry beans than in the humid rain forest. The major reason offered for using tarpaulins was to avoid accumulation of sand particles in the produce which often lowered the quality of the produce and making sorting of the beans for consumption and/or sale laborious and difficult. Poor postharvest practices can lead to lower grain quality, dry matter losses, mold growths and at times resultant mycotoxin contamination [23, 24]. Most of the farmers interviewed stored beans in their living houses mainly in polyvinylchloride (PVC) bags, though a few farmers stored their grains in traditional granaries. This corroborates the observations of Ngamo et al., [25] that the largest quantity of food in the tropics is stored in traditional granaries. These indigenous storage facilities

Table 9. Reasons why participants wanted to learn improved methods of beans storage

Reasons	Highland savanna n (%)	Humid rainforest n (%)
To make more money in future	58 (16.07)	27 (17.09)
To increase duration of storage	237 (65.65)	37 (23.42)
Both	66 (18.28)	94 (59.49)
Total	**361 (100.00)**	**158 (100.00)**

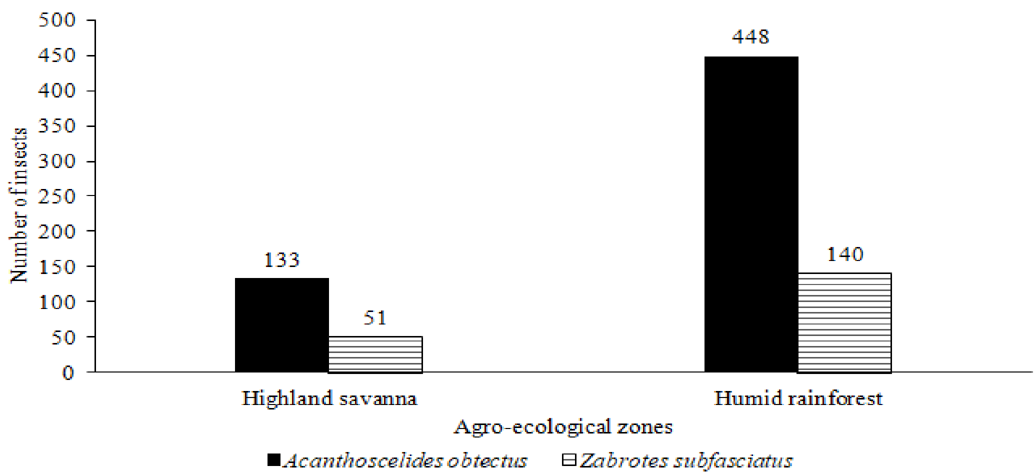

Fig. 5. Numbers and species of weevils that emerged from beans purchased from farmers

and methods are often not quite appropriate to prevent insect infestations which often also create favorable conditions for the proliferation of various molds in storage. This underscores why the participants in this study were interested to learn about improved grain storage methods. Farmers are also interested in improved low-cost and effective methods of storing grains in order to increase their incomes by selling the produce when the prices are more attractive; appropriate postharvest storage of grains by farmers is also a way of ensuring the availability of good quality seeds for planting. Two major stored product insects, *Acanthoscelides obtectus* and *Zabrotes subfasciatus* emerged from the dry bean grains purchased from the farmers interviewed and subsequently incubated in the laboratory. These two weevil species are known to be the major insect pests of stored beans in Africa [26]. These insects cause quantitative losses in stored beans as well as cause poor seed germination during subsequent plantings.

Acanthosecelides obtectus is a cosmopolitan pests of stored beans that can be transferred from the field to storage. After six month of storage, it can cause up to 80% of damage [27]. However, this damage varies depending on storage facilities and conditions. The farmers in this study therefore used both synthetic insecticide and plant-derived powders to supplement their inappropriate storage facilities and methods as means to minimizing the post-harvest losses of beans. However, the effectiveness of most of these indigenous materials needs to be tested scientifically prior to their vulgarization. The proper control of these weevils (bruchids) in storage is of major importance to the resource-poor farmers since the stored beans are used both as food and as seeds. The farmers interviewed used sun-drying to minimize mold infestation. However, this solar radiation can also be used to kill bruchids in the beans [28], if the temperatures are appropriately high.

5. CONCLUSION

The studies showed that most bean farmers in the highland savanna and humid rainforest face serious problems of insects, mold and their interactions in storage, together with lack of appropriate and adequate drying and storage facilities. Insect problems were more important than mold and these were usually controlled by the use of local plant materials and various synthetic chemicals. These insects and molds caused quantitative losses of beans which resulted in reduced rate of bean seeds germination, as well as increased bean prices due to additional expenditure for storage.

DISCLAIMER

The products used for this research are commonly used products in the area of research and country. There is no conflict of interest between the authors and producers of any product mentioned in the research since they were only mentioned for the advancement of knowledge. Also, the research was not funded by the producing company but by the authors.

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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