Original Research Article

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

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 administered to 519 bean farmers with 356 of them from the Highland savanna and 163 from the Humid rainforest ecozones in order to document their perceptions on various constraints hampering beans postharvest handling/storage and their indigenous methods of mitigating these constraints.

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(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%) store bean grains for 1-3 months, though farmers in the Highland savanna generally store beans longer than those in the humid rainforest. The insect infestations were controlled mainly by using conventional pesticides and local plants materials while mold was mainly 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.

Comment [C1]: -Don't retire as title words in keywords. This increases the chance of finding the article in an internet search.

Introduction

Food and nutrition insecurity is a major challenge to smallholder farmers and the developing world in general. Therefore boosting agricultural productivity and food availability 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]. Bean is one of the most common food in schools with adolescents due to its high nutritional quality in terms of percentage protein. It high mineral content especially iron and zinc are advantageous in regions with high prevalence of micronutrient deficiencies such as iron deficiency anemia [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. Beans 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 improves 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

Comment [C2]: Put a bibliographic reference, it was not you who measured that beans are one of the most consumed legumes (third place), this data is in some table or article.

conducted to document beans 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 573m above sea levels. It is at the east slope of Mount Cameroon, with an annual rain fall of about 4,090mm, rich volcanic rocky soils and a temperature range of 20 -27^0C. It has an equatorial climate with a rainy season from 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 3000m above sea level; it has temperature range between of between 19.5^0C-25.0^0C and an annual rainfall between 1100m-2000m. It has a dry season from November to March and rainy season from March to November.

2.2 Survey

A semi structured questionnaire was administered to 519 male and female bean farmers comprising 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 mitigate or control stored insect pests (g) what they do with the beans damaged by post-harvest factors.

Comment [C3]: What is the research development period, year (dates?). The characterization of the area is not so important because it is not evaluating the bean planting. It is important to characterize how the interviews were carried out, period of the year, characteristics of the interviewees...

Comment [C4]: Characterizing the interviewees, age, economic level, education level, whether they were men or women, all these data can interfere with the answers given. Also characterize rural properties, whether they were large or small (hectares), whether producers used a lot of technology in production...

2.3 Data Analysis

Data collected were keyed into Microsoft Excel spread sheet 2016 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.

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 were not statistically significant (P > .05).

Table 1: Duration of bean storage in the various regions of study

Region	**Duration of bean storage in months 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

Comment [C5]: Typically, the word "Table x" is written in bold, check the journal's standards.

Comment [C6]: Check the journal's rules for tables and figures. Line spacing is not normally used within tables.

Tables have open sides. This one is not a table, it's a frame (it has closed sides), edit the table.

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 tapulin; 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 suspending on ropes in the verandas which also served as storage sites (Figure 1).

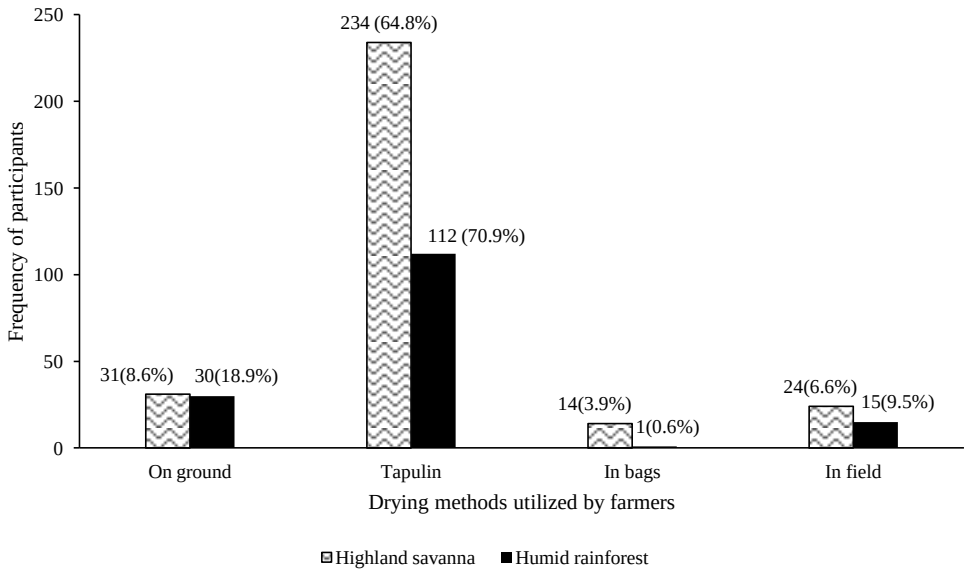

Figure 1: Different methods that farmers dry beans in the Humid rainforest and Highland savanna agroecological zones

Comment [C7]: Typically, the word "Figure x" is written in bold, check the journal's standards.

3.3 Areas where farmers dry beans

Irrespective of the region, most farmers prefer 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 (Figure 2).

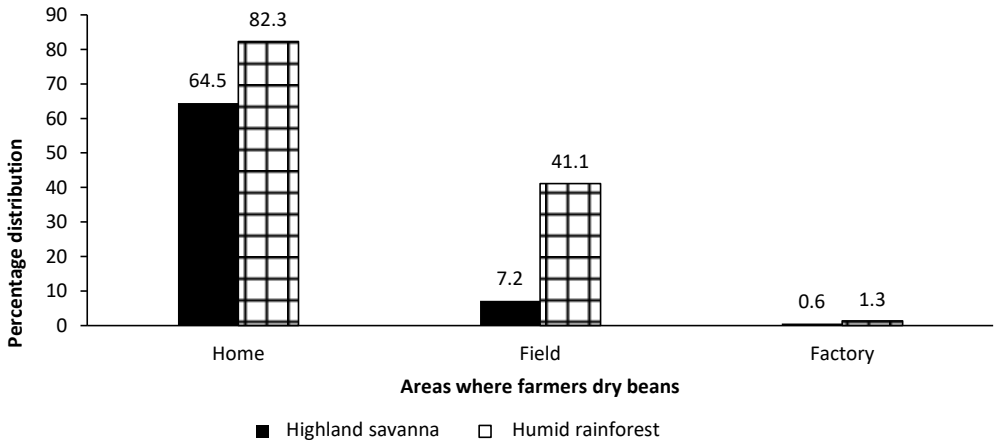

Figure 2: Different places where farmers dried harvested beans

3.4 Farmers perceptions of what causes bean post-harvest losses

Most farmers in the Highland savanna 251(69.5%) 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).

Table 2: Participants perceptions of what causes post-harvest loss of beans

Causes	**Highland savanna N (%)**	**Humid rainforest N (%)**
Heavy rainfall	17(4.7)	0
Diseases	15(4.1)	0
Mold/rot	108(26.2)	5(1.3)
Insects	**251(69.5)**	**134(84.8)**
Rodents	3(0.8)	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

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 transfered from the field into stores though the identity of the insects was not precised

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. Surprisingly, 19 (13.8%) of the farmers mentained grasshoppers in the Humid rain forest while 51 (16.6%) of those in the Highland savanna reported Crickets (Table 3).

Table 3: Participants' perceptions of the pests that are transferred from field to storage

Pests	**Humid rainforest**	**Highland savanna**
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

3.6 Where insects attack 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 (Figure 3).

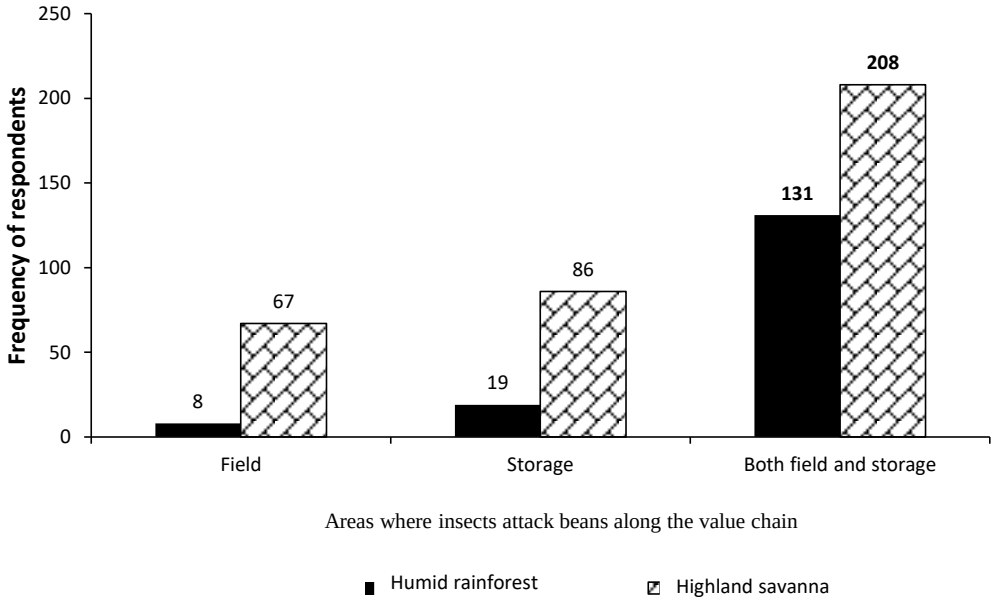

Figure 3: Farmers perceptions about where insect are serious in the bean value chain

3.7 Farmers' method of controlling insects in storage

Regardless of the region, most widely used conventional pesticide in storage was Poudrox (Organophosphate/pyrethoid) with an active ingredient Malathion 50g/kg, 38(41.75) in Highland savanna and 31(59.61) in the Humid rain forest respectively. In the highland savanna out of 5(5.49) who used Cypercal® (active ingredient Cypermethrine) to control insects and mold in storage; 5(9.61) of them also use the same synthetic chemical in the humid rainforest.

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

Comment [C8]: What would be the reason for the greater amount of insecticides in the savannah region, if you didn't find the answer in the field you will find it in articles

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/fungicide	Pirimiphos-methyl+thiamethoxan	0	7(13.46)
Cigogne	Pyrethoid	Insecticide	Cypertmethrine	4(4.39)	0
Cypermethrine	Pyrethoid	Insecticide	Cypermethrine	6(6.59)	0
Cypercal®	Pyrethoid	Insecticide	Cypermethrine	5(5.49)	5(9.61)
Dursband	Organophosphate	Insecticide	Chlorpyrifos	12(13.18)	0
Pyriforce EC	Organophosphate	Insecticide	Chlorpyriphos-ethyl 600g/L;EC	11(12.08)	0
Parastar 40 EC	Neonicotinod + pyrethoid	Systemic and contact Insecticide	20gr/L Imidachlopride +20gr/L Lambdacyhalothrine	4(4.39)	0
Manizang	Organophosphate	Contact fungicide	50g Fungicao 72WP	2(2.19)	0
Mocap	Organophosphate	Nematocide/Insecticide granules	Terbufos	0	1(1.92)
Antouka® Super	Organophosphate	Insecticide powder	Pirimiphos-Methyl 16g/kg +Permethrine3g/kg;DP	9(9.89)	0

3.8 Local plants used by farmers to control bean storage pests

Amongst the plants used, cypress (cypens 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 it's 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).

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 (*Cyperus 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
Sun flower (*Thitoma sp*)	7 (10.77)	0
Tobacco plant (*Nicotiana tabacum)*	5 (7.69)	0
White pepper plant (*Piper nigum*)	5 (7.69)	0
Reason for using plants		
Drive pests (repelling odor)	44 (67.69)	5 (55.55)
Easy accessibility	2 (3.07)	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

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 and put inside 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. For those who used bush pepper, majority in the Highland savanna 4 (66.67%) ground the pepper fruits and mixed with the beans grains while 2 (66.67%) in the humid rainforest mixed the pepper grains with the stored beans (Table 6).

Comment [C9]: Put the scientific name of the bush pepper in parentheses ().

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(*Cyperus sp*)	Harvest and put inside the container for beans	30 (88.23)	6 (100.0)
	Grind and sprinkle on beans	3(8.82)	0
	Grind and mix with beans	1(2.94)	0
Bush pepper plant (*Piper guineense*)	Mix pepper grains with beans during storage	2 (33.33)	2 (66.67)
	Grind bush pepper and mix with beans grains	4 (66.67)	1(33.33)
Masepo (*Ocimum sp*)	Harvest and put inside the container of beans	6 (75.0)	0
	Grind and sprinkle on beans	2 (25.07)	0
Sun flower (*Thitoma sp*)	Grind and sprinkle on beans	7 (100.0)	0
Tobacco plant (*Nicotiana tabacum*)	Mash, dry and mix with beans	5 (100.0)	0
White pepper (*Piper nigum*)	Mix pepper grains with beans during storage	1(20.0)	0
	Grind and sprinkle on beans	3 (60.0)	0
	Grind and mix with beans	1 (1.20.0)	0

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%) in the humid rain forest. This was followed by storage in sealed containers as revealed by 122 (33.8%) of the respondents in the highland savanna and 58 (36.7%) in the humid rainforest. Storage in bans was more popular in the highland savanna than in the humid rainforest, few farmers in both ecozones stored beans on the floor.

Most of the beans was stored as threshed grains as revealed 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 in the pods (Figure 4).

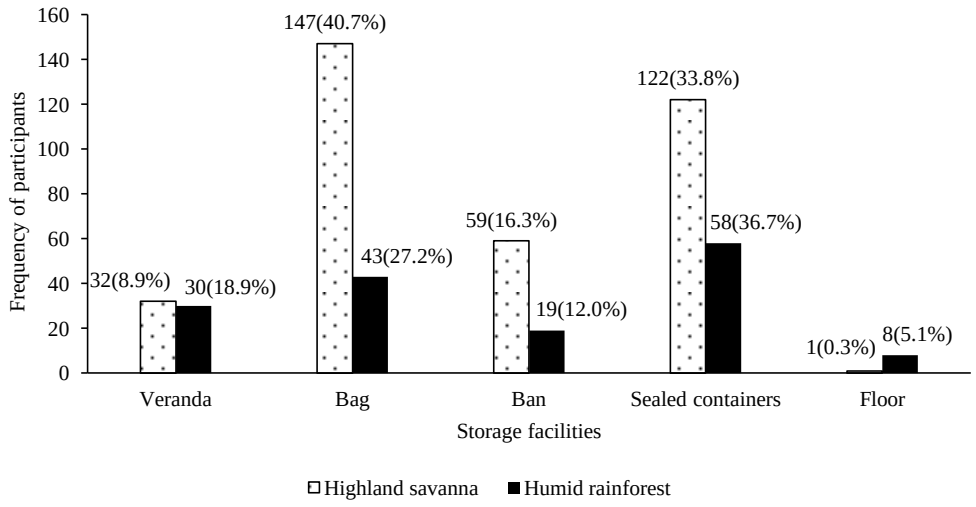

Figure 4: Different Beans storage facilities used by participants in the study areas

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).

Comment [C10]: Put the scientific name in parentheses ().

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
	Dry pepper (*Piper guinense*)	8(2.66)	0
	Sun-drying	163(54.15)	60(50.00)
	Groundnut oil	5(1.73)	0
	Use kitchen and poultry wastes	9(2.99)	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)**

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 does 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 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	1 (14.3)
	Costly (high cost)	0	2 (28.6)
	Short protective period	0	4 (57.1)
Use of dry pepper (*Piper guineense*)	Limited availability	0	4 (50.0)
	Costly (high cost)	0	4 (50.0)
Expose beans to sunlight (solarization of beans)	Costly (high cost)	0	3 (1.8)
	Short protective period	0	1 (0.6)
	Lack of adequate drying facility	11 (18.3)	60 (36.8)
	Lack of adequate storage facility	0	18 (11.0)
	Insufficient sunlight during rains	49 (81.7)	60 (36.8)
Use of vegetable oil	Costly (high coat)	0	1 (20.0)
	Short protective period	0	4 (80.0)
Use of kitchen/poultry waste	Short protective period	0	9 (100.0)
Use of wood ash	Limited availability	19 (73.1)	50 (58.8)
	Short protective period	0	30 (35.3)
	Lack of storage space	2 (7.7)	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
	Lack of storage space	10 (29.4)	0

χ^2:1514.457, df: 280, $P < .001$

3.14 Why farmers wish to improve on their beans storage methods

Comment [C11]: 3.13

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 above improve storage methods to prolong the shell life and also increase their profit from beans sold during offseason (Table 9).

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)**

3.15 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 (Figure 5). Generally, the numbers of insects that emerged from beans in the highland savanna was significantly lower than those from the humid rainforest ($P<0.05$), irrespective of the insect species (Figure 5).

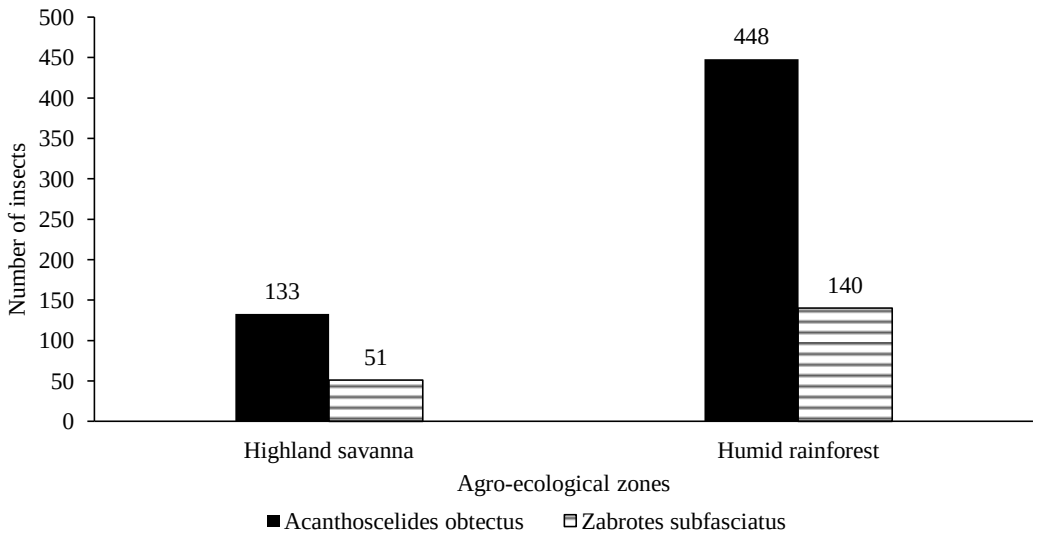

Figure 5: Numbers and species of weevils that emerged from beans purchased from farmers.

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 concurrs with previous reports [12,13,14,15,16,17,18] who observed that 15-25% loss of maize grain in developing countries occurs during storage.

Farmers in both ecological zones were of the view that insects cause more damage on their stored beans than rot/mould and these insect attacks also increases 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].

Most of the farmers dried their beans on the bare grounds which further predisposes the grain to mould 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 ubiquitons [22]. More farmers in the highland savanna used tarpullins to dry beans than in the humid rain forest. The major reason advanced for using tarpullins was to avoid accumulation of sand particles in the produce which often lowers 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 [25] that the largest quantity of food in the tropics is stored in traditional granaries. These indigenous storage facilities 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 products 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 weevils' species are known to be the major insect pests of stored beans in Africa [26]. These insects cause quantitative losses in store 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 fascilities and conditions. The farmers in this study therefore used both synthetic insecticide and plant-derived powders to supplement their inappropriate storage fascilities 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 bruchids in storage is of major importance to the resource- poor farmers since the stored beans is 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.

In conclusion, the studies showed that most beans 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's problems were more important than mold and these were usually controlled by the use of local plants materials and various synthetic chemicals with limited use of environmentally friendly methods like local plants and their derivatives. These insects and molds cause quantitative losses of beans which results in reduced rate of bean seeds germination, as well as increase in bean prices due to additional expenditure for storage.

Comment [C12]: Insert the bibliographic reference.

Comment [C13]: It's weird to start the sentence with a scientific name, rewrite this sentence.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

Comment [C14]: Cite recent articles, preferably from the last five years (2018-2022). Replaces old references with newer ones.

1. Maingi, J.M. C.A. Shisanya, N.M. Gitonga, B. Hornetz (2001).Nitrogen fixation by common bean (*Phaseolus vulgaris* L.) in pure and mixed stands in semi-arid south-east Kenya Eur. J. Agron., 2001; 14 (1): 1-12,
2. Kimatu, J. N., Mutuli, W. M., Mbiri, J. W., Mweu, B., Musimba, N., Akuja, T., & Nguluu, S. The dynamics of physical properties, seed moisture content, market economics and post-harvest management of six bean varieties (*Phaseolus vulgaris*) grown in the sub Saharan region in Africa,journal of advances in agriculture. 2014. Vol 3, No1.
3. Buruchara, R., Chirwa, R., Sperling, L. Mukankusi, C. Rubyogo, J.C., Muthoni, R. and Abang, M.M. "Development and delivery of bean varieties in Africa: The Pan- Africa Bean Research Alliance (PABRA) Model",African Crop Science Journal. 2011.Vol. 19 No. 4, 22 7–245.
4. Wortmann, C. S. *Phaseolus vulgaris* L. (common bean).Record from PROTA4U.Brink, M. & Belay, G. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l"Afriquetropicale), Wageningen, Netherlands.2006.

5. Coproduits de fruits et légumes et coproduits de conserverie: fiche n° 24. Comité National des Co-produits, ADEME, IDELE. CNC (2004). Available : http://idele.fr/recherche/publication/idelesolr/recommends/coproduit-de-haricots... components/DI0469-04....
6. Bedoussac, E.-P. Journet, H. Hauggaard-Nielsen, C. Naudin, G. Corre-Hellou, E.S. Jensen, L. Prieur, E. Justes. Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. A review. Agron. Sustain. Dev.2015; 35: 911-935.
7. Latati, M., Bargaz, A., Belarbi, B., Lazali, M., Benlahrech, S., Tellah, S. The intercropping common bean with maize improves the rhizobial efficiency, resource use and grain yield under low phosphorus availability. Eur. J. Agron.. 2016; 72: 80–90.
8. Andukwa H and Ntonifor N. Farmers' knowledge and Perception on Common beans production constraints and their mitigationmethods in the humid rainforest and highland savanna of Cameroon. Journal of Experimental Agriculture International. 2021; 43 (2): 70-85.
9. Hell K, Cardwell KF, Setamou M, Poehling HM. The influence of storage practices on aflatoxin contamination in maize in four agroecological zones of Benin, West Africa. J. Stored Prod. Res.2000; 36(4):365-382.
10. Mboya R, Bogale A.Mycotoxin contamination of food and its possible implications on sustainable development in Rungwe District, Tanzania. OIDA. Int. J. Sust. Dev. 2012 ; 5(7):37-46.
11. Kamala A, Kimanya M, Haesaert G, Tiisekwa B, Madege R, Degraeve S, Cyprian C, De Meulenaer B. Local post-harvest practices associated with aflatoxins and fumonisins contamination of maize in three agro ecological zones of Tanzania. F. Add. Cont.: Part.2016; A33(3):551-559.
12. Rugumamu CP. Insect infestation of maize, *Zea mays* (L.) in indigenous storage structures in Morogoro region, Tanzania.Tanzania J. Sci.2004; 29(2):1-10.
13. Demissie G, Teshom A, Abakemal D, Tadesse A. Cooking oils and „„,Triplex"" in the control of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in farm-stored maize. J. Stored Prod.Res.2008; 44:173-178.

14. FAO. Global food losses and food waste-extent, causes and prevention. FAO, Rome, Italy.2011.
15. Abass AB, Ndunguru G, Mamiro P, Alenkhe B, Mlingi N, Bekunda M.Postharvest food losses in a maize-based farming system ofsemi-arid savannah area of Tanzania. J. Stored. Prod. Res.2014; 57:49-57.
16. Kaminski J, Christiaensen L. 2014.Post-harvest loss in sub-Saharan Africa-what do farmers say?. G. F. Secur. 2014;3(3):149-158.
17. Affognon H, Mutungi C, Sanginga P, Borgemeister C .Unpacking postharvest losses in sub-Saharan Africa: A meta-analysis. WorldDev.2015; 66:49-68
18. Suleiman RA, Rosentrater KA, Chove B . Periodic physical disturbance: an alternative method for controlling *Sitophilus zeamais*(maize weevil) infestation. Insects 2016; 7:51.
19. Miller, J. D.Fungi and Mycotoxin in grains: Imlicaton for stored products research, journal of Stored Products Research. 1995;31:1-16.
20. Milton, R. F., and Pawsey, R. K. Spoilage relating to the storage and transport of cereals and oil seeds. International Journal of Food Microbiology. 1998;7:214-217.
21. Sauer, D, B. Effects of fungal deterioration on grain. Nutritional value,toxicity and germination. International formal of food microbiology 1998; 7:267-275.
22. Kaaya, A. N., Kyamuhangire, W., and Kyamanywa, S. Factors affecting aflatoxin contamination of harvested maize in the three agroecological zones of Uganda. Journal of Applied Sciences. 2006 6:2401-2407.
23. Tangi EK, Pussemier L. Ochratoxin A and citrinin loads in stored wheat grains: impact of grain dust and possible prediction usingergosterol measurement. F. Add. Cont. 2006;23(2):181-189.
24. Magan N, Aldred D. Post-harvest control strategies: minimizing mycotoxins in the food chain. Int. J. F. Microb.2007; 119(1):131-139.
25. Ngamo TSL, Ngassoum MB, Mapongmetsem PM, Malaisse F, Haubruge E.Current post harvest practices to avoid insect attacks on stored grains in Northern-Cameroon. Agricultural Journal. 2007; 2(2): 242- 247.

26. Abate T and Ampofor, J.K.O. Insects pests of beans in Africa: Their Ecology and Management. Annual Review of Entomology. 1996;41:45-73.

27. Cardona C, Schwartz HF, Pastor-Corrales MA. Insects and other invertebrate pests in Latin America and their constraints. Bean production problems in the tropics. Second edition. CIAT Cali Colombia. 1998 ; 505-571.

28. Fulton J. Murdock L, Moussa B, Stanish L, Everhart-Valentin K, Lowenberg-DeBoer J Applying research with extention: 22years of strengthening cowpea storage in Africa. Purdue University.2009.