Original Research Article

Farmers' Knowledge and Perception on Beans Posth ~~-H~~arvest 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~~ highland savanna and ~~Humid~~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 in order to document their perceptions on various constraints hampering beans postharvest handling/storage and their indigenous methods of mitigating these constraints. ~~with~~ Of these, 356 ~~of them~~were from the ~~H~~highland savanna and 163 from the ~~Humid~~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%) stored bean grains for 1-3 months, though farmers in the ~~Highland~~ highland savanna generally stored beans longer than those in the humid rainforest. The insect infestations were controlled

Comment [A1]: Highland and humid are common names, thus small letters. Unless it is the acknowledged official name of the area.

Comment [A2]: Distributed? Administered sound as if it was ingested, like medicine.

Comment [A3]: I think it reads easier if you break it up in two sentences – the one concerned with the place and numbers and the other one why it was done.

mainly by using conventional pesticides and local plants 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 humid rainforest, Highland highland savanna, agro-ecologies.

Comment [A4]: Since you are talking about plant material, the materials take the plural.

Introduction

Food and nutrition insecurity is a major challenge to smallholder farmers and the developing world in general. Therefore boosting 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 is are one of the most common foods in schools with adolescents 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 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 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-

Comment [A5]: I think it is safe to say that all people will consume beans and not a single bean, thus it is better to use the plural. Unless of course you mean an individual bean.

Comment [A6]: Surely all schools and not only those that have adolescents? I'd go with schools and leave the 'with adololescents".

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 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 573 m above sea levels. It is at the east slope of Mount Cameroon, with an annual rain-fall 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 Midmid-November and a dry season from Midmid-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.

Comment [A7]: Good idea to leave a space between a number and its unit just for ease of reading. Exception % and degrees Celsius

2.2 Survey

A semi structured questionnaire was administered 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 (pidginPidgin) 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 ~~do~~ did with the beans damaged by post-harvest factors.

Comment [A8]: All reporting should be in past tense, even if the actual questionnaire was in present tense

2.3 Data Analysis

Data collected were keyed into Microsoft Excel 2016 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~~ western highland savanna 118 (39.20%) stored bean grains for 1-3 months; generally farmers in the ~~Highland~~ highland savanna stored beans for longer periods than those in the humid rainforest (Table 1), but the difference ~~were~~ was 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 [A9]: What does this N stand for? Number of months? Since you are talking about beans, my first thought was nitrogen loss perhaps. I think you should clarify it. Or leave it out. The % seems at an odd place. It looks as if it is on the x-axis, but it should be on the y axis. I realise you cannot put it there, because your areas are there. Maybe rephrase the title? Something like: percentage of farmers storing beans for different durations in the various regions of the study

3.2 How farmers dried beans

Majority of the farmers in the ~~Highland~~ highland savanna 234 (64.8%) and ~~Humid~~ humid rainforest 112 (70.9%) dried beans on tarpaulin~~; few~~; a few farmers 30 (18.99%) in the humid rainforest and 31 (8.59%) in the ~~Highland~~ highland savanna dried beans on the bare ground. A few farmers in the ~~Highland~~ highland savanna also dried beans by suspending on ropes ~~in~~ underthe verandas which also served as storage sites (Figure 1).

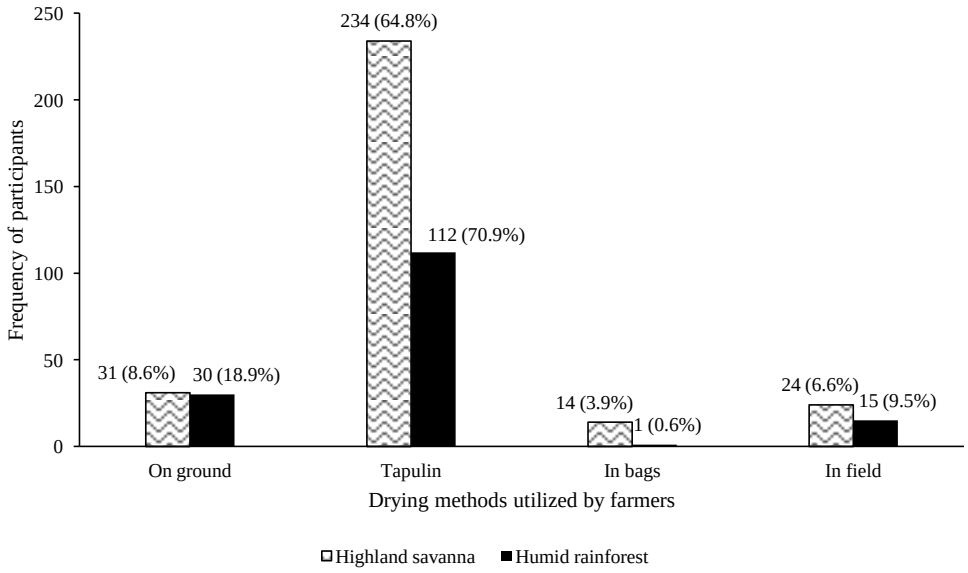

Figure 1: Different methods for drying beans utilized ~~that~~ by farmers ~~dry beans~~ in the ~~Humid~~ humid rainforest and ~~Highland~~ highland savanna ~~agroecological~~agro ecological zones

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~~ highland savanna (64.5%) dried beans at home compared to 82.3% in the ~~Humid~~ humid rainforest (Figure 2).

Comment [A10]: Unless humid and highland are part of the official name and not an indication of region? Then it should be capital letters. But you used small letters earlier on.

Comment [A11]:

Comment [A12]: What do they suspend on ropes – surely not the beans themselves. Some sort of tray? Be specific so that any person can understand the concept.

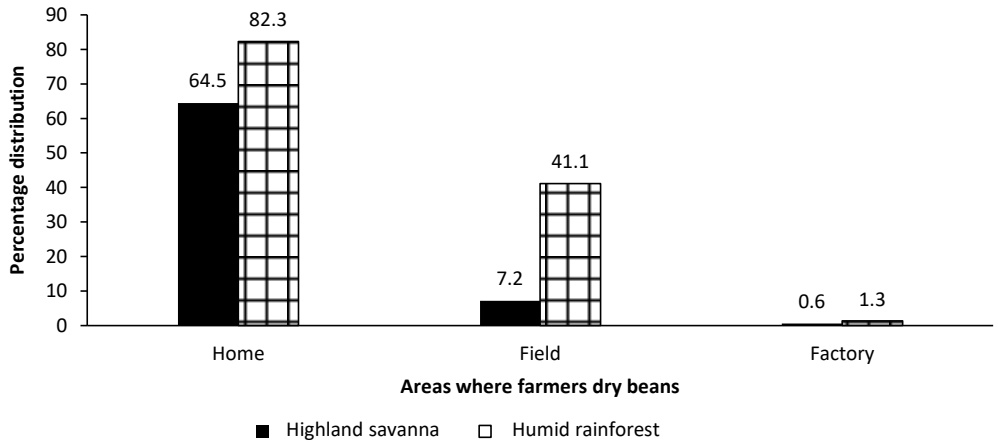

Figure 2: Different places where farmers dried harvested beans

3.4 Farmers' perceptions of what ~~causes~~ caused bean post-harvest losses

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

Comment [A13]: Is this an official name (then capital letters) or a geographical area (then small letters)?

Table 2: Participants' perceptions of what ~~causes~~ caused 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~~field-to-storage insects

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

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~~ humid rainforest and 180 (58.6%) in the ~~Highland~~ highland savanna. This was followed by caterpillars, 23 (16.7), in the ~~Humid~~ humid rain forest and 55 (16.1%) in the ~~Highland~~ highland savanna. Surprisingly, 19 (13.8%) of the farmers ~~mentained~~mentioned grasshoppers in the ~~Humid~~ humid rain forest while 51 (16.6%) ~~of~~) of those in the ~~Highland~~ highland ~~savanna reported~~savanna reported ~~Crickets~~ crickets (Table 3) as a problem in storage areas.

Comment [A14]: Maybe say why you thought this was surprising? I would think that a grasshopper will eat the leaves but not the harvested (dry?) beans.

Table 3: Participants' perceptions of the pests that ~~are~~ were 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

Comment [A15]: I know it is still the case, but you report on what happened in the past. Who knows, with climate change the pest may change as well in the future!

3.6 Where insects attacked beans along the value chain

In the ~~Highland~~ highland savanna 208 (57.6%) and in the ~~Humid~~ 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~~ humid rainforest, 8 (0.6%) stated that insects attacked their beans only in the field (Figure 3).

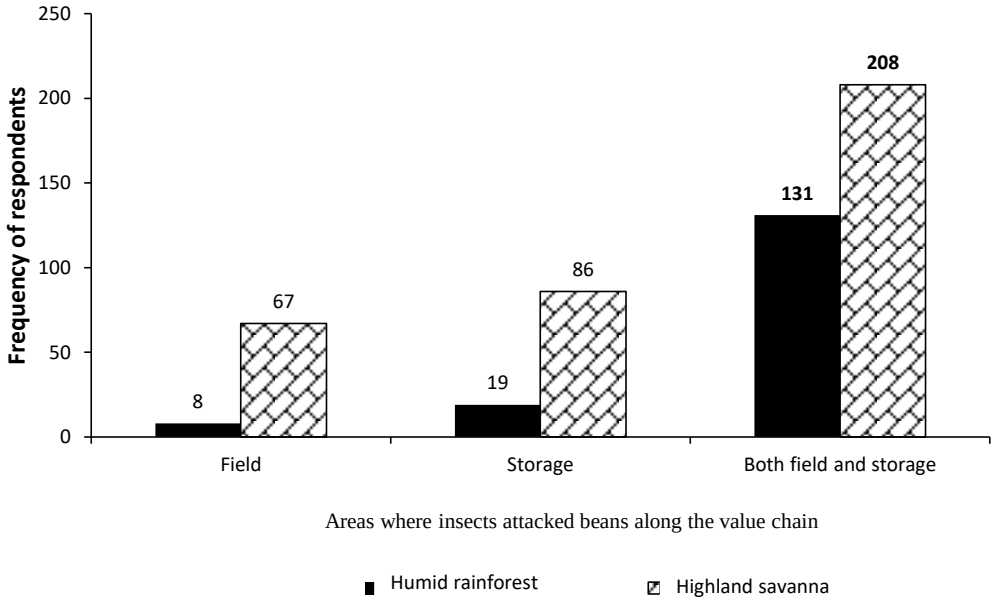

Figure 3: Farmers perceptions about where insect are serious in the bean value chain

3.7 Farmers' methods of controlling insects in storage

Regardless of the region, the most widely used conventional pesticide in storage was Poudrox (oOrganophosphate/pyrethoid–) with an active ingredient Malathion– 50g/kg, –38 (41.75%) in ~~Highland~~ highland savanna and 31 (59.61%) in the ~~Humid~~ 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~~ were used on ~~to~~ the stored beans in the ~~Highland~~ highland savanna ~~-~~than in the ~~Humid~~ humid rain forest, ~~-~~but the percentages were very low (Table 4).

Comment [A16]: This sounds as if the pesticide was in storage. I think you mean the pesticide was used in stored beans? Maybe: The pesticide most widely used in combating insects in stored beans, was…. Then also, the 50 g/kg and 38 (41.75%) is difficult to read – all those numbers. Maybe break it up in two sentences. After naming the pesticide and its active ingredient, new sentence: 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.

Comment [A17]: This sentence doesn't make sense. It seems as if you are talking about the same 5 people, but that cannot be. Do you mean that only 5 people in both regions (5.49% and 9.61% respectively), used Cyperacal? then maybe put it like that.

Comment [A18]: I am no statistician, and you should ask your statistician this question. Isn't the fact that you had more respondents in the highland savanna the reason you had a bigger variety of chemicals used? Or maybe the insects were more varied? I am just thinking here, know it was not the aim of the study.

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~~ 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	20g~~r~~/L Imidachlopride +20g~~r~~/L Lambdacyhalothrine	4 (4.39)	0
Manizang	Organophosphate	Contact fungicide	50g Fungicao 72 WP	2 (2.19)	0
Mocap	Organophosphate	Nematocide/~~I nsecticide~~ insecticide granules	Terbufos	0	1 (1.92)
Antouka® Super	Organophosphate	Insecticide powder	Pirimiphos-Methyl 16g/kg +Permethrine	9 (9.89)	0

Comment [A19]: The N is still confusing. Isn't the N for the whole population and n for the sample? Check with your statistician.

Comment [A20]: Something wrong with the font

Comment [A21]: I've googled actellic gold – it is an insecticide, but I cannot find anything about it being a fungicide as well.

Comment [A22]: Why do you include the action only in this case? Either include ALL modes of action or leave it out completely.

Comment [A23]: The formulation (WP, EC, DP) is not part of the active ingredient, only the way it is administered. Add it to the name/family/type column if you want to. And the names – why do only some have the ®? Surely all of them are registered trademarks?

				3g/kg; DP		

3.8 Local plants used by farmers to control bean ~~storage pests~~storage pests

Amongst the plants used, cypress (cypens sp) was the most frequently ~~reported both~~reported ~~in~~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~~and 2 (22.22) in the Humid rainforest ~~who reported~~who reported that they use local plants because of it~~'s~~s long preservation. Meanwhile 8 (12.31) of the farmers in the highland savanna ~~and only~~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~~used Local plants ~~by farmers~~by farmers to ~~control stored~~control stored bean pests

Common names of Plants used	**Highland savanna N (%)**	**Humid rainforest N (%)**
Cypress (~~*Cyperus*~~ *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
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)

Comment [A24]: Cyperus is a members of the reed family. Just make sure which one you are talking about – cypress trees or cyperus reeds. I can understand the smell of cypress being repellant to insects

Comment [A25]: I know sunflower as Helianthus sp.The only reference I could get to thitoma was a very old book with no photos. It refers to red-hot-poker, an aloe (kniphovia). Check the plant name – it could have changed.

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~~adding these to the storage container ~~-~~together with the beans, as reported by 30 (88.23%) ~~-~~of the farmers in the ~~Highland~~ highland savanna and 6 (100.0%) in the humid rainforest. ~~For those who used bush pepper,~~ The majority of farmers that used bush pepper in the ~~Highland~~ highland savanna 4 (66.67%), reported using ground ~~the~~ pepper ~~fruits~~ corns and ~~mixed~~ mixing it with the bean~~s grains,~~ while 2 (66.67%) in the humid rainforest mixed the whole pepper ~~grains~~ corns with the stored beans (Table 6).

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*~~ *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
	Grind and mix with beans	1(2.94)	0
Bush pepper plant (*Piper guineense*)	Mix pepper ~~grains~~corns with beans during storage	2 (33.33)	2 (66.67)
	Grind bush pepper corns 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 nigrum*)	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

Comment [A27]: Freshly ground?

Comment [A26]: Check the name

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~~bags, compared to 43 (27.2%)~~–~~ of the respondents in the humid rain forest. This was followed by storage in sealed containers, as ~~revealed~~ reported 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~~ either ecozone~~s~~ stored beans on the floor.

Comment [A28]: Revealed sounds as if it was a secret.

Comment [A29]: Bins, barns or bags? It cannot be bans. BAN means exclude. Like banning face masks so that we can get back to normal!

Most of the beans was stored as threshed grains, as ~~revealed~~ 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 (Figure 4).

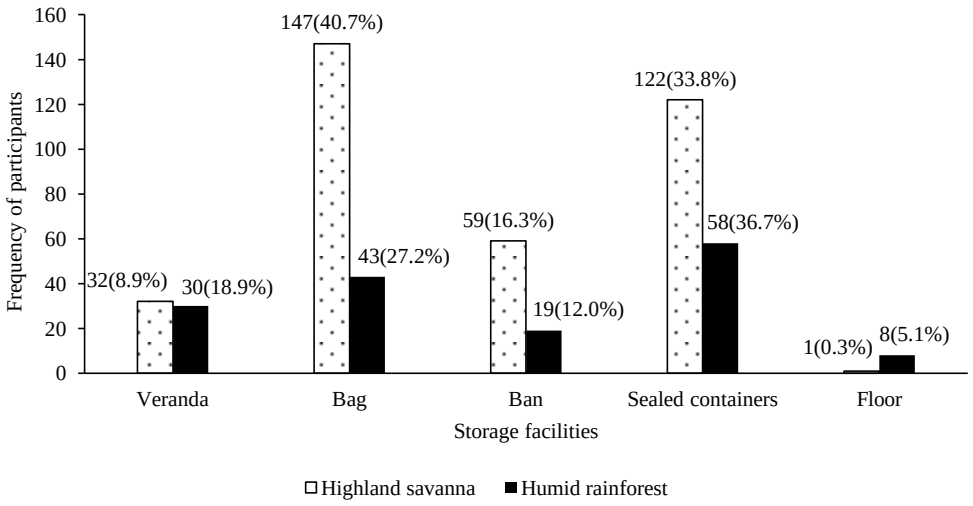

Figure 4: Different ~~Beans~~ bean storage facilities used by participants in the study areas

Comment [A30]: The facilities are the subject here and takes the plural s

Comment [A31]: Check the bin/bag/barn. Cannot be BAN. Add spaces between number before bracket and bracket.

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).

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 guineense*)	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 do~~es~~ 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 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 ~~above~~ about ~~improve~~ improved storage methods to prolong the shelf~~l~~ 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	Humid rainforest

	N (%)	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~~ were significantly lower than those from the humid rainforest ($P<0.05$), irrespective of the insect species (Figure 5).

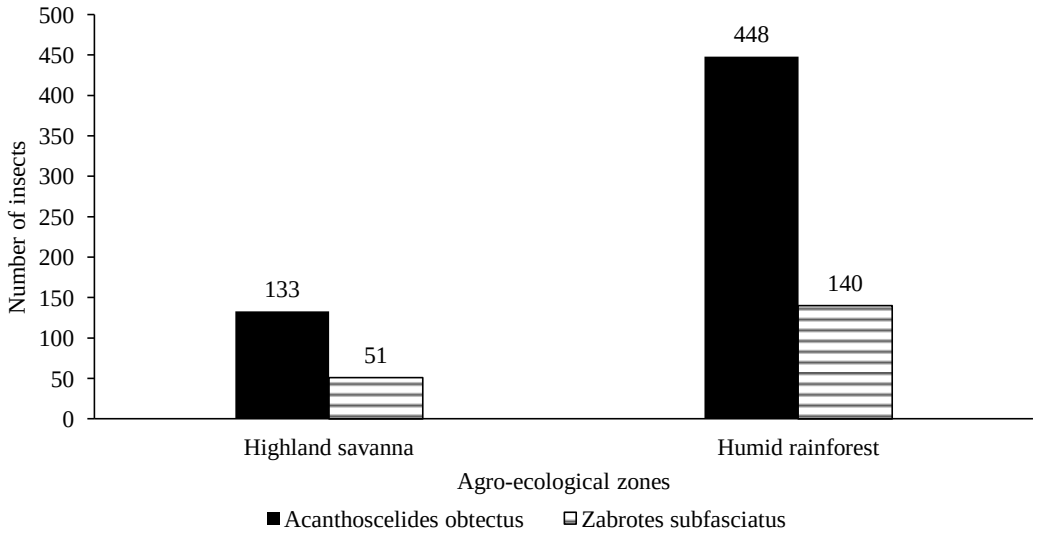

Figure 5: Numbers and species of weevils that emerged from beans purchased from farmers.

Why this gap?

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

Farmers in both ecological zones were of the view that insects caused more damage on their stored beans than rot/~~mould~~mold and these insect attacks also increase~~d~~s 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~~foods which increase the water activity and temperature of the commodity to levels suitable for fungal growth and multiplication [20, 21].

Comment [A32]: 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 grounds which further predisposes predisposed the grain to mouldmold 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 ubiquitonsubiquitous [22]. More farmers in the highland savanna used tarpullinstarpaulins to dry beans than in the humid rain forest. The major reason advanced offered for using tarpullinstarpaulins was to avoid accumulation of sand particles in the produce which often lowers 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 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 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 fascilitiesfacilities and conditions. The farmers in this study therefore used both synthetic insecticide and plant-derived powders to supplement their inappropriate storage fascilitiesfacilities 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

Comment [A33]: You cannot refer to a number in this instance, but have to mention the actual name.

Comment [A34]: If your finding that most farmers stored their grains at their homes and Ngamo found that most farmers used granaries, how can your findings be a corroboration of their findings? I's day your findings were in contrast to theirs!

Comment [A35]: Maybe say that the common name bruchid refers to a legume-specific seed boring insect? I didn't know the word and had to google it.

importance to the resource–poor farmers since the stored beans ~~is~~ 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.

In conclusion, the studies showed that most bean~~s~~ farmers in the ~~Highland~~ highland savanna and ~~Humid~~ 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 plant~~s~~ materials and various synthetic chemicals with limited use of environmentally friendly methods like local plants and their derivatives. These insects and molds caused quantitative losses of beans which ~~results~~ resulted in reduced rate of bean seeds germination, as well as increased ~~in~~ bean prices due to additional expenditure for storage.

Comment [A36]: You are contradicting yourself here. First you say 'usually controlled by the use of local plant materials' and in the same sentence you state 'limited use of environmentally friendly methods like local plants'.

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

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 African 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~~ perception on ~~Common~~ pommon beans production constraints and their mitigation methods in the humid

Comment [A37]: Make sure what format the editor wants. You are mixing formats here. Should you use , or ; between author names? Should you use name and then initials throughout or only the first author? Should there be a comma after an author name or only after the last initial? Should you use & before the last author or and or nothing? Should the year be after the names of authors or after the name of the journal? Or both? Should the title of the article be in " " or not/? Should the journal names be in full or abbreviated?

Comment [A38]: Check with the editor to see what format the journal wants, but as I have it the full link must be given as well as the date you as author has accessed it.

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 of semi-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(3-4):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: Implication 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 nutritional value, toxicity and germination. International formal journal 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 using ergosterol 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 extentionextension: 22 years of strengthening cowpea storage in Africa. Purdue University.2009.

Comment [A39]: This is not the correct citation as given by google. Please check. It is a chapter in a book it seems.