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Postharvest Management of Grains in Haiti and Gender Roles

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Abstract: Food security is a continuing challenge in Haiti. The demand for food far exceeds local supply. As a result, Haiti imports nearly 50% of its national food needs. Postharvest management is an often neglected link in the grain value chain that has potential to improve food availability. We interviewed 214 farmers in three departments in July–August 2017 to assess postharvest handling and storage of grains and gender roles in Haiti. Results showed that among the respondents: 64% were male; 55% were over the age of 40 years; and about half had attended secondary school. Maize and beans were the most grown and stored crops. The average production for maize and beans was 288 kg and 88 kg, respectively. About 75% of the respondents stored less than 100 kg of either crop. Rodents and insects were the main causes of loss during storage. Farmers who produced more grain, stored longer, and experienced losses during drying and seed storage were more likely to use insecticides on stored products. Postharvest management practices were gendered at the lower end of the value chain; where women played a key role in marketing the grain. Addressing postharvest management challenges, through targeted interventions, to increase food availability while investing in maize and bean production can improve food security in Haiti.

Keywords: insect pests; grain storage loss; hermetic bags; food security; Caribbean

1. Introduction

Food insecurity has been a continuing challenge in Haiti [1]. The situation was exacerbated by a 2010 earthquake, longstanding drought, floods, landslides and the devastating 2016 category 4 Hurricane Matthew that severely affected two million people in Haiti [1]. Other drivers of food insecurity are poor performance of the agricultural sector that leads to heavy dependence on food imports [2]. Haiti is making progress, but its global hunger index is at an "alarming" threshold with about half of its population undernourished [2]. Haiti's food and nutrition requirements are ensured mainly through imports for a wide variety of goods including cereals, pulses and edible oils [3]. The majority of Haitian farmers operate small-scale subsistence farms and have less than two hectares of land [3]. Staple crops produced in Haiti are maize, wheat, sorghum, beans, peas, yams, cassava, sweet potatoes, bananas and plantains [3]. In Haiti, crop production is extremely vulnerable to the adverse effects of climatic events and shocks such as insufficient rainfall, hurricanes, flooding, and droughts [4].

Postharvest losses in Haiti are due to several factors including inadequate handling and storage practices. Haitian farmers typically store their crops for three to four months [5]. Farmers suffer high postharvest crop losses: losing up to one-third for cereal grains and legumes and nearly 50% for fruits and vegetable crops [6]. Cereal and pulse losses are due to one or several of these factors including insects, rodents, birds, and high moisture content. Insect pests alone cause an estimated 20–30% postharvest loss in developing countries [7]. Reducing cereal and legume losses caused by insects, microorganisms, and rodents during storage can significantly increase food supplies and have the same effect as putting more land into production [8].

To manage these postharvest challenges, most Haitian farmers transfer storage risks to the market by selling grain after harvest and buying later during lean season or at sowing time [9]. For the grain that is not sold, farmers use a variety of strategies including traditional methods and in some instances insecticides [10]. However, poor storage practices and technologies still result in high infestation of seed during storage [3]. By custom and as means of livelihoods, women in Haiti are actively involved in most agricultural activities at the farm level, and more importantly in postharvest activities. Just like in many other regions of the world, women are involved in grain storage [11,12]. In addition, women in Haiti are involved in sales and informal market development of agricultural products such as fruits, vegetables, and tubers [12]. A study conducted in Haiti showed that access to postharvest storage technologies can increase women's financial control of resources from stored maize [13].

Several efforts have been directed at addressing postharvest losses including the United Methodist Committee on Relief (UMCOR) project, which was implemented in conjunction with the United States Agency for International Development (USAID) [14]. The goal of the UMCOR project was to improve postharvest management to increase incomes of farmers in the Cul-de-Sac Plain and hence stimulate their crop production and improve yields beyond mere household consumption level. Under this project, farmers in the Cul-de-Sac Plain received agricultural training and were provided with silos and humidity meters [14]. After Hurricane Matthew, a non-profit organization piloted the introduction of the Purdue Improved Crop Storage (PICS) bag to farmers in the Grand'Anse [15]. The goal was to reduce postharvest losses and increase income of farmers. With an investment of US $4 in purchasing a 50 kg PICS bag, entrepreneurial farmers made a profit of $8 for storing maize for about three months [15]. Improved postharvest pest management is key to minimize storage losses and improve food availability. Research conducted in Haiti showed that PICS bags increase maize availability in all seasons and allow women to use it for various household needs [13].

As the interest continues to grow in promoting improved storage technologies, there is need to assess the current postharvest practices among smallholder grain producers in Haiti. In particular, it is important to understand smallholder drying, moisture assessment and storage practices, and the role of gender in postharvest management. Therefore, this study was conducted to assess: (i) grain production and postharvest management practices, (ii) factors affecting farmers' decisions to use insecticides, (iii) return on investment (ROI) using hermetic storage bags, and (iv) gender's roles during grain postharvest management.

2. Materials and Methods

2.1. Study Area

This study was conducted in three governmental departments (Ouest, Centre, and lower Artibonite) in Haiti in July–August 2017. A map of the survey area is shown in Figure 1. The survey was implemented in the Cul-de-Sac Plain, which is the second most important agricultural plain in Haiti. The general climate of Haiti is tropical; however, it varies with elevation. The Cul-de-Sac Plain is relatively warmer (26.2 °C) and dryer (740 mm) compared to the national mean annual temperature (24.5 °C) and mean annual precipitation (1220 mm). The plain has two distinct rainy seasons April–June and October–November. Thus, there are two main growing seasons per year. Crops produced in the Cul-de-Sac Plain include cereals (corn, sorghum, and rice) and legumes (black beans, red beans, Congo beans, peas, pigeon pea, and peanuts). In addition to rainfed agriculture, the plain has an irrigation dam (Rivière Grise barrage) that provides permanent irrigation water to 10,000 farmers.

The proximity of the Cul-de-Sac Plain to the capital city Porte-au-Prince is significant as a large market for agricultural products.

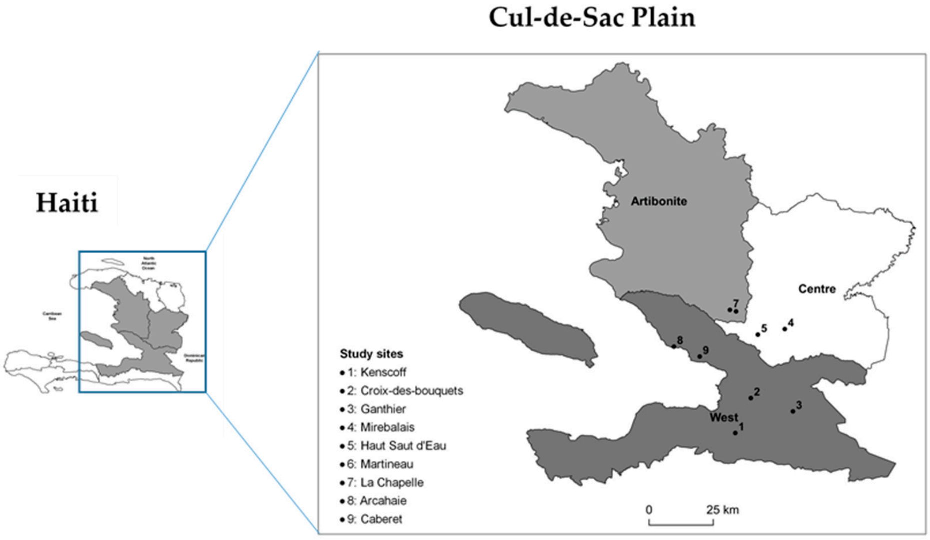

Figure 1. A map showing the different departments of Haiti with numbered locations where farmers were interviewed. This map was made using QGIS software.

2.2. Sampling and Data Collection

A sample of 10 respondents was randomly selected from a list of 20 farmers who were members of a farmers' association. We planned to interview 200 farmers (belonging to 20 farmers' associations) over a period of 19 days between July and August 2017; fortunately, we exceeded our target. Responses were collected from 214 farmers: 80 from the Ouest department, 63 from the Centre department, and 71 from the lower Artibonite department. The survey questionnaire was developed in English and translated to Haitian Creole. Then, it was transferred into the Kobo Toolbox platform (Harvard Humanitarian Initiative, Cambridge, MA, USA). The questionnaire was administered through the use of Android tablets via a downloaded data collection application, Kobo Collect. The survey had open and close-ended questions. Data collected included:

(i) socio-demographics of the respondents,
(ii) types of grain produced,
(iii) storage and drying techniques,
(iv) pesticide usage,
(v) pest problems (insects, rodents, mold),
(vi) postharvest losses of maize and beans,
(vii) market prices for grains at different times after harvest, and
(viii) gender roles associated with crop production, storage, and marketing.

2.3. Data Analysis

Field data was downloaded from the Kobo cloud server into Microsoft Office Excel 2011, cleaned and coded. Descriptive statistics were calculated (frequencies, cross tabulation) using the SPSS 24.0 (IBM Corporation, 2016, New York, NY, United States). Gender responses were compared using chi square tests using GraphPad QuickCalcs software (GraphPad Software 2018). The factors affecting decisions to store and use insecticides were assessed using the logistic regression model (GLM) in R v.3.5.3. The analysis aimed at finding statistical significance of variables which increased or decreased the probability to use insecticides. The logistic regression models were tested for fitness using the likelihood ratio (LR) test.

3. Results

3.1. Socio-Demographics and Grain Production, Drying and Storage Practices

The sociodemographic data of the respondents are shown in Table 1. Most respondents were male (63.6%). The majority of farmers were over the age of 30 (81.8%) with 48.6% of respondents being middle-aged farmers (31 to 50 y). Secondary school was the highest level of education for 48.6% of the respondents. Nearly half (47.7%) of the interviewed farmers were married. A large majority of the respondents (93.0%) reported agriculture as their main economic activity. A little over half (55.6%) of the farmers reported owning/renting less than 1.3 ha of land. Most farmers reported maize as the main crop (91.6%) along with beans (88.3%).

Table 1. Socio-demographic and grain production characteristics of respondents drawn from three departments Ouest, Center and Artibonite of Haiti.

Variable	Parameter	% Respondents * (n = 214)
Gender	Female	36.4
	Male	63.6
Age (years)	20–30	18.2
	31–40	26.2
	41–50	22.4
	50 +	33.2
Level of Education	None	18.2
	Literate	2.3
	Pre-School	7.0
	Primary School	16.8
	Secondary School	48.6
	College	7.0
Marital Status	Single	46.3
	Married	47.7
	Widowed	5.6
	Divorced/Separated	0.5
Principal Economic Activity	Agriculture	93.0
	Full-Time Employee	4.7
	Trade	2.3
Land Size	Less than 1.3 ha	55.6
	1.4–2.5 ha	–
	2.6–3.9 ha	39.7
	4.0–5.1 ha	–
	5.2–6.5 ha	1.9
	More than 6.5 ha	2.8
Grains Produced	Maize	91.6
	Beans	88.3
	Sorghum	34.1
	Rice	29.0
	Peanuts	18.7
	Millet	6.5
	Soybeans	0.9

* All sample size was true for all of the data.

Quantities of maize and beans produced and stored are shown in Table 2. For maize, about 56% and 90% of farmers produced and stored less than 200 kg, respectively; while for beans, about 70.0% and 91% of farmers produced and stored less than 200 kg, respectively.

Table 2. Quantities of maize and beans produced and stored in three departments Ouest, Center and Artibonite of Haiti.

Quantity (Kg)	**Maize (% Respondents) n = 161**		**Beans (% Respondents) n = 149**	
	Produced	Stored	Produced	Stored
0–50	17.4	57.1	24.8	60.4
51–100	17.4	18.6	19.5	17.4
101–200	21.1	13.7	25.5	13.4
201–500	34.2	9.3	24.8	6.0
> 500	9.9	1.2	5.4	2.7

Further analysis into the mean quantities produced, stored, purchased, consumed and sold is shown in Table 3. While farmers produce for consumption, a big fraction of both crops are intended for sale.

Table 3. The total maize and beans' production, storage, consumption and sale for the 2016–2017 growing season across three departments (Ouest, Center and Artibonite) of Haiti.

Parameter	**Average Quantity (Kg)**	
	Maize (n = 161)	**Beans (n = 149)**
Purchase	9.05	14.92
Consumption	18.59	12.27
Sale	84.39	58.39

Data on grain drying practices are shown in Table 4. Nearly all farmers (98.5%) in all departments dry their grain at home in the sun mainly on a mat/tarpaulin (39.9%). The most significant challenge during drying was rain (79.5%). The sources of grain losses during drying were: insects (57.5%), rodents (38.8%), moisture (34.6%), birds and other animals (47.2%), and theft (8.9%).

Table 4. Drying practices and challenges in three departments (Ouest, Center and Artibonite) of Haiti.

Variable	**Parameter**	**% Respondents**
Drying practices		n = 203
	Drying in the Field	7.4
	Drying at home in the Sun	98.5
	Drying in the House	2.0
Drying surfaces		n = 203
	Drying on the Ground	7.9
	Drying on a Mat	25.1
	Drying on a Tarpaulin	14.8
Drying challenges		n = 195
	Rain	79.5
	Lack of Drying Space	36.9
	Contamination	21.0
Drying losses		n = 214
	Insects	57.5
	Rodents	38.8
	Mold	34.6
	Birds	26.2
	Animals	21.0
	Theft	8.9

Data on grain storage practices are shown in Table 5. The great majority of farmers (93.0%) stored grain after harvest mainly using sisal sacks (83.4%), and barrels or metal drums (41.2%). The most reported storage location was a room in the house (87.4%).

Table 5. Storage practices and challenges in three departments (Ouest, Center and Artibonite) of Haiti.

Variable	Parameter	% Respondents
Storage Method		n = 199
	Sisal Sack	83.4
	Barrel	41.2
	Bucket	6.5
	Polyethylene bag	0.5
	Other	1.0
Storage Place		n = 199
	Room in the House	87.4
	Silo	17.1
	Tree Tops	15.6
	Family Store	0.5
	Other	2.0
Duration of Storage (Maize)		n = 161
	Less than 3 Months	34.2
	3–6 Months	34.2
	6–9 Months	19.9
	More than 9 Months	11.8
Duration of Storage (Beans)		n = 149
	Less than 3 Months	46.3
	3–6 Months	39.6
	6–9 Months	8.7
	More than 9 Months	5.4
Pest Control Methods		n = 199
	Chemical Products	55.8
	Natural Products (Plant Extracts)	14.1
	Do Nothing	28.1
	Other	2.0
Storage Losses		n = 197
	Rodents	77.2
	Insects	56.9
	Mold	5.6
	Theft	5.1
	None	2.5

Storage duration was less than 6 months for 68.4% and 85.9% of farmers for maize and beans, respectively. Use of chemical control to manage pests during grain storage was reported by just over half (55.8%) of the farmers. Of the other half, 14.1% used natural products (plant extracts) and 28.1% did nothing to control pests during storage. Of those who did not report using chemical products during storage, 23.8% were concerned about toxic or health problems, while 28.9% reported the products were either not available or there was no information on how to properly use or find them. Most farmers (77.2%) reported rodents as a major source of grain loss during storage, followed by insects (56.9%).

3.2. Decision to Use Insecticides

Some factors were found to influence farmers' decisions to use insecticide during storage and the logistic regression model was well fitted (LR test $p < 0.001$; Table 6). The use of insecticides to protect stored grain was significantly ($p < 0.05$) influenced by seed loss (farmers who experienced seed loss during storage were more likely to use insecticides), drying losses (farmers who experienced grain loss during drying were more likely to use insecticides), the quantity produced (farmers who produced more were more likely to use insecticides), and the duration of storage (farmers who stored for more than 3 months were more likely to use insecticides).

Table 6. Factors affecting the use of chemical insecticides during grain storage among farmers in three departments (Ouest, Center and Artibonite) of Haiti.

Variable	Parameter	OR [a]	95% CI [b]	p	LR test [c]
Location	Ouest	1.0	referent		
	Center	1.6	[0.6, 3.8]	0.328	
	Artibonite	0.6	[0.2, 1.6]	0.316	
Seed Loss	No	1.0	referent		$X^2 = 21.4$
	Yes	2.1	[1.0, 4.4]	0.041	$df = 7$
Quantity Stored		0.9	[0.9, 1.0]	0.357	$p = 0.003$
Storage Duration	Less than 3 months	1.0	referent		$LogLik = -90$
	3 to 6 months	3.4	[1.4, 8.7]	0.008	(df = 11)
	6 to 9 months	5.9	[2.1, 18.5]	0.0013	
	More than 9 months	7.9	[2.3, 30.6]	0.0016	
Storage Decisions	Male	1.0	referent		
	Female	1.4	[0.6, 3.1]	0.401	

[a] OR = odds ratio. [b] CI = confidence interval. [c] LR = likelihood ratio test; X^2 = chi-square value; df = degrees of freedom; p = probability value; $LogLik$ = model's log likelihood.

3.3. Return on Investment if Farmers Stored Their Grain in PICS Bags

Price seasonality (price at harvest and during the lean season) varied between crops and sometimes between the different departments (Table 7). Overall, gross margins on maize price showed a near doubling effect between harvest and lean seasons. Beans showed a price increase of between 120 and 138 Haitian gourdes per kg on average. Using PICS hermetic technologies as a possible intervention for storage among Haitian farmers, estimates of the return on investment (ROI) were calculated. The ROI ranged from 39% to 50% for maize and 36% to 41% for beans. Ouest had the highest ROI for maize (50%) while Artibonite had the highest ROI for beans (41%).

Table 7. Estimates of the return on investment (ROI) when farmers store grain for 6 months using hermetic PICS bags in Ouest, Center and Artibonite departments of Haiti. Grain and PICS prices are in Haitian gourdes (HTG).

		Price (HTG/kg)			HTG			
County	Crop	Harvest	Lean Season	Gross Margin	Price PICS *	OCC **	Net Gain	Percent ROI ***
Ouest	Maize	1082	2135.6	1053.6	256.65	120.48	676.47	50.53
	Beans	4428.8	6833.4	2404.6	256.65	421.69	1726.26	36.84
Centre	Maize	983.4	1840.8	857.4	256.65	111.60	489.15	39.45
	Beans	5397.2	7951.4	2554.2	256.65	508.85	1788.70	31.64
Artibonite	Maize	1083.4	1991.6	908.2	256.65	120.60	530.95	39.62
	Beans	4718.8	7493	2774.2	256.65	447.79	2069.76	41.60

* Price PICS: Price of a hermetic 50 kg PICS storage bag is $4US (US $1 = 64.1634 HTG on 17 December 2017). ** OCC: opportunity cost of capital is estimated at 9% for 6 months. *** ROI: Return on investment estimates are conservative because the cost is for one season use (some HST bags can be used for 2 or 3 years).

3.4. Gender Roles in Postharvest Management Practices

Gender roles in postharvest practices are shown in Table 8. Overall, 66.4% of the farmers reported that the male in the household owns/rents the land (x^2 = 49.64; df = 2; p < 0.0001). Grain drying activities were reportedly female dominated (53.7%) (x^2 = 22.71; df = 2; p < 0.0001). For grain storage activities, 49.2% said that the women were responsible, while 31.2% reported both men and women were responsible (x^2 = 12.86; df = 2; p = 0.0016). For marketing maize and beans, 88.2% (x^2 = 134.54; df = 2; p < 0.0001) and 96% (x^2 = 149.66; df = 2; p < 0.0001) reported that the women were responsible for taking the grain to the market, respectively.

Table 8. Gender postharvest practices across three departments Ouest, Center and Artibonite of Haiti. Percentages with shared letters are not significantly different from each other (chi square; α = 0.05).

Gender	Parameter (% Respondents)					
	Land Ownership (n = 214)	Saving/Buying Seed (n = 214)	Grain Drying (n = 205)	Grain Storage (n = 199)	Maize Marketing (n = 161)	Beans Marketing (n = 149)
Male	66.4a	33.2a	14.6a	19.6a	6.8b	5.4b
Female	15.4b	43.0a	53.7b	49.2b	88.2a	90.6a
Both	18.2b	23.8a	31.7c	31.2c	5.0b	4.0b

It is also important to note that women play an important role in saving and buying seed (43%), though it seems that both men and women are nearly equally responsible for this task (x^2 = 5.420; df = 2; p = 0.0665) (Table 8). Overall farmers source seed from the market (76.6%), and own seed saving (62.6%) and agroshops (31.3%) (data not shown). Some of the most important saved seed included maize, beans, rice and vegetables. Among 134 farmers who save their own seed for planting, 86.6% said that they incur losses during storage (data not shown).

4. Discussion

4.1. Grain Production, Drying and Storage

This study showed that smallholder farmers in Haiti rely heavily on agriculture for their livelihoods. Prior work in northwestern Haiti found that agriculture accounted for nearly 90% of farmers' livelihoods [11]. Therefore investment in Haiti's smallholder farmers and the agricultural sector in general is vital to building food security. Land available to each farmer for agricultural activities is scarce and this study shows 55% own less than 1.3 ha. In 2003, the average plot was 2.7 hectares [16,17]; while at the time of this study, the land holdings were less than 1 ha. These data may be compared to other countries such as Malawi, where 90% of total agriculture comes from smallholder farmers who own less than 1 ha [18,19]. Grain production was dominated by small scale farmers producing and storing less than 200 kg of either maize or beans. On average, farmers reported storing 87 kg of maize and 80 kg of beans each season. Most of the produced grain is sold right after harvest to earn cash to meet other household needs [9]. This leaves the households' food insecure and vulnerable to shocks (e.g., climate). The small amount of grain being stored may be kept for consumption and/or seed for the next planting. It is critical to increase productivity for Haitian smallholder farmers in the plain to meet household and national food needs.

The majority of the respondents reported drying their grain at home in the sun on mats or tarpaulins. Some of the associations interviewed had received tarpaulins from the UMCOR project in 2013/2014. The project had distributed 800 tarpaulins to 25 farmers' associations in the Cul-de-Sac Plain [14]. Some farmers pre-dry their grain in the field or dry them on the side of the roads. Drying challenges reported include rain, insects, rodents, birds and animals. Since drying grain is done out in the open and often on the ground, the grain is predisposed to moisture and humidity leading to mold growth, decay and aflatoxin contamination that persists during storage [20]. Presence of aflatoxin contamination in peanuts and maize has previously been reported in Haiti [21,22]. Both of the studies found aflatoxin levels well above the American and European standards [21]. We observed that farmers typically leave maize in the field after maturity thus exposing the grain to weather events such as tropical downpours, which often occur on a daily basis. In a comparable study on the effects of delayed harvest in Uganda by Kaaya et al. 2005 [23], aflatoxin levels increased as much as 7-fold when the maize harvest was delayed by three or four weeks after crop maturity. Training farmers on proper postharvest handling and drying technologies would help improve grain quality.

Sisal sacks were the most widely used storage containers, probably due to their low cost, availability, ability to further grain drying during storage, and ease of transport when selling grain at market [24]. Often second-hand cleaned oil drums were used as hermetic containers for protecting grain from insects and rodents [25]. Bulk storage systems, such as silos, were not commonly used due to the high cost of construction, maintenance (repair), and the large quantities of grain needed to fill them to capacity [19]. However, in this study about 17% of farmers reported using silos for storage. This may be due to the 2013/2014 UMCOR project intervention that distributed 95 silos to 25 agricultural farmers' associations [14]. Introducing cost-effective on-farm storage methods, such hermetic storage bags that have been widely disseminated in Africa and other regions of the world [26], would diversify postharvest management options for farmers in Haiti.

Duration of storage was less than 6 months with farmers storing beans for slightly shorter times than maize. The duration of storage depends on quantity stored and household needs such as cash and food/consumption. Because most maize and beans were sold at harvest, most farmers did not have much grain to store for long. Maize and beans are often sold in the market giving them a "cash crop" status while other crops are kept and consumed in the home [11]. During storage, insects and rodents were the two most important pests. Studies in several countries in Africa have found that rodents are major pests of stored products—coming before or after insects [27]. Higher rodent damage in Haiti may be attributed to the inadequate storage facilities, close proximity of the storage space to surrounding fields and poor storage hygiene [28]. In addition, most farmers used sisal sacks to store their grains, which often draw mice and rats. Rodents pose a threat to grain quality and consumer health because they are disease-vectors [29]. Insect infestations that start during harvesting and drying often continue during storage. Storage insects cause 20–30% loss for cereal crops like maize [7]. Prior work has documented important insect pests in Haiti such as the rice weevil (*Sitophilus oryzae* L. (Coleoptera: Curculionidae)) and the granary weevil (*Sitophilus granarius* L. (Coleoptera: Curculionidae)) in stored maize [30]. An extensive checklist was compiled for the Island of Hispanola (Haiti and Dominican Republic) and it was reported that the bean weevil (*Acanthoscelides obtectus* Say (Coleoptera: Bruchidae)) was found in stored beans [31]. Rodent and insect control measures can be put in place at a household level with integrated pest management training through extension services.

4.2. Decision to Use Insecticides

Farmers relied heavily on pest control methods such as chemicals and natural plant extracts to control insects. Elsewhere, in Zambia and Malawi, over 70% of smallholder farmers used synthetic pesticides to control insect pests of maize and beans [32]. The decision to use insecticide was mainly determined by seed loss, drying losses, and storage duration. Farmers who did not report using chemical products during storage were concerned about their toxicity or health risks. Pesticide use in developing countries poses many challenges due to lack of strict regulations and farmers' limited knowledge on their proper use [33]. Cases of pesticide poisoning are known and can be attributed to using inappropriate chemical products, incorrect dosage, and timing and targeting of application [34,35]. Given their reliance on chemicals, Haitian farmers may be receptive to non-chemical methods (e.g., hermetic storage technologies) for protecting their grain.

4.3. Return on Investment

The Return on Investment (ROI) using PICS hermetic technology varied by crop and by department. Overall, Haitian farmers would increase their income should they store their maize and beans in hermetic PICS bags for about 6 months. ROI for maize was highest in Ouest (50%) while ROI for beans was highest in Artibonite (41%). The data suggests that it is more profitable to store maize for sale than any other crop in Haiti. Maize is an important food crop in Haiti and is grown across 10 departments [5]. Recently, the departments of Northeast, Northwest, Nippes, South, and Center were affected by a drought between 2018 and 2019 [5]. These intermittent droughts mean that there is always demand for grain on the market. Farmers who are able to store grain in PICS for several months can increase their income [15,26,36].

4.4. Gender Implications

Gendered results in this study mainly apply to land ownership and grain sales. Men tend to own the land on which grain crops are grown. Although women are also entitled to own and manage land, they generally end up with smaller plots, due to informal and unfavorable customary land laws that undermine women inheritance rights [37]. In some cases, customary laws radically forbid women from owning land [38]. In Haiti, approximately 70% of Haitian women do not own land titles, 20% own a property jointly with relatives, and only 9% own property on their own [39]. Women are mainly responsible for taking the grain to the market for sale. Sales of produces are considered "women-only activities". The informal markets in which sales occur are usually female dominated [40].

A gender and food security assessment on PICS bags conducted in the Grand'Anse department of Haiti revealed that women heads of households were too busy, hence did not gain from the "konbit"-a cost-saving form of traditional organization of labor through reciprocal assistance among farmers [13]. These women end up paying for additional labor to work their land. Haitian female-headed households account for 81.4% of the agricultural workforce and are most vulnerable to food insecurity and poverty [39,41]. The assessment also highlighted ways in which postharvest management efforts using hermetic PICS bags can positively affect the welfare of women farmers. Women who used PICS bags to store maize can save considerable time during grain storage. They reported using the extra time to engage in other income-generating activities. Such an asset (time) is certainly beneficial for women heads of households working in the grain value chain. Moreover, with grains being available all year round, women were able to keep grains in various unprocessed and processed forms, which contribute to diversifying households' diets and improving their household food and nutrition security [42].

5. Conclusions

This study revealed that there is need for preharvest and postharvest intervention to improve production and food security in Haitian. Increasing productivity of farms in the Cul-de-Sac Plain of Haiti will significantly increase the quantity of grain produced and eventually stored, thus cushioning Haitians from shocks of food insecurity. Farmers are likely to store more if they produce more. Strengthening postharvest extension and education activities can help Haitian farmers improve grain handling and storage to reduce postharvest losses. Introducing drying technologies adapted to smallholder farms would improve grain quality and reduce aflatoxin contamination. Scaling-up chemical-free and cost-effective storage technologies (e.g., hermetic bags) to supplement silos may help mitigate storage losses and reduce chemical use. Adoption of hermetic bags will improve overall livelihoods of the farmers through the additional income. Targeted interventions that are gender sensitive would be needed to empower women since they play such a pivotal role in the grain value chain (e.g., producers and traders).

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Conflicts of Interest: Dr. Dieudonne Baributsa is a co-founder of PICS Global Inc. a social enterprise that commercializes post-harvest technologies (including PICS bags) to smallholder farmers across the world and hence declares a conflict of interest. The other authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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