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# Market Power & Economic Consequences of Post-Harvest Losses in Rwandan Dry Bean Markets

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## Abstract

To date there is extremely limited knowledge of the economic consequences of post-harvest losses for smallholders in sub-Saharan Africa. Major contributors to economic losses are price penalties for poor quality marketed grain. This study investigates farm-gate level discounts demanded by rural Rwandan bean traders for insect-damaged dry beans. We use a simplified contingent evaluation methodology with physical grain samples to elicit seasonal damage discount schedules, gathering data from 270 trader interviews in 25 regionally-diverse rural markets, in periods of both grain abundance and grain scarcity. We find that while levels of 5-10% grain damage can generally be sold with a moderate discount, grain with 20-30% damage is largely unmarketable. We additionally use a two-stage model to investigate physical and non-physical drivers of buying insect-damaged grain and, if so, the demanded discount intensity. Results indicate that while grain damage levels play a central role, large volume traders penalize damage less while traders in the seed market, storing before re-sale, or purchasing heavily from farmers (vs. other traders) penalize damage significantly more. Findings have helped develop more evidence-based extension programming for the Post-Harvest Task Force of the Rwandan Ministry of Agriculture. Additionally, derived discount coefficients help evaluate the cost-effectiveness of technologies throughout the region which prevent post-harvest damage.

Keywords: post-harvest losses, crop storage, storage technology, food security, Rwanda, sub-Saharan Africa

## Introduction

Post-harvest losses are a major contributing factor in food and income insecurity in sub-Saharan Africa (SSA). Physical grain losses from insects, mold, and rodents are estimated at 10-20% of production (World Bank, 2011). Storage insects in particular cause significant losses for grain and legume producers. Economic losses through insect damage result from reduced quantity and quality of food for home consumption and a significant reduction in grain value for market sale.

While many analyses focus only on weight or quantity losses, the price discounts for insect damage can be a greater driver in total value loss in storage (Jones, Alexander, and Lowenberg-DeBoer, 2014). For marketing producers lacking effective storage technology, these damage discounts also cause early sale as market penalties can quickly erode gains from seasonal price increases. Therefore, understanding the economic implications of storage insect damage is important in assessing the cost-effectiveness of grain and legume storage technologies and deriving a national post-harvest strategy.

The goal of this article is to quantify the price discounts which Rwandan farmers face when selling damaged beans. In doing so, this study makes a contribution to both the grain marketing and storage economics literature in SSA. In the Republic of Rwanda, the Ministry of Agriculture (MINAGRI) created a Post-Harvest Task Force in 2010 to combat increasing post-harvest management challenges arising after successful MINAGRI efforts to raise yields through the Crop Intensification Program. Dry beans, a nationally important source of protein and culturally significant food item, are a focus crop for the PH Task Force given widely recognized post-harvest constraints. In a recent bean post-harvest survey, Mvumi et al. (2012) list insect damage is the greatest factor in Rwandan farmers' frequent market rejection for poor quality beans, as well as documenting extensive farmer calls for greater marketing information and training. However, no study in SSA has yet analyzed informal market discounts for insect-damaged dry beans at the farm-gate, making it difficult to execute an evidence-based post-harvest extension strategy.

Research in SSA on grain damage discounts is still an emerging field. Previous work examines the issue from two angles, namely at the farm-gate where traders buy from farmers, and at the retail level where consumers purchase from traders. While distinct, the two levels are inherently linked as discounts traders face from consumers should be passed on to farmers at the point of wholesale purchase. However, implications of farm-gate discounts are most directly relevant to farmers. The farmer may also sell directly to consumers in rural markets, however the extent of this importance in surveyed Rwandan markets was generally low, especially in months after long storage periods.

Previous research at the retail-level perspective was conducted for Tanzanian dry beans by Mishili et al. (2011) and for West and Central African cowpea by Langyintuo et al. (2003), Faye et al. (2004), Langyintuo et al. (2004), Mishili (2005), Mishili et al. (2009), and Ibro (2011). The vast majority of this research was conducted through the Bean/Cowpea Collaborative Research Support Program (CRSP). The method employed was hedonic price modeling, where researchers make weekly market purchases and record many physical, chemical, and price characteristics of grain samples. After enough observations are collected over a multi-year period, regression analysis is performed to isolate the effects of each characteristic on price, including insect damage. Mishili et al. (2011) find a 2.3% reduction in price for every hole in 100 dry bean seeds. Seasonal discount fluctuations are not acknowledged. Cowpea researchers find a wider range across West and Central African markets, from 0.17 – 2.30% reduction for every hole in 100 cowpea seeds. While researchers had hypothesized West and Central African consumers would tolerate some insect damage before demanding a discount, or the

presence of a grain damage tolerance threshold, data indicate that cowpea consumers discount from the very first insect hole.

Farm-gate level research, at the point of sale between the farmer and the trader, is extremely limited. The first work in sub-Saharan Africa was conducted by Compton et al. (1998) for Ghanaian maize, in which visual samples of varying grain damage were appraised by focus groups of grain traders at strategic points in the storage season. Grain samples were ranked according to damage levels by focus groups, arranged linearly in rank order, and then appraised for price from least to most damage by panel groups. Researchers found a 0.60 – 0.97% price reduction for every 1% of damaged maize kernels. Compton et al. found clear differences in seasonal discount intensities, outlined in Figure 1. Traders became more tolerant of grain damage later in the season when grain is scarcer and the presence of insect damage common, and the lean or “hunger” season period displayed a threshold of 5-7% grain damage before discounts were applied.

[Figure 1 about here]

The advantages of the method employed by Compton et al. are the ease of visual scale construction and data collection implementation, as well as the focus on the farmer-to-trader sale point. However, the disadvantage of the focus group method is that the linear and simultaneous display of grain damage samples most likely does not represent the way grain samples are presented to traders in the market. A farmer’s grain sample is generally appraised in a market by individual traders, not groups, and appraisal in panel-group setting may decrease naturally inherent variance in application of grain damage discounts.

Jones et al. (2012) employed a choice model approach with Malawian maize traders using physical maize samples of varying insect damage, mold damage, and local vs. hybrid varieties. The advantages of the choice model approach include the ability to statistically rank importance of grain quality attributes, and the ability to statistically control for attribute non-attendance. The disadvantages of the choice model approach are that it relies on state preference data and the complexity of statistical analysis makes this methodology difficult for wide application.

Based on the literature, we decided that the most effective and reproducible way to approach Rwandan market discounts for grain damage would be:

- 1) At the farm-gate level (discounts demanded by traders purchasing from farmers)
- 2) Using physical grain samples
- 3) Conducted in actual grain markets on market days
- 4) With individual grain traders
- 5) At multiple time periods to contrast discounts in immediate post-harvest months with discounts found after many months of storage
- 6) An analytically simpler method to facilitate local institutional replication

## Methods

### Grain Samples and Procedure

Visual samples of beans were constructed to physically display graduated insect damage levels. Damage levels utilized were 0, 5, 10, 20, and 30% of grains with visible signs of insect damage (emergence holes). This range of damage was based on findings by Compton et al., observations in the market and farmer household stocks, as well as discussions with key extension and agricultural officials. While Compton et al. used a broader range of high damage rates, samples over 30% would be extremely rare in Rwandan market transactions and judged unnecessary for this study.

Infested bean samples were purchased on the market. Bean samples were a homogeneous mixed local variety, based on nearly complete representation in markets (survey confirmed >95% of samples sold in markets are mixed local). Grains with visible emergence holes had an average 2.1 holes per grain. Grains were hermetically stored to kill insect populations and stop progression of insect damage. Grains were then separated into two categories: those with visible insect damage and those without. A small quantity of visibly molded grains, with or without insect damage, was removed to avoid introduction of confounding variables.

Then, 0.5L water bottles were filled to produce each set of five scaled samples. For practicality, the percentage of damaged grains was estimated volumetrically<sup>1</sup>. Water bottles serve as a very useful display device for several reasons. The first is they serve as a portable, transparent, and easily

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<sup>1</sup> i.e. 10% damage sample is 50ml of damaged grains and 450ml of undamaged grains, for a total of 500ml

manipulated medium for traders to examine samples. Grain is easily removed for closer examination. The second benefit is that they provide continued hermetic storage, preventing advances in insect damage which could skew estimates over time. Since insect damage does not progress, the visual scales can be re-used in subsequent studies to decrease potential bias.

Trained agent enumerators from the MINAGRI Post-Harvest Task Force approached traders in the market on market days. After a 10-15 minute survey collecting demographic and trade data, enumerators presented the bean samples individually in random order, drawn from an opaque sack. Traders were first asked if they would currently purchase beans of the sample's quality from farmers. If responding no, traders were simply presented the next sample. If responding yes, then traders were subsequently asked what they considered their "fair" final purchase price for grain of that quality.

Both hedonic pricing methods and choice experiments were considered for this evaluation. However since the goal was to choose a methodology that MINAGRI would continue to use, based on the financial and labor constraints, neither hedonic pricing methods or choice experiments were feasible. An advantage of hedonic pricing methods is that the data are based on revealed preferences, or actual prices of grain traded in the marketplace, and detailed laboratory analysis of each sample. The disadvantage of hedonic pricing methods is the financial and time investment required to collect this detailed level of laboratory analysis and multi-year price series. A choice experiment following Jones et al. (2012) would also allow analysis of many physical attributes beyond insect damage, however the complexity of analysis does not lend itself to easy reproducibility by MINAGRI as part of post-harvest monitoring activities.

## Market Selection

In Season B 2012, a total of 25 markets were surveyed in 19 of 30 Rwandan districts. In Season A 2013, 17 markets were surveyed in 15 of 30 districts. Figure 4 displays a map of all markets surveyed. Markets selected were primarily rural-designated data collection markets in the Rwandan 'eSoko' market price information system. Since no Kigali Province markets in the eSoko market information system are designated rural, only markets in the East, North, South, and West provinces are considered. Following MINAGRI's eSoko data collection practice, prevalent price reporting by volumetric bowls – locally, 'mironko' or 'ingemeru' – was converted to RWF/kg at the rate of 0.8:1. All but one rural-designated eSoko market (in very remote Nyamasheke district) was surveyed. Once at a rural-designated market, other immediately surrounding small rural markets were also surveyed when

infrequently possible to match market days. When in a market, all willing traders in the central market area and surrounding shops were interviewed. In the majority of cases, 100% participation was achieved.

[Figure 2 about here]

## Time Period Selection

Two national market surveys were conducted at the end of the Season B 2012 marketing period (Nov-Dec 2012) and the beginning of the Season A 2013 marketing period (Feb 2013). These survey periods represent periods of relative local grain scarcity and abundance, respectively, making these two key points in the marketing season for insect-damage evaluation, following Compton et al. (1998). The first period is after 4-5 months of storage, in which one would expect some level of insect damage and grain is much scarcer. The second period is after very little storage, in which grain is relatively abundant and one would expect less insect damage.

## Survey Population Totals

Table 2 outlines the 148 bean traders interviewed at the end of Season B and 122 traders interviewed at the beginning of Season A. Overlap between seasonal traders was about 20%, owing to several factors which include transitive and temporary employment in the informal grain trade and seasonal climate difficulties. The heavy rainy season in the beginning of Season A caused some markets to shut down on the weekly market day, with no traders arriving. While every attempt was made to re-visit these markets in Season A, this was not always possible due to limited time windows for season-specific data collection periods. Seasonal trader totals were partially counteracted by increased density of traders per market in Season A, a period of grain abundance. A perfect panel is thus not claimed for this study, however key demographic similarities point to validity of pooling for a more robust analysis.

[Table 1 about here]

## Double Hurdle Model

### Conceptual Model

As equation 1 displays, the dependent variable is the grain sample-specific percentage difference of the appraisal price of damaged grain with insect emergence holes  $P_h$  by trader  $i$  vs. the appraisal price of undamaged (clean) grain  $P_c$  by the same trader  $i$ . Thus, as the price difference between damaged and non-damaged samples increases, the discount intensity for grain with holes  $D_h$  increases. No traders reported higher valuation of damaged grain than non-damaged grain.

$$(1) D_{hi} = \frac{P_{ci} - P_{hi}}{P_{ci}}$$

Common bean prices in East Africa are known to be affected by many physical properties of grain, including insect emergence holes (Mishili et al., 2011). However, since all physical grain properties were controlled except insect damage, only the number of insect emergence holes in a sample of 100 grains  $H$  enters the model. For example, following Langyintuo et al. (2003) and Mishili et al. (2011), this means that five beans with two insect holes each is counted as a total of ten holes in 100 grains. Trader marketing practices such as trading volumes, sourcing entities, marketed grain intended use (consumption vs. planting), and storage time before sale enter the model through  $M$ . Trader demographics enter the model through  $Z$  and a seasonal dummy enters through  $S$ , defined “1” for the Season A immediate post-harvest period. It has been demonstrated that trader discounting of insect damage changes over time, so  $S$  must enter the model even though the pooled data do not represent a true panel (Compton et al., 1998).

$$(2) D = f(H, M, Z, S)$$

### Empirical Model

Estimation of how insect damage intensity affects trader price discounting was performed by specifying the conceptual model as follows:

$$(3) D_{hi} = \alpha H + \beta X_i + S + \varepsilon$$

where  $D_{hi}$  represents the damage discount intensity applied by trader  $i$  to a sample  $h$  of damaged grain (relative to clean grain price). The principle variable of interest is the sample-specific number of holes in 100 grains, denoted  $H$ ;  $\alpha$  is the corresponding parameter, from which estimates are drawn to determine

the increase in discount intensity as holes per 100 grains increase. Trader-specific explanatory variables encompassed by  $X_i$  include key marketing and demographic characteristics which may influence to what extent commercial actors apply damage discounts.

## Functional Form

A modified Double Hurdle (DH) model is selected to estimate drivers of a) the decision to purchase damaged grain and b) the extent of discounts applied to damaged grain. Traditional DH models apply a probit model for the binary decision process for purchase or adoption and then a truncated regression for post-choice continuous intensity (see, for example, Ricker-Gilbert and Jayne, 2011). This article's purchasing context requires an adjustment, as the binary choice to purchase is then followed by another choice- whether or not to discount, and, if so, to what extent discounts are applied. In this study, 13.4% of "purchased" bean samples were not discounted, thus censoring (and not truncating) the discount at zero becomes important to maintain this key subgroup. The model specified is thus a probit hurdle for purchase of damaged grain followed by a tobit model for discount intensity of damaged grain (with respect to undamaged sample appraisal). The tobit model, proposed by Tobin (1958), is suited to this context as the underlying assumption is that the decision to discount and the intensity of the discount applied are one and the same.

## Results

### Survey Population Descriptive Statistics

Survey periods are statistically identical in almost all parameters regarding demographics and scale of trading activities. The Season A round included traders selling simultaneously in slightly more markets. Differences do arise in sourcing and marketing practices, as the Season A round included more traders dealing directly with farmers and selling greater variety of beans on market days. This naturally follows the pattern of greater sales volumes from farmers in the immediate post-harvest season.

[Table 2 about here]

## Derived Seasonal Discount Schedules for Dry Beans, Descriptive Results

When a trader evaluates an acceptable transaction price with a bean farmer, grain quality plays a critical role. In particular, Figure 3 demonstrates that insect damage must be considered and that traders are more tolerant of damage at the end of Season B than the beginning of Season A. This is logical for two major factors: the first, that insect damage is naturally likely to be more prevalent after many months of storage, especially if proper storage protection is not employed; and second, that beans are in shorter supply at the end of the season and traders cannot be as selective. Traders' quality demands must be linked to their final markets' quality demands, so consumers should also implicitly be more tolerant of damage later in the marketing season.

After about 4-5 months of storage of the Season B harvest, an average Rwandan farmer with 5 and 10% of beans with insect holes has 98.6 and 94.6% chance, respectively, of successfully marketing this quality grain to this trader population. A farmer with 20 or 30% insect damage will have a much more difficult time marketing grain, with a 37.8 and 14.2% chance, respectively, of selling grain to these traders. At the beginning of Season A, after only about 1-2 months of storage, 5% damaged grain would still have a 93.6% chance of being sold, while 10% damaged grain sales would drop to 63.9%. Grain with 20 or 30% damage becomes virtually unmarketable this soon after harvest when beans have little chance of reaching high damage levels.

Marketed grain with insect damage at 5% or higher predominately receives a lower price than zero-damage grain. In limited cases, some traders do have a grain damage "threshold" below which discounts are not demanded. At the end of Season B, about 36% of traders would consider 5% insect-damaged grains within an acceptable same-price threshold, and only 7.4% of traders would similarly accept 10% damaged grains without a discount. In the beginning of Season A, tolerance for damaged grain declines with only 8.2% of traders accepting 5% damaged grains without a discount.

Otherwise, discounts are demanded which penalize farmers according to grain damage level. Interestingly, the marginal discount per hole for 5, 10, 20, and 30% insect-damaged grains are statistically indistinguishable at the end of Season B. The end Season B average discount is 0.76% ( $\pm 0.6\%$ ) per 1% seeds damaged, translating to a 0.36% ( $\pm 0.3\%$ ) discount for each hole in 100 grains.

Comparatively, discounts for grain damage increase dramatically in the immediate post-harvest period of Season A, increasing by 77.1% for 5% insect damage and by 67.1% for 10% insect damage. Marginal per-hole discounts for 5% and 10% damage are statistically indistinguishable ( $p$ -value=0.33). Season A insect damage levels of 20% and 30% present an interesting case, as the marginal discounts drop. This drop contrasts sharply with the dramatic increase in rejection levels for these samples, thus pointing to the fact that the few traders willing to even accept the grain ( $n=4$  and  $n=1$ , respectively) would also be those with the loosest quality demands. Traders such as these may be blending with better grain and/or bulk selling to less quality-conscious market outlets. While samples under 20% damage appear to be the only ones generally accepted by traders, the beginning Season A national average discount is 1.28% ( $\pm 0.6\%$ ) per 1% grains damaged, translating to a 0.61% ( $\pm 0.3\%$ ) discount for each hole in 100 grains.

[Figure 3 about here]

Lean season marginal damage discounts are contextualized to a 100kg bag of beans in Figure 4. Total price loss is incremented by each damage level's marginal discount (up to 5%, up to 10%, up to 20%) and prices are based on a survey-wide average buying price of non-damaged beans at 357 RWF/kg (0.59 USD/kg)<sup>2</sup>. A 100kg bag is thus valued, on average, at 35,700 RWF (58.58 USD). This represents a significant portion of a typical Rwandan farmer's agricultural revenue and 9.1% of the 2012 GDP per capita of 644 USD (GoR, 2013). Damage at the 5% level leads, on average, to price loss of 1,232 RWF (2.02 USD) per 100kg bag. Farmers may be fortunate to find the one-third of traders not discounting at the 5% damage level, though the 62.8% of traders demanding discounts all reported buying 5% damaged beans that season. At the 10% level, this revenue loss increases to 2,927 RWF (4.80 USD) per bag. While less likely to be accepted by traders, marketed beans damaged at the 20% level would incur an average price loss of 5,712 RWF (9.37 USD) per bag. While damage under 5% was not measured in this survey, the 5% marginal discount parameter is extended for hypothetical purposes. Thresholds before discounting may be more widespread for beans with less than 5% damage.

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<sup>2</sup> Exchange rate of RWF:USD at 609.4:1 on 01/01/2013

[Figure 4 about here]

## Econometric Results

Econometric results are discussed in two stages. First, we present a pooled probit model identifying factors driving the binary decision to purchase insect damaged bean grains with 5%, 10%, 20%, or 30% damaged grains. Second, we present an extended pooled tobit model investigating factors driving subsequent price discounts for damaged grain samples vis-à-vis the undamaged sample.

The pooled probit model indicates that each hole in a 100 grain sample of beans reduces the likelihood of making a sale by 1.34%. The intended use for beans appears to be quite important, as traders selling heavily in the seed market are significantly less likely to purchase damaged beans. However, more educated and experienced traders are more likely to purchase damaged samples. This may be indicative that more knowledgeable traders understand how to blend poor quality grain with clean grain to arrive at sample which does not exceed a damage threshold for their future customers, as is common practice in the US grain trading industry.

Among the samples which traders indicated they would purchase, the pooled tobit model indicates that discounting was driven by a variety of physical, demographic, and behavioral factors. Each hole in a 100 grain sample of beans results in a 0.40% ( $\pm 0.02$ ) price discount for farmers in the lean season, closely matching descriptive results. Larger volume traders are statistically significantly less stringent about quality compared to smaller scale counterparts; their larger volume provides greater ability to blend low quality grain. Traders who are engaged in the seed market significantly discount physical grain damage in addition to being less likely to purchase damaged grain. Traders who typically store beans longer before sale also discount more heavily for insect damage, with an additional 0.23% discount per average week stored. Interestingly, traders who buy primarily from farmers discount more heavily for insect damage than traders buying primarily from other middlemen. This may indicate information asymmetries between traders and farmers which could be exploited in the trader's favor. Further notable is the fact that while more educated traders are more likely to purchase insect-damaged beans, they also discount more heavily than less educated traders. This does make sense in a world where it is quite profitable understanding how and when to purchase discounted damaged beans, blend with clean grain, and sell the resulting blend to consumers.

[Table 3 about here]

## Conclusion

This research was conducted for the Rwanda MINAGRI to better advise the Post-Harvest Task Force extension services about the potential cost-effectiveness of post-harvest technology which prevents such insect damage. The economic implications of insect damage for marketing producers include heavy price discounts and the possibility of outright market rejection. Rwandan common bean farmers are faced with these potential market penalties if effective storage technologies are not employed.

We show that in Rwandan rural markets, traders will generally purchase beans with 5% or 10% insect-damaged grains and largely reject 20% or 30% insect-damaged grains. Most traders purchasing damaged beans will demand a lower price than they offer for non-damaged grain. Descriptive results indicate that about 4-5 months after harvest, bean traders discount at an average rate of 0.36% ( $\pm 0.03\%$ ) per hole in 100 grains. In the immediate post-harvest months this discount for grain damage increases dramatically to 0.61% ( $\pm 0.03\%$ ) per hole in 100 grains. Econometric results indicate that drivers of both the decision to purchase damaged grain and the intensity of grain damage price discounts (vis-à-vis undamaged grain prices) extend beyond just the physical attributes of the grains. Compared to previous results from Compton et al. (1998), discounts for insect-damaged Rwandan beans are very similar to penalties demanded by Ghanaian maize traders (in the mid-1990s). Discount estimates in this study are much lower than those found for common beans in the retail markets of Morogoro, Tanzania (Mishili et al., 2011). One main reason for this is the potential difference in purchasing scrutiny at the farm-gate vs. retail level, possibly combined with varied insect pest density and geographically diverse quality concerns. Rwandan rural bean traders also penalize less at the farm-gate for insect damage than Malawian maize traders (Jones et al., 2012).

With regionally diverse market-specific data from this study, MINAGRI's Post-Harvest Task Force was able to provide greater evidence-based extension messages to farmers seeking to optimize returns to storage. With this information, we can cross-reference expected revenue loss from insect damage on per bag basis with the costs of preventing such losses through investment in storage chemicals or hermetic methods like Purdue Improved Crop Storage (PICS) or GrainPro sacks. When armed with this improved market information, Rwandan farmers can thus make smarter decisions on how to most profitably protect their grain stocks and increase agricultural incomes.

Economic investigation into crop storage and post-harvest management in the developing world is very sparse, with significant room for further research. Simple methodologies such as that employed in this study could help make economic research more accessible to resource-constrained agencies. If approaches are standardized, more relevant economic comparisons can be drawn between crops and market regions. Studies could also directly examine insect and mold discount transmissions from the farm-gate to retail level.

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## Tables

**Table 1: Survey Participant Distribution**

Province	End of Season B, Nov-December 2012	Beginning of Season A, February 2013	Total
East	64	30	94
North	17	20	37
South	19	16	35
West	48	56	104
<b>National</b>	<b>148</b>	<b>122</b>	<b>270</b>

**Table 2: Survey Population Descriptive Statistics**

Key Variables of Interest	Season B End Nov-Dec 2012 n=148 Mean ( $\pm$ SE)	Season A Beg. Feb 2013 n=122 Mean ( $\pm$ SE)	T-test Sign.
<b><u>Demographics</u></b>			
Female (%)	66.9 ( $\pm$ 3.9)	73.8 ( $\pm$ 4.0)	-
Years of Grain Trade Experience	7.6 ( $\pm$ 0.7)	7.7 ( $\pm$ 0.8)	-
Education Exceeding Primary School (%)	62.8 ( $\pm$ 4.1)	63.9 ( $\pm$ 4.4)	-
<b><u>Scale of Trading Activities</u></b>			
Markets Selling Beans	1.1 ( $\pm$ 0.0)	1.3 ( $\pm$ 0.1)	**
Districts Selling Beans	1.0 ( $\pm$ 0.0)	1.1 ( $\pm$ 0.0)	-
Districts Sourcing Beans	1.1 ( $\pm$ 0.0)	1.2 ( $\pm$ 0.1)	*
Avg. Total Beans Bought in 12mo. Period (kg)	12,643 ( $\pm$ 3,608)	6,324 ( $\pm$ 994)	-
Avg. Monthly Beans Bought in Active Trading Months (kg)	1,284 ( $\pm$ 384)	694 ( $\pm$ 134)	-
Grain Sales as Primary Income (%)	64.8 ( $\pm$ 4.0)	62.3 ( $\pm$ 4.4)	-
Accessing Credit (%)	24.8 ( $\pm$ 3.6)	18.0 ( $\pm$ 3.5)	-
<b><u>Beans Sourcing Practices</u></b>			
Buy Beans Brought to Market by Farmers (%)	77.9 ( $\pm$ 3.5)	96.7 ( $\pm$ 1.6)	***
Leave Market to Buy Beans (%)	35.2 ( $\pm$ 4.0)	38.5 ( $\pm$ 4.4)	-
Only Buying Beans from Farmers (%)	40.7 ( $\pm$ 4.1)	80.3 ( $\pm$ 3.6)	***
Portion of Total Beans Sourced from Farmers (%)	65.4 ( $\pm$ 3.0)	87.5 ( $\pm$ 1.7)	***
Selling Own Beans as well (%)	7.6 ( $\pm$ 2.2)	9.0 ( $\pm$ 2.6)	-
<b><u>Bean Marketing</u></b>			
# Bean Samples Selling on Survey Day	1.2 ( $\pm$ 0.0)	1.4 ( $\pm$ 0.1)	***
Beans Sold to Another Trader (%)	9.7 ( $\pm$ 1.6)	9.6 ( $\pm$ 1.9)	-
Beans Sold to Consumers (%)	90.3 ( $\pm$ 1.6)	90.4 ( $\pm$ 1.9)	-
Beans Sold as Seed (%)	13.8 ( $\pm$ 1.2)	10.9 ( $\pm$ 0.9)	*
Using Storage Protectants for Sourced Beans (%)	15.9 ( $\pm$ 3.0)	12.3 ( $\pm$ 3.0)	-
Storage Time Before Sale (weeks)	3.1 ( $\pm$ 0.3)	2.0 ( $\pm$ 0.2)	***

Note: \*, \*\*, \*\*\* represents significance at the 90%, 95%, and 99% confidence interval

**Table 3: Drivers of Damaged Bean Purchase and Price Discounting**

	Step 1: Decision to Purchase Insect Damaged Beans		Step 2: Discount Intensity (%) of “Purchased” Beans (vs. undamaged appraisal)
	<u>Pooled Probit</u> N=1,024 Log Likelihood = -296.64; LR $X^2=825.03$ , $p>X^2=0.000$ Pseudo $R^2=0.5817$		<u>Pooled Tobit</u> N=530 Log Likelihood = 560.37 LR $X^2=289.50$ , $p>X^2=0.000$ Pseudo $R^2=-0.3483$
	Coefficients (SE)	Avg. Marginal Effects (SE)	Coefficients (SE)
Holes in 100 grain sample (#)	<b>-0.0817***</b> (0.0043)	<b>-0.0134***</b> (0.0001)	<b>0.0040***</b> (0.0002)
Female (=1)	<b>0.2439*</b> (0.1408)	<b>0.0399*</b> (0.0230)	-0.0049 (0.0069)
Years Experience Trading (#)	<b>0.0174**</b> (0.0074)	<b>0.0029**</b> (0.0012)	0.0005 (0.0004)
Education past Primary (=1)	<b>0.3300**</b> (0.1302)	<b>0.0540**</b> (0.0211)	<b>0.0164**</b> (0.0064)
Monthly Avg. Sourcing Quantity [ln(kg)]	-0.0332 (0.0654)	-0.0054 (0.0107)	<b>-0.0062**</b> (0.0031)
Percentage of Total Purchases Directly from Farmers [vs. Middlemen] (%)	-0.0412 (0.2321)	-0.0067 (0.0380)	<b>0.0385***</b> (0.0109)
Markets Currently Selling Beans (#)	0.0375 (0.0988)	0.0061 (0.0162)	-0.0057 (0.0053)
Weeks storing grain before re-sale (#)	0.0035 (0.0219)	0.0001 (0.0036)	<b>0.0023**</b> (0.0011)
Percent of beans sold for planting purposes [as seed] (%)	<b>-2.4606***</b> (0.4964)	<b>-0.4028***</b> (0.0784)	<b>0.0643***</b> (0.0241)
Northern Province (=1)	0.2962 (0.2015)	0.0485 (0.0329)	<b>-0.0386***</b> (0.0102)
Southern Province (=1)	<b>0.5747***</b> (0.1986)	<b>0.0941***</b> (0.0322)	<b>-0.0392***</b> (0.0092)
Eastern Province (=1)	<b>0.8830***</b> (0.1601)	<b>0.1445***</b> (0.0252)	<b>-0.0256***</b> (0.0075)
Season A (=1)	<b>-1.2661***</b> (0.1517)	<b>-0.2073***</b> (0.0224)	<b>0.0360***</b> (0.0068)
Constant	<b>2.9441***</b> (0.4822)	-	0.0014 (0.0219)

Note: \*, \*\*, \*\*\* represents significance at the 90%, 95%, and 99% confidence interval

## Figures

Availability of maize on the market	Maize given top price (% damaged grains)	Price of highly damaged maize ( > 90% damaged grains)	Simplified damage-price equation and suggested standard deviation for single grain sample <sup>a</sup>
Plentiful (after harvest)	0-5%	Unlikely to sell	$P = 100 - D \pm 15$
Moderate (mid-season)	0-5%	Unlikely to sell	$P = 100 - 0.85D \pm 15$
Scarce (lean season)	0-7%	25%	$P = 100 - 0.75D \pm 15$
Very scarce (bad years)	0-10%	30%	$P = 100 - 0.65D \pm 15$

\*D = percent damaged grains as defined in text. P = price as percent of top price. After calculating P, it can be multiplied by the mean price of good-quality grain to get the expected cash price for a given damaged batch of maize.

**Figure 1: Damage Threshold and Discount Summary for Previous Wholesale-level Ghanaian Research**

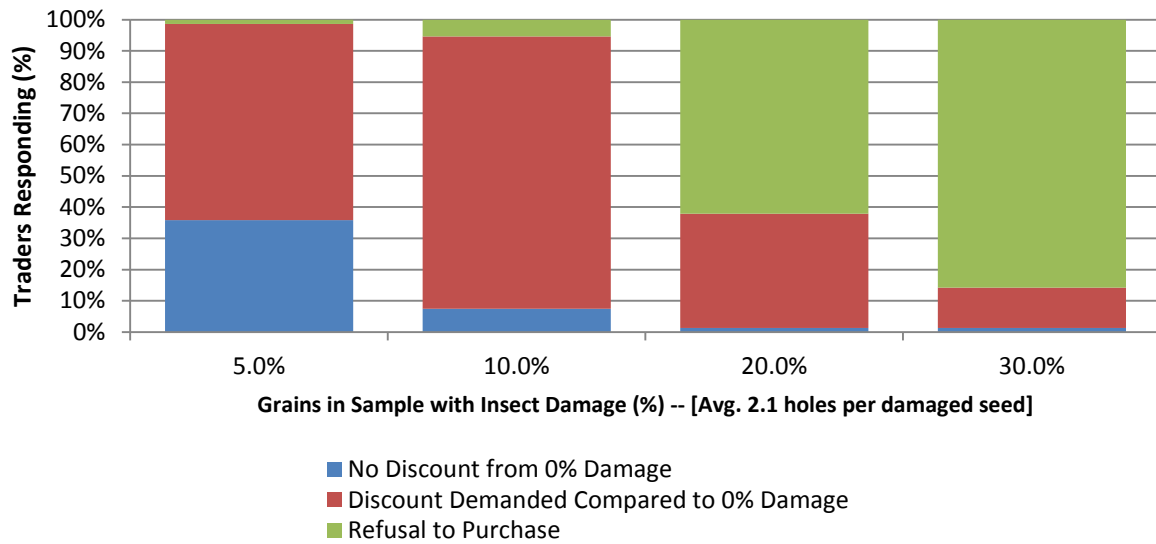
Source: Compton et al. (1998)



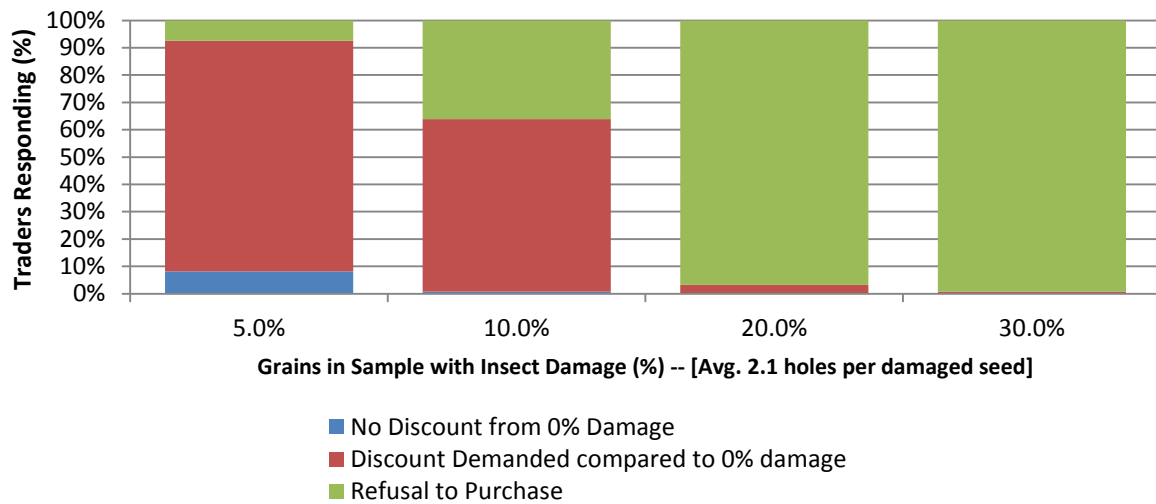
**Figure 2: Map of markets surveyed (starred)**

Base Map credit: CGIS-UNR

### End Season B: Nov-Dec, Season B 2012; about 4-5 mo after harvest



### Beginning Season A: Feb, Season A 2013; about 1-2 months after harvest



Damage Level (%)	Season B End					Season A Beginning				
	5%	10%	20%	30%	Avg.	5%	10%	20%	30%	Avg.
No Discount (%)	35.8	7.4	1.4	1.4		8.2	0.8	0.0	0.0	
Discounting (%)	62.8	87.2	36.5	12.8		84.4	63.1	3.3	0.8	
Rejecting (%)	1.4	5.4	62.2	85.8		7.4	36.1	96.7	99.2	
Avg. Discount (incl. 0% disc) (±SE)	3.5 ±0.3	8.2 ±0.4	16.0 ±0.1	21.5 ±0.3		6.2 ±0.4	13.7 ±0.1	15.5 ±0.5	14.3 -	
Discount (%) per 1% damaged seeds (±SE)	0.69 ±0.06	0.82 ±0.04	0.80 ±0.06	0.71 ±0.08	0.76 ±0.06	1.24 ±0.08	1.37 ±0.10	0.78 ±0.02	0.48 -	1.28 ±0.06
Discount(%) per hole in 100 seeds (±SE)	0.33 ±0.03	0.39 ±0.02	0.38 ±0.03	0.34 ±0.04	0.36 ±0.03	0.59 ±0.04	0.65 ±0.05	0.37 ±0.01	0.23 -	0.61 ±0.03

Figure 3: Seasonal Derived Dry Bean Discount Schedules for Insect Damage

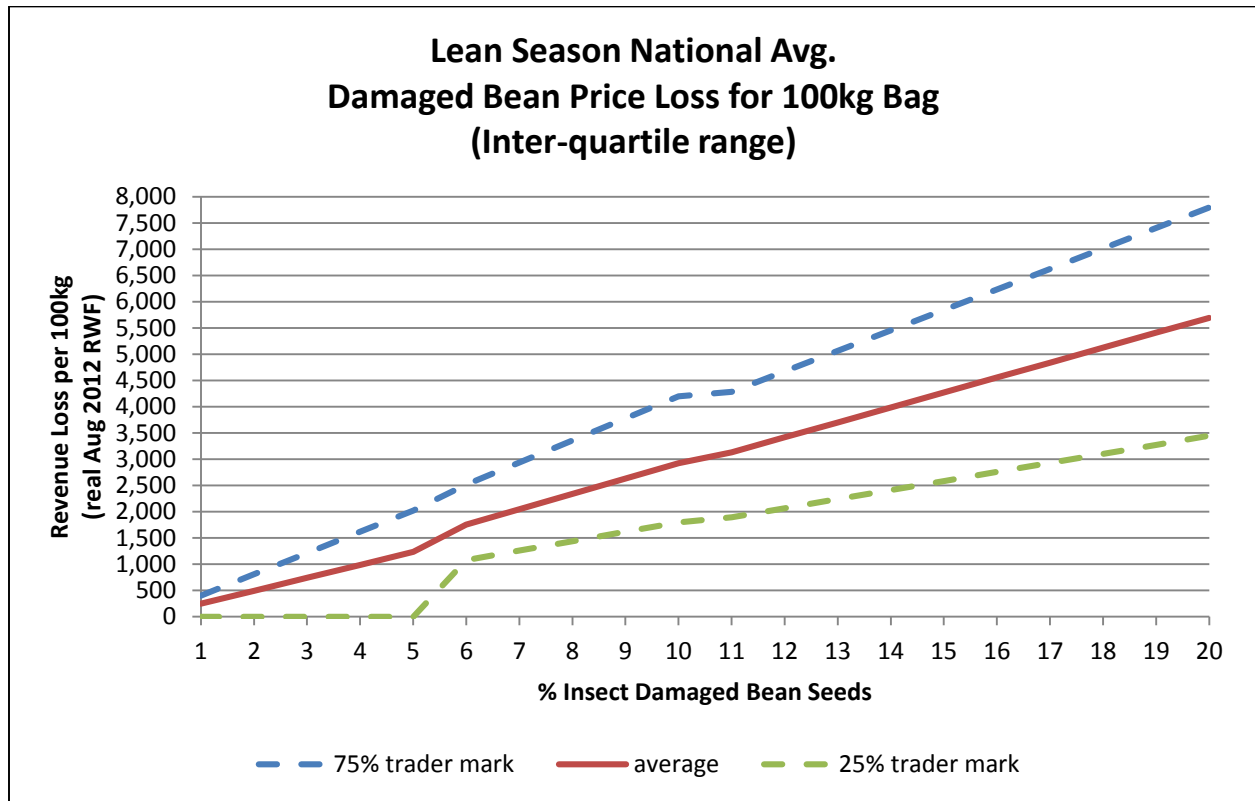


Figure 4: Damaged Bean Price Loss in 100kg Bag (Lean Season N'nl Avg)