WILLINGNESS TO PAY FOR QUALITY COWPEA SEEDS: EXPERIMENTAL EVIDENCE FROM NORTHERN GHANA

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ABSTRACT

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High cost of seed relative to grain price, and the lack of actual or perceived quality difference between available seed products and grain have contributed to the low demand for seeds of improved varieties for legume crops. This study reports the results of agronomic field experiments and incentivized experimental auctions conducted in Ghana to address the following research questions: 1) Are farmers able to perceive quality differences among three types of seed products that can be used as planting material – recycled grain, certified seed, and quality declared seed (QDS)? 2) Given the perceived quality difference, what is farmers' willingness to pay for these seed products? Results indicate that on average certified seeds performed significantly better than QDS and the recycled grain. Participants were willing to pay 73% and 20% more for certified and QDS over recycled seed, respectively. This was consistent with farmers' observed seed quality difference obtained through their subjective plot rankings. Consistent with the theory of downward sloping demand curve, there was an inverse relationship between willingness-to-pay a premium price for quality seed and the number of farmers willing to pay the premium price. On the supply side, the average cost of producing one kg of certified seed was estimated to be twice the average cost per kg of producing cowpea grain. The findings of this study have important policy implications on seed dissemination approaches to reach farmers across the spectrum based on their willingness-to-pay for quality seed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background and Motivation

The importance of seed in any crop-based production system cannot be overemphasized. Over the years, a large number of improved varieties (i.e., varieties with genetically improved traits that are generated by plant breeding research) have been released by both international and national research institutions. Improving the genetics of planting materials of preferred crops can greatly contribute to agricultural productivity improvement. However, there is an alarming gap between the rate of release of improved varieties and their use by farmers (Walker and Alwang 2015, Shiferaw et. al 2008). Full expected gains from the investment in plant breeding research depends on both the genetic improvement embodied in the seed as well as the existence and performance of a seed system that can deliver this improved genetic gains to farmers in the form of good quality seeds (i.e., planting materials). How to build and promote an efficient and sustainable seed system that can deliver quality seeds of improved varieties of staple crops has remained one of the major agricultural development challenges in many developing countries (Maredia et al., 1999; Louwaars and de Boef 2012; Sperling et al. 2014).

Recognizing the importance of quality seed (i.e., planting material), governments, donors and development organizations, have made significant investments in recent years to scale up efforts to make seeds of improved varieties available to farmers (McGuire and Sperling, 2015). Many of these efforts are based on the distribution of subsidized or free seeds (during or after emergencies) which may not be sustainable in the long run. Hence, there is great interest from development practitioners in understanding the demand and supply side economics of the seed system with the goal of finding alternative models that are more market driven and sustainable. One of the key factors that determines the sustainability of a seed system is the 'effective demand' for quality seeds of improved varieties as reflected by the volume and frequency of new seed purchased by farmers. Quality seeds are characterized by good germination rates, seedling vigor, and are free from seed-borne diseases and other impurities. These seed quality characteristics and genetic traits (i.e., tolerance to biotic and abiotic stresses, duration of maturity, nutritional traits, etc.) are both necessary to realize the productivity gains from adopting an improved variety. It is true that in the case of self-pollinated crops like cowpea (*Vigna unguiculata)*, the seed can preserve the genetic quality from one generation to the other. As a result, farmers don't have to purchase fresh seeds of an adopted improved variety at the beginning of each planting season. However, one-time adoption of an improved variety with low frequency of seed replenishment (either due to non-availability of seeds or farmers' inability to perceive and value the importance of seed quality) will not have the desired impact on crop productivity if the seed of that variety is infected with diseases or its physical quality deteriorates due to poor post-harvest handling and storage (Harrington, 1972).

For a given variety, production and marketing of quality seed involves taking specific and extra measures compared to grain production. These include the use of inputs and management practices to control weeds and pests during seed production, post-harvest processing, conditioning and treatment, and packaging, and also complying with specific country's seed regulatory requirements to be able to sell the product as seed. 'Seed' production thus has higher production and transaction costs than grain production.

The viability of a seed market will thus depend on the co-existence of the following demand and supply conditions. On the demand side it depends on: 1) whether farmers are able to perceive or recognize the 'seed' product as a quality planting material, and 2) given the perceived quality difference, whether farmers are willing to pay a premium price for seed compared to grain price.

On the supply side, it depends on: 3) whether the price farmers are willing to pay is high enough to recover the cost of producing quality seed; and 4) whether the quantity and frequency of seed demanded at that price is large enough to attract suppliers to produce and sell quality seed. To the best of our knowledge, no rigorous work has been done to systematically examine these demand and supply side conditions in the context of the seed system of a self-pollinated legume crop such as cowpea. This gap serves as a motivation for this research.

1.2 Study Objective

The overall objective of this study is to use field experiment and incentivized experimental auctions to systematically analyze the economics of the demand and supply side characteristics of the cowpea seed system in the northern part of Ghana.

1.3 Research Questions

This study achieves the stated objective by addressing the following research questions:

a. For a given variety, what is the difference in the performance (as measured by yield and other characteristics important to the farmers) of cowpea crop across three seed types- Certified, Quality Declared Seed (QDS), and farmer saved cowpea grain when the seeds are planted and managed by farmers under their own farm conditions?
b. How does the observed differential performance of different types of seeds translate into farmer's willingness to pay for quality seed?
c. What factors determine the cost of producing certified seeds, QDS and cowpea grain, and how do these costs compare to their relative market prices?

1.4 Organization of the Study

The thesis is divided into seven chapters. **Chapter two** focuses on the review of existing literature and presents major issues confronting seed system development in general, and legume seed system in Ghana, in particular. The gaps in the literature and motivations for developing a sustainable seed system are discussed in this chapter.

Chapter three describes the study setting and the study methodology. It describes the criteria used to establish experimental plots, and explains the methodology, process, and design of the experimental plots and bidding experimental auctions.

Chapter four describes the conceptual framework and the empirical strategy employed to estimate farmer's willingness to pay. A hedonic price model is used to explore the influence of perceived seed quality on the coefficient of interest.

Chapter five provides description of different types and sources of data used. Summary statistics of data collected from the farmer survey are also presented in this chapter.

Chapter six presents the results from the field experiment, experimental auction and the cost of producing different types of seed products.

Chapter seven presents the econometric model estimation results. Determinants and factors that influence a farmer's WTP for quality seeds are presented and the results are discussed.

Chapter eight discusses the policy implications of the overall results, limitations of this study, opportunities for future research, and concludes with recommendations for building a sustainable seed system.

CHAPTER 2: LITERATURE REVIEW

2.1 Seed system Issues for legume Crops

Inefficiencies in the seed system in many Sub-Saharan African countries has contributed to the low adoption rate of improved seed variety in the region (Tripp, 2001). About 90% of seeds used by smallholder farmers in Africa is accessed through the informal sector which comprises of borrowing, farmer-to-farmer seed exchange, on-farm savings, and local grain purchases (Maredia et. al 1999). The informal seed system is characterized by unstructured and unregulated activities ranging from seed selection, multiplication and dissemination mostly by farmers themselves and with no or little involvement of institutional entities. Farmer-to-farmer dissemination of seed is mostly informed by observing and learning from others (i.e., family and neighbors). The informal seed system, however, is vulnerable to shocks due to its unstructured process. For instance, in the case of extreme weather conditions such as flood and drought, there are higher chances of experiencing seed shortages. Recycling of seeds by farmers also poses constraints since the availability of seeds depends on the yield and quality of saved seeds. Quality of seed can be impacted by production practices used (or not used), and can diminish during storage.

The formal seed system, initiated by governments through the establishment of parastatal seed companies and research laboratories was a response to address some of the constraints of the informal seed system. However, these state run corporations faced high costs of production and distribution challenges, and inefficiencies in meeting the seed needs of a broad range of farmers. It has focused on a relatively narrow range of crops/varieties, mostly hybrid maize and crops with relatively high seed demand. Even with the few crops that they produced, the seed quality was not consistent over time. These challenges coupled with the rolling out of structural adjustment programs across Africa lead to the closure of many parastatal companies. Due to the way these parastatals operated, it did not create an enabling environment for the private sector to gradually replace the parastatals in its absence.

There are also other barriers that restricted the private sector from entering into the seed sector in Africa. These include poor rural infrastructure, inadequate or no seed policy and regulatory framework to protect the private seed companies. As a result, the governmental and non-governmental organizations have been working together to strengthen the formal seed system by providing farmers with free samples of improved variety seeds, and distributing seed during emergencies and natural disasters. However, emergency seed distribution programs have been criticized as competing with local seed enterprises and undermining the emergence of private seed sector instead of supporting them. The emergence of a hybrid (i.e., semi-formal) system which leverages on characteristics from both the formal and the informal seed sector is gaining attention. The semi-formal system allows for training and monitoring of farmers to produce quality seeds for sale to members in their community. The production stage has features similar to a formal seed system whereas the distribution leans more towards an informal system. However, this hybrid system is not legally recognized in most countries and there is no seed certification by a government recognized agency. In Tanzania seeds produced in this system are called Quality Declared Seeds (QDS), which is also the case in Ghana (Shiferaw et. al 2008). Like in Tanzania, the QDS in Ghana has been recognized legally, and seed producers need to be trained before they can produce and sell QDS seed.

2.2 Legume Seed System in Ghana

The legume seed system in Ghana, like many other African countries, is faced with low and inconsistent seed demand and supply, particularly for new improved varieties. Farmers usually recycle cowpea grain from their own harvest, and use that as planting material. In addition, a lack of proper seed regulatory frame work contributes to low availability of seed and consequently, low seed demand. Designated governmental departments responsible for regulating seed quality in most cases fail to do so. As a result, farmers end up buying counterfeit (low quality) seed and are left with a reduced incentive to buy fresh certified seeds in subsequent seasons.

Adopting the seed system evolution framework described by Maredia et al. (1999), the Ghanaian legume seed system can be classified under phase two of the evolution process. This phase is characterized by the development of improved varieties of seeds by public research institutes. The use of inputs (e.g., fertilizer) is limited but increasing. The private sector is gradually becoming involved in the multiplication and distribution of seeds. There are about 11 seed companies and 192 registered seed growers in Ghana (Etwire et al. 2013). The Semi-formal seed system in Ghana also faces the problem of lack of access to foundation seeds, inadequate training and monitoring as well as market access and distribution challenges. As a result, most of the QDS producers still operate in the informal farmer-to-farmer mode of seed distribution. Recently, community projects sponsored by NGO's in partnership with research institutions and government extension agents are leading the QDS production and distribution. The role of the research institute is to supply quality foundation seeds to seed producing farmers and the extension agents are required to provide training and technical advice to farmers on quality seed production.

2.3 Methodological Approaches for Assessing Seed Demand Existing Practices and Gap

In this sub-section, we review two strands of existing literature that are closely related and provide the rationale for analytical approaches used in this study.

The first strand of literature looks at how plant breeders and agronomists assess the demand for genetic attributes. Effective seed demand to a large extent depends on farmer's ability to link desired seed characteristics to a particular seed. However, some of these desired characteristics cannot be physically observed at the time of seed purchase. For example, the genetic make-up of the seed which enables the seed to be tolerant to drought, resistant to pest and diseases, or have short or long maturity period cannot be observed. It is in tandem with this gap, that researchers and NGO's have adopted the demonstration field experiments as a mechanism to assist farmers in recognizing the genetic quality of seed variety. Farmer's inability to link the genetic attributes to the type of seed variety at the time of purchase is more likely to affect the demand for seed as a planting material. Over the years, researchers in particular have employed participatory crop varietal trials to include farmers in the selection of improved varieties (Morris et al. 2004). Farmers are invited to observe experimental varietal trials and share their opinions on preferred varietal traits and characteristics. One major short fall of this approach is that the demonstration trials are managed by researchers, which may not be representative of farmers' growing conditions and practices. In this study we follow a similar methodology of conducting field demonstration trials, but address the aforementioned shortcoming by conducting these trials under the host farmer's farming conditions and practices.

The second strand of literature this study draws from looks at measuring demand for attributes from the perspective of an economist. According to the Lancaster's theory, consumers do not derive utility from a good itself, but rather from its characteristics (Lancaster 1966). This implies that the same products with different characteristics provides different satisfaction levels (De Groote et al., 2011). Consumers are continually making choices among products. Not only do they not have reliable information about the price of the product, but they also have poor quality valuation among the products probably because information on product quality is hard to find. Researchers have used experimental auctions to value consumer's preference for a new product or competing attributes in the face of tradeoffs. Experimental auctions have been applied in various forms to estimate consumer's Willingness-To-Pay (WTP) for staple crops. This includes aflatoxin-free maize in Kenya (De Groote et al. 2015) and biofortified yellow and white maize meal in Kenya (De Groote et al. 2011). These papers focus on consumer's preference for taste and how that translates into either a premium or discount they are willing to pay for the staple. In the case of seed, farmers are interested in both the consumption and production traits of the seed. Some of these desired characteristics cannot be physically observed at the time of seed purchase. For example, the genetic make-up of the seed which enables the seed to be tolerant to drought or resistant to pest and diseases cannot be observed. Waldman et al. (2014) studied both production and consumption preferences of Rwandan farmers for a common bean variety. They combined binding experimental auctions with participatory varietal selection to derive farmers' varietal preferences. They confirmed that auctions revealed varietal demand more accurately than stated non-binding preferences. Again, the participatory varietal selections enabled them to understand how farmers evaluated tradeoffs between crops. In this study we draw from this literature and design binding auction experiments to assess how farmers' perception about seed quality attributes translates into their willingness to pay for quality seed.

2.4 Importance of Building a Sustainable Cowpea Seed System in Northern Ghana

Cowpea provides a plant source of protein (Appiah et al. 2011; Ahenkan et al. 1998), bridges the hunger period during the crop growing season, and is one of the staple crops that is resilient under low rainfall conditions. It also has a high biological nitrogen fixing ability (Singh et. al 2003) which can reduce the need for farmers to purchase expensive inorganic fertilizers. Given these characteristics, cowpea is highly suitable for the three Northern regions of Ghana, which are also considered the poorest in the country (GSS 2014). For these reasons, exploring possible demand and supply side constraints that farmers face in their cowpea seed adoption decisions can help inform decisions on designing suitable interventions which can increase cowpea productivity by improving accessibility of quality seeds to cowpea farmers. Such institutional innovations in the cowpea seed adoption process can significantly contribute to the general wellbeing and poverty reduction in the region.

CHAPTER 3: STUDY SETTINGS AND METHODOLOGY

3.1 Criteria for Establishing Experimental Fields

One of the objectives of this research is to understand whether farmers are able to perceive quality differences among three types of seeds that have undergone different quality control measures during the production, post-harvest processing, and marketing stages. Ultimately, we are interested in knowing how these perceived seed quality differences translate into relative differences in farmers' willingness to pay for these three types of seeds. To examine this, we conducted agronomic field experiments and incentivized Experimental Auctions in 10 villages in the Northern part of Ghana.

Unlike the villages in the southern part of Ghana where farmers stay at one place (dwelling) and move to the outskirt of the villages to farm, most of the villages in the Binduri district in the Northern Region of Ghana practiced compound farming system, where farmers live on their farm lands. Host farmers were selected in consultation with the Ministry of Food and Agriculture (MOFA) extension officers and village leaders. Recommended and selected farmers owned enough land, were major cowpea decision makers, and were willing to host the demonstration fields. Another important requirement was the existence of a cordial relationship between the selected host farmer and the rest of the community members[1].

Selected host farmers were briefed on the entire project and their respective roles were emphasized. The designated fields (or sub-plots) for the Field Experiments (FE) were clearly demarcated and marked with identification labels representing each seed type.

[1] In one of the villages (Azumsapeliga), we had to replace the selected host farmer because he had marital issues some time ago which resulted in dispute with quite a large proportion of the community. This obviously might affect the attendance and participation during the field days.

3.2 Field Experiment (FE)

The field experiments were established to demonstrate the value of planting different types of quality seeds of the same cowpea variety, called Songotra. The main reason for selecting this variety was its genetically improved quality to resist *Striga gesnorioides,* a major parasitic weed that has detrimental impact on the productivity of staple crops in Sub-Saharan Africa. The weed survives by drawing off water and nutrients from the crops for its own growth. It causes substantive damage to its host crop before emerging from the soil by producing phytotoxins which are harmful to the host crop (Ouédraogo et al. 2001). For the cowpea breeder collaborator in Ghana, this experiment also served the purpose of evaluating the genetic qualities of this variety (i.e., striga resistance) under the on-farm conditions.

The three types of seeds of this variety evaluated in the FEs included certified seed, QDS, and recycled seeds. The intention was to evaluate the performance of the cowpea crop planted with three different seed quality, but controlling for the genetics (i.e., same variety) and all other environmental and management conditions. These field demonstration plots were used to provide the farmers an opportunity to observe the agronomic performance of the cowpea plants in terms of yield and other plant characteristics. This observation and first-hand experience was the basis for conducting an incentivized Bidding Experimental Auction (BEA) for estimating the relative difference in farmers' WTP for the different types of seeds representing different quality. The characteristics of the three seed types used in these experiments are as follow.

- Certified Songotra Seeds: These are supposedly the highest class and quality of seed available for farmers as planting material. This type of seed is produced from foundation seeds that are produced from the breeder seed. The government research program has the responsibility to maintain the seed stock of both the breeder seed and the foundation seed.

Certified seeds are produced by trained seed producers or seed companies under the required field conditions and have to undergo field inspection and seed quality tests, and must meet the required standards to obtain official certification from the Ministry of Food and Agriculture**.** Only approved seed that meet the seed quality tests (i.e., germination rate, humidity and purity) are marketed as 'certified seed' and sold commercially in sealed packages with appropriate labeling.

- Quality Declared Seed: In Ghana, this type of seed is produced by seed producers (either individual farmers or a farmer group) with guidance from experts but do not go through formal certification process. QDS producers receive foundation seeds from government or NGO's. In most cases, the farmers would have to pay back the cost of the foundation seed in kind after their harvest. QDS are sold to other farmers living in the same village or nearby communities. The objective is to solve the travel and search costs that farmers face in order to acquire quality seeds for planting. Unlike certified seeds, quality declared seeds are not required to pass purity, germination and moisture content test before being sold to farmers. QDS are normally cleaned manually and packaged for sale. Another major difference between certified and QDS is that, quality declared seeds are currently not legally recognized as a category of seed type in Ghana.
- Recycled seed: This is the grain saved by farmers from their previous season's harvest of cowpea. These are selected after a season's harvest and stored for future use as seed. This is the traditional method through which seed has been preserved over the years in Ghana.

The certified seed was bought from a certified seed seller in the market, QDS was acquired from a breeder who has a private business of producing QDS[2] for sale in the district. Recycled seed

[2] QDS seeds came in an uncertified bag

was purchased from a farmer who had purchased seeds of Sangotra variety and had stored grains from previous harvest to be used as seed in the following year.

A total of 10 villages were selected and one farmer from each villages was identified to host the field experiments. The intent was to sub-select eight villages with the best plots to conduct the field days and bidding experimental auctions. Each farmer hosting the FE was given 2.7 kg of each seed type. A sample of each seed type was sent to the laboratory for seed purity, germination and general seed health status test.

The FE was established as a double blind experiment, where neither the farmers (host farmers and other village farmers) nor the field assistant knew the identity of the three types of seeds included in the experiment. Technical staff implementing the FE and host farmers only knew the name of the variety and were also told that there were three types of seeds, namely certified, QDS and recycled seed to be planted on separate plots, however, the seed packages were labeled seed type G (which was certified seed), seed type M (which was recycled seed), and seed type L (which was QDS) and the technical staff and farmers were not told which code was associated with which seed type. The reason for doing the FE as a double blind experiment was to reduce any systematic bias on the part of the farmer managing the plot towards or against any pre-conceived notion of higher and lower quality seed type. The double blind experiment was expected to also reduce any bias farmers as observers may have towards a specific seed type based on their prior personal experience or 'hearsay.' The same seed codes used in the FE were used throughout the study to be able to match all the information collected.

A 10m x 20m dimension plot was planted for each seed type in each village. Spatial separation between plots was also encouraged for easy identification and movement of participants during field days. Each seed type plot was properly and prominently labeled by the seed codes G, M and

L. (see pictures below). The order in which these three types of seeds were planted across the eight FEs was random. For example, in some fields, the seed was planted in the following order—M, G, L; in some it was planted in the order – L, M, G, etc. Extension officers and local collaborators supervised the establishment of the FE in selected villages to ensure uniform planting rate, not mixing up with plot labels and other practices.

Two field days were organized during the study in eight out of ten villages selected for the FEs.[3] All farmers in each village were invited to attend the field days. On the first field day which was organized during the flowering stage, all farmers who attended were handed a ranking sheet to rate the overall best plot at the flowering stage. Before the individual ratings, participants discussed and agreed on important criteria with which they will rate a seed plot as good or bad at the flowering stage. These desired traits included potential yield/productivity, vigor of plant growth, plant stand, signs of no disease, and number of flower sets.

[3] The two villages that were dropped were located along the river (White Volta), which is prone to flooding during the main season (July- September). Farmers around this area normally use residual moisture during October to December to grow cowpea. Since this type of farming was a special case, it was decided to exclude them from the activities involving farmer surveys and experimental data collection.

After the first field day, 35 participants (each representing one household) were randomly selected from a list of participant households. A survey was administered to these participants and each received a unique ID tag which they were instructed to bring with them on the second field day. The second field day was held a week before harvest. This was to enable participant

Figure 3.1a: Experimental Plot 1

Figure 3.1b: Experimental Plot 2

Observe full formed pods to inform their rating decisions. On the second field day, participants were again asked to rate the best and the worst plot and to give reasons for their choices. After rating the plots, a bidding experimental auction was carried out on the same day. All participants who were sampled and surveyed after the first field day but did not show up on the second field day were replaced with farmers who took part in all the activities in the first field day and were also present in the second field day.

To avoid the chances of the same people (farmers) showing up on two field experiment sites (i.e., in two neighboring villages), villages were carefully selected to ensure they were located at some distance from each other. In selecting the villages, we also took into consideration the number of households in a village. Since the ultimate sampling goal was to select 35 representative cowpea famers, we selected villages with an approximate number of households between 80 and 120. On the second field day which fell on a week before harvesting and also coincided with the auction experiment, two FEs were visited per day.

3.3 Experimental Auction

The Bidding experimental auction (BEA) was conducted to determine how much farmers were willing to pay for the different types of seeds (planting materials) and this was done during the second field day approximately two weeks after the first field day). This was advantageous since farmers had gotten the opportunity to evaluate the performance of different types/grades of seeds planted in the FE, and used this performance observation as the basis for making the decision regarding their WTP for each seed type. Although farmers did not know yield data during the BEA, they could easily predict the relative difference in the yield across plots at maturity (based on their observations of how filled the pods were and how healthy the plants looked relative to each other).

We followed the Becker-DeGroot-Marschak (BDM) (Becker et al, 1964) method in designing the BEA. Unlike the classical auction where the highest bidder gets to buy the good, BDM mechanism is quite unique in the sense that bidders do not bid against each other but rather each one bids against his/her own self as the winning bid is determined by comparing their own bids to a randomly generated price.

The BDM elicitation mechanism is typically performed using one of two methods – a full bidding or an endow-upgrade method. In the full bidding method, participants are asked to "bid" their maximum willingness to pay for a given quantity. A random price is then drawn and compared to the bid. If the bid is greater than or equal to the randomly drawn price, then the participant gets to buy the good at the randomly drawn price (not their bid price).

In the endow-upgrade method, the participants are endowed with a given amount of the "lower value" good and asked to "bid" their maximum WTP to upgrade to an equivalent amount of the "higher value" good. Again, this bid would be compared to a randomly drawn price and if their bid is greater than or equal to the randomly drawn price, they would pay to upgrade, but will only pay the randomly drawn price (not their bid). In this method, the bid itself reveals the premium given to the "higher value" good. In both methods, the participant is likely to pay less than their bid (unless the bid and random price are equal) and thus the auctions are theoretically incentive compatible with regards to eliciting participant's true WTP. In both these auctions each participant receives a cash endowment at the beginning with which to either pay for a good or to upgrade. Each method has its advantages, but the literature (e.g., Lusk and Shogren 2007, and Alfnes 2009) appears to lean towards using the full bidding method, especially if very similar products are readily available in the market place.

This study followed the first method explained (i.e., full-bidding method) due to the nature of "blindness" of the FE and auctions (i.e., farmers were bidding without knowing the type/grade of seed they are bidding for) and the similarity in the seed variety (Songotra). BDM is also a convenient method for researchers because it is compatible with both individual and group administration. However, it is quite expensive (in terms of cost and time) to gather all participants at one place to execute it.

In this study, the group approach was used for the BEA. After farmers had completed the field visit and evaluated the experimental plots, farmers were asked to gather at one place where someone from the research team explained the farmers in their local language the BEA exercise and the steps involved. The script used during this exercise is given in Appendix F. A trial BEA was implemented first with a bar of soap to demonstrate the procedure to ensure that the bidding mechanism and the concept of drawing a random price was properly understood by the participants. Each participant was given GHC 2 (equivalent to $0.57 at the exchange rate at the time of the exercise) as the endowment for the soap BEA.

During the seed auction, farmers were asked to record their bids on a recording sheet (see Appendix G) for the three seed types (seed type L, G and M) used to plant the plots observed by the participants. Each participant was given GHC 10 (about $2.63 at the official exchange rate) and asked to record their bids ranging from GHC 0 to GHC 9.90 at an increment of GHC 0.10. After collecting the bidding sheets, a price was randomly generated by the participants for the seed in three steps. First, three spaces were written on a board with a dot in between the first and second space. The third digit was filled with zero. Secondly, since the second digit could be a 0, 1, 2, 3, 4, 5, 6, 7, 8 or 9, one participant was asked to roll out a 10-sided die. This second digit was whatever was rolled unless a 10 was rolled, in which case the second digit was 0. Lastly, the first digit could also be a 0, 1, 2, 3, 4, 5, 6, 7, 8 or 9. To determine this digit, a 10-sided die was rolled. If a 1, 2, 3, 4, 5, 6, 7, 8 or 9 was rolled, the first digit was that number. If a 10 was rolled, the first digit was 0. If a participant's bid was higher than this randomly generated price, the participant bought the seed at the random price and kept the balance from their GHC 10 endowment. If their bid was lower than the random price, they did not purchase the seed and kept the GHC10 endowment. The difference in the bids between the three auctions is interpreted to reveal the premium (or discount) a farmer is willing to pay due to the different quality attributes as observed/perceived by the farmer in the FEs (i.e., performance of seed type G, L, and M).

3.4 Collection of Cost of Production Data

As noted before, the three seed types vary in terms of inputs, management practices, and regulatory supervision, which have different cost implications and ultimately affect the quality of the final product (i.e., seeds) produced. To gauge these differences in cost of production across the three types of seeds included in the experiments, a sample of seed producers producing these different types of seeds were selected from the same area where the study was conducted. Detailed data on inputs, labor and post-harvest expenses were collected from farmers for the main cowpea growing season in 2016. Regular visits were made by trained enumerators to collect the data from the seed producers, who were trained to keep a record of all the input and labor costs incurred at all stages of the growing season.

CHAPTER 4: CONCEPTUAL FRAMEWORK AND EMPIRICAL STRATEGY

4.1 Conceptual Framework

Lancaster (1966, 1971) proposed an alternative theoretical approach to the traditional demand theory based on the principle that all goods possess characteristics or **attributes** that are demanded by the consumers, not the goods themselves. The new consumer demand theory was based on the assumption that a good in question does not give utility but rather the characteristics possessed by the good provides utility. Also, collective goods may possess traits different from those possessed by separate goods. This theory in effect implies that utility can be modelled in terms of the characteristics of a good.

Our model builds on the framework used by Hoffman and Gatobu (2013), which is rooted in the Lancaster theory of consumer demand. Consider a model where a farmer derives utility from growing cowpea using either one of three types of seeds $X_j,\ j = 1,2,3$ (where, 1=certified, 2=QDS and 3=recycled) and other complementary inputs m. Certified and quality declared seeds can only be obtained through the market whereas recycled seeds are assumed to be available to farmers from their previous season's harvest. The seeds possess a vector of attributes $\bar{t}$= [o, e, c], where o represents observable qualities such as the presence or absence of foreign materials such as dirt, stones or dead insects, and the uniformity in the shape and size of the grains, their appearance, etc., e represents experience attributes which can be known only after planting the seed, for example, plant vigor, and c, is the credence attributes, which are completely unobservable characteristics to the farmer such as the genetic make-up of the seed, its germination rate, moisture content, etc.. When a household uses recycled seed, some elements of o and e can be controlled. For example, good harvesting and storage practices can reduce the bad quality elements of o and increase farmer's confidence in the experience attribute. On the other hand, a household that purchases certified or QDS, can only control for o and to some extent c but the experience attribute is expected to be always new and unknown to the farmer. Hoffman and Gatobu (2013) proposed that a reputation effect will transmit information about the experience attributes.

Holding all other inputs (m) constant, we represent the quality of a seed type planted by a household as q($\bar{t}_1$), q($\bar{t}_2$) and q($\bar{t}_3$), for certified, QDS and recycled seeds, respectively. Prior to planting, the expected values of q is dependent on o (observed attributes) and household's expectations over e and c. Famers are expected to update their beliefs and perceptions about a particular seed type after their experience. The quantity harvested from different seed type, y_1, y_2, y_3, which are functions of their respective quality values enter the choice function. If seed quality is discovered after purchase or after planting to be bad such that there is no grain output for consumption, sale or planting as seed in the next season, then q($\bar{t}_j$)=0 J=(1,2,3), then a farmer is expected to form a lower perception about the seed type and as a result, not willing to pay a premium for the seed. The household's first decision problem is to choose a seed type that will maximize output, holding all other complementary inputs constant.

$$E\ Y_j = Y(X_j(q(\bar{t}_j)), m) \qquad \text{where } j=1, 2,3 \qquad (1)$$

The household then decides how much they are willing to pay for quantities of the seed type selected in equation 1 above. Willingness to pay is expected to be influenced by the perceptions formed about seed type after a household's experience with the seed type. In this study, this learning process is assumed to be done through a social learning experience, i.e. the field experiment.

The credence (c) and experience (e) attributes of recycled seeds are influenced by the household's farm practices. This is the case because in most instances the credence attribute (e.g., genetic makeup) can be preserved if a farmer observes good farming practices during and after harvesting. Harvesting and drying under the right temperature, adoption of good storage practices like hermetically sealed bags (e.g., the Purdue Improved Crop Storage (PICS) technology) can help preserve the genetics and seed qualities of the grain. But it is totally out of the farmer's control for seeds purchased from outside the farm (e.g., certified and QD seeds). One may argue that it may be better to implement the BEA before planting (in the following season) when farmers' demand for seed and their "true" WTP for seed would be revealed. However, since we are interested in the relative WTP, implementing the BEA at the end of the growing season still achieved the objective of this study. Thus, we did not include a time dimension in this model.

The model helps us to predict how farmers' perception about different seed attributes affects their willingness to pay for quality seeds. This perception is informed by participant's observations of experimental fields. The double-blind nature of the experiment controls for any pre-conceived perception of the quality of certified, QD or recycled seed, a farmer participant may have based on his prior experience or credence opinion.

4.2 Empirical Model

Following the estimation model used by De Groote et al. (2016), the seed characteristics of interest in the case of this study is perceived quality based on the observation of plant performance in the farmer's field. At the time of bidding, farmers did not know the identity of the seed type they were bidding for. However, they had 'observed' and 'experienced' the performance of the three types of seeds planted in the field during the flowering and harvest stages, and formed perceptions on the quality of these seeds. This perceived seed quality is estimated by creating a seed quality rating scale 1 to 3, with 1 being the worst seed plot, 3 being the best ranked seed plot and 2 representing neither worst nor best seed plot. Each participant submitted a bid for three seed types.

Since participants were randomly selected for the bidding exercise, we can safely assume that individual's effect is not correlated with any of the explanatory variables. A general OLS specification captures household characteristics and perceived seed quality. Household's and individual farmer's characteristics are assumed to vary across each other, which in turn induce varying levels of WTP among farmers. Hence including household's characteristics Z_i will be appropriate. The household's characteristics included are demographic, economic and some behavioral variables (De Groote et al., 2011).

We estimate the relationship between farmer participant i's willingness to pay for seed type j (WTP_{ij}) as a simple model specification using the farmer fixed effect as specified below

$$WTP_{ij} = \alpha + \beta X_{ij} + \delta_i + \varepsilon_{ij} \qquad (5)$$

Where, WTP_{ij} represents farmer i's bid for seed type j; X_{ij} represents the perceived seed quality rating for seed type j by farmer i, δ_i is the farmer fixed effect, and ε_{ij} is the error term for farmer i's WTP for seed type j.

Next we substitute the farmer fixed effect variables with a vector Z_{ij} representing farmer and household characteristics such as demographic, socio-economic, and behavioral variables. This allows us to explore the relationships between these characteristics and farmer's WTP for different quality seeds (equation 6).

$$WTP_{ij} = \alpha + \beta X_{ij} + \gamma Z_i + \varepsilon_{ij} \qquad (6)$$

Model specifications 5 and 6 are estimated using ordinary least squares (OLS). In both the models, the coefficient of interest is β, which measures the average price premium farmers are willing to pay for each unit increase in the perceived seed quality rating (i.e., when seed quality rating changes from worst to neutral to best).

De Groote et al. (2010) showed that WTP increased with the endowment amount. Some researchers have explored this by giving an endowment that is in value twice the market price (De Groote et. al., 2014; Morawetz et. al., 2011). In this study, we are interested in the relative difference in WTP not the absolute WTP for a product. Thus this criticism may not hold for this study. However, since the market price of cowpea certified seed was widely known, the amount was carefully set at 25% higher than the market price of cowpea certified seed to avoid low WTP for a very low amount and overstating of WTP for a very high amount.

CHAPTER 5: DATA DESCRIPTION

5.1 Data and Sample Selection

A total sample size of 269 participants was used for the analysis presented in this study after accounting for attrition. This comprised of 35 farmer observations per village, one person from each household. The participants in the survey, field evaluations, and BEA were either the major cowpea decision maker or one of the main decision makers in the household. Attrition problem was tackled by replacing sampled farmers who did not show up on the second field day with farmers who were listed in the first field day visit and had showed up on the second field day. A total sample of 269 cowpea growing farmers participated in the BEA exercise. All the farmers who participated in the BEA were surveyed either on the first or second field day to collect the household demographic and other socio-economic characteristics, and their knowledge and experience with different types of cowpea seeds.

In all the villages where field experiments are established, we also collected yield data at harvest for all the three seed types (Certified, Quality Declared and Recycled). Samples of harvested grain from three of these FEs were sent to the lab to test for moisture, purity and germination rates. As noted before, samples of seeds planted in the FEs of all three types (certified, quality declared and recycled grain) were also tested at the lab for seed quality (Appendix H). The cost of seed production data was collected over the same period as the FEs. There were only two certified seed producers in the district so they were both included as part of the survey. Three QDS and five grain producers were sampled. The QDS producers were selected from a USAID funded community seed production program focused on assisting one community member in each village to produce and sell quality seeds. All the three QDS producers in the district under the program were included in the study (table 5.1 below). A survey template was designed and administered by enumerators during the 2016 main farming season to collect the cost of production data from all the seed producers included in the study. Enumerators regularly visited seed producers to assist them record the inputs and labor costs incurred. Post- harvest expenses were also captured for certified and QDS producers. Data for cost of producing grains were also taken from certified and QDS producers to control for farmer fixed effect.

Table 5.1: Description of the Different Types of Data used in the Analysis

Activities	**Data Collection method**	**Sample size**	**Number of Participants by Gender**
Field Experiment	Yield data from all experimental plots and Seed quality test	3 plots x 10 villages	Male - 8 Female - 2
Field Day 1 (Flowering stage)	Household survey and farmer ranking of seed plots in 8 villages	269	Male - 118 Female - 151
Field Day 2 (Harvest stage)	Farmer ranking of seed plots and Experimental Auction in 8 villages	269	Male - 118 Female -151
Cost of seed production	Cost of cowpea seed production (survey and record keeping)	Certified – 2 QDS – 3 Recycled - 6	Male - 8 Female - 3

5.2 Sample Characteristics

As reported in table 5.2, out of the 269 respondents, 51% were household heads, 46% were spouse of household heads and the remaining 3% were either sons or daughters of the household head. The average age of respondents was 42 years with average formal education of 3 years. There were more female respondents (57%), and compared to men they were slightly older (47 years) with less formal education (on average less than 1 year). Most of the respondents who participated in the experiments were illiterate (74%), who could not read or write in English or any other language. Sampled households had an average of 5.6 acres of owned land out of which they had cultivated 4.9 acres during the 2016 season. The average cowpea yield per household was estimated to be about 250 kg per acre. About 15% of respondents had purchased or used certified cowpea seeds which was lower than percentage of respondents who had used Quality Declared seed (30%). Meaning the experience of using certified and QDS seed was quite low among the respondents. About 39% of survey respondents identified themselves as early adopters of a new technology. Also, 29% of the farmers reported that they had used their own saved seeds as planting material in the last season, 14% had bought grain from the market, 51% had bought cowpea seeds from the market and 6% had received their seeds from NGO's and government support programs.

Table 5.2: Characteristics of Survey Respondents

Number of observations	**269**	
Farmer characteristics	Mean	SD
Age (years)	42	14.1
Gender (% male)	0.43	0.49
Percentage of participants who were head of the household	0.51	0.5
Number of years of education completed	3.13	4.74
Cannot read or write (%)	0.74	0.56
Number of years of experience growing cowpeas	17.91	14.47
Membership in a farmer organization (% yes)	0.33	0.47
Self-reported adoption behavior (% early adopters of new technologies)	0.39	0.48
Household characteristics		
Gender of the head = male	0.85	0.34
HH size	8.88	4.93
Poverty score (0-100)	29.77	11.3
> 75% probability of living below $1.25/capita/day (% of farmers)	0.01	0.1
Have used certified seeds of any crop (% yes)	0.18	0.39
Have used certified cowpea seed before (% yes)	0.15	0.36
Have used QDS cowpea seed before (% yes)	0.30	0.46
Purchases cowpea 'seed' every year or other year (% yes)	0.72	0.44
Last time purchased seed less than 4 years ago (%)	0.64	0.47
Source of cowpea seed planted in the last season that was (%)		
Saved from own harvest	0.29	0.45
Purchased as grain from market/others	0.14	0.34
Purchased as seed from market/others	0.51	0.50
Received from NGOs/government	0.06	0.22
Percentage of farmers reported planting an improved variety in the last season	0.11	0.31
Average yield of cowpea from the last harvest (kg/acre)	250.29	177.84
Total land area owned (acres)	5.59	3.7
Tropical Livestock Units (TLU) owned	4.92	2.48
Cowpea reported as most important crop on the farm in terms of: (% of farmers)		
Area planted	0.06	0.24
Inputs used	0.16	0.37
Source of income	0.73	0.44
Percentage of farmers who grew songotra variety in the last season	0.03	0.15

Source: Household Survey August-2016

CHAPTER 6: RESULTS

6.1 Descriptive Statistics on Field Experiments

Table 6.1 below presents the results of farmers rating of the best plot at the flowering and harvest stages. Note that due to the double blind nature of the study, farmers did not know the identity of the seeds when they were rating the plots. Hence the rating of different seed types are identified by their plot IDs (i.e., G, L, M). At flowering stage, 90% of farmer's rated plot type G (certified seed) as the best (Table 6.1). About 8% and 2% rated plot type L (QDS) and M (recycled) as the best plot at flowering stage, respectively. A second plot ranking was done one week before harvest which recorded 95%, 4% and 0.7% of farmers ranking certified, QDS and recycled seed plots, respectively as the best. It is quite obvious that at the harvest stage, there was a clear distinction between the three plots resulting in almost all farmers rating certified seed (i.e., plot G) as the best.

Table 6.1: Farmer's Best Plot Rating at Flowering and Harvesting Stages

Seed type	**Flowering Stage** **% of farmer's (N =269)**	**Harvesting Stage** **% of farmers (N =268)**
Plot G: Certified Seed	89.93	95.17
Plot L: Quality Declared Seed	7.87	4.09
Plot M: Recycled Seed	2.24	0.74

Source: Field experiment data, Ghana-2016

At the harvest stage, farmers were also asked to rate the worst plot among the three, and 77% rated recycled seed plot as worst and quite a substantial percentage rated QDS plot as second worst (22%) (Table 6.2). Clearly, farmers were confident about rating seed type G (certified) as the best and least worst, but the same cannot be said about seed types L (QDS) and M (recycled).

Table 6.2: Farmers Rating of Worst Plot (% of farmers) at Harvest Stage

Seed type	% of farmers (N=269)
Plot G: Certified Seed	0.37
Plot L: Quality Declared Seed	21.93
Plot M:Recycled Seed	77.70

Source: Field experiment data, Ghana-2016

Farmers gave various reasons for rating a plot as the best or worst. These reasons are categorized in Table 6.3. About 69% of farmers rated a plot as best because of higher yield, 14.87% rated best plot with high seed quality criteria. Unhealthy appearance of plants and lower yields were the major reasons given by famers for rating a plot as worst.

Table 6.3: Characteristics Cited as a Reason for Rating a Seed Type as Best or Worst (N=269)

Reasons for rating a plot 'BEST'	% of farmers	Reasons for rating a plot 'WORST'	% of farmers
At Flowering		**At Harvesting**	
1. Yield/Productivity		1. Plants look unhealthy	**39%**
2. Vigorous		2. Pods have not filled nicely	**15%**
3. No disease		3. Lower yields	**38%**
4. Plant Stand		4. Poor seed quality	**8%**
At Harvesting			
1. Higher yield	**69%**		
2. Plants look healthy	**7%**		
3. Good seed quality	**15%**		
4. Pods have filled nicely	**9%**		

Source: Farmers' ratings recorded on Field Day 1 and 2, Ghana-2016

The data from all the ten communities where the FEs were established were pooled together for analysis of the mean yield performances of the three seed types and are presented in Table 6.5. Seed quality test results for the different seed types are presented below in table 6.4

Table 6.4: Seed Quality Test Results before Planting

Reference - Before planting	Seed type	Moisture Content %	Purity	Germination %
Before planting	Certified	9.9	99.9	98
	QDS	9.5	99.9	92
Before planting	Recycled	9.9	88	98

Source: seed test results from the plant protection and regulatory service department MoFA –Ghana, 2016

Certified and QDS passed the seed purity test of 98% for cowpea by the FAO. Recycled seed however, had 88% of seed purity test results. The acceptable threshold for moisture content by FAO is 10% this implies that all the three seed types failed the moisture content test. Germination rate for certified seeds and QDS were 99.9% for both seed types, which was higher than the 98% acceptable threshold for cowpea seeds. Recycled seed on the other hand did not pass the germination rate test (88%).

Table 6.5: Agronomic and Grain Yield Parameters of the Seed Type across Ten Communities

Seed type	Plants at 2-weeks after planting ($25m^2$)	Plants affected by root rot ($25m^2$)	Plants at harvest ($25m^2$)	No. off-type plants ($25m^2$)	Grain yield/ha (kg)
Certify seed (G)	403	3.5	400	1	1500
Quality declared seed (L)	403	30	375	2	870
Recycled seed (M)	394	90	304	26	455
Mean	**400.0**	**40.5**	**360**	**9.4**	**941**
LSD	**9.82**	**17.72**	**22.5**	**6.30**	**286.9**
CV%	**2.6**	**46.6**	**6.7**	**71.3**	**32.4**

The means represent data from the study sites of 10 communities
LSD is the Least Significant Difference
CV is the Coefficient of Variation

The parameters considered necessary to bring out differences among the seed types were plant establishment two weeks after planting, plants affected by root rot disease, the number of off-type plants per seed type, plants that survived till harvesting and grain yield. Other agronomic data including dates to flowering, maturity, plant height, etc. were collected but not reported here because they were not different among the seed types.

Although the certified seed (plot G) and the quality declared seed (plot L) recorded higher plant establishment than the recycled seed plots, the differences were not statistically significant. Across all the ten communities, at two weeks after planting, all the seed types recorded over 90% establishment, which is considered good.

A significantly higher number of plants in plot M (recycled seed) were severely infected with the root rot disease. On the other hand, the certified seed (plot G) recorded significantly lower number of plants with root rot disease. The number of root rot infected plants recorded against the recycled seed plot was 3 and over 25 times higher than the infected plants in the QDS and certified seed plots, respectively.

The total number of plants that survived till the time of harvesting ranged between 304 to 400 per plot planted. Certified seed recorded significantly higher number of plant survival than the other two seed types, the seed type with the least number of plants at harvest was recycled seed. When the number of plants at harvest were expressed as a percentage over plants that were established 2 weeks after planting, certified seed plot recorded 99% survival, QDS had 93% survival rate, while in plots with recycled seeds only 77% of plants survived until the harvest time.

The recycled seed plot recorded significantly higher number of cowpea plants as off-types (indicating mixtures of varieties other than Songotra). The off-type plants recorded in the certified and QDS plots were lower, and did not differ significantly. The number of off-type plants found in the recycled seed plot were 26 and 13 times higher than those found in certified and QDS seed plots, respectively.

On average, across all 10 villages certified seed plots recorded significantly higher grain yield per hectare (1500 kg/ha) than yields on both QDS (870 kg/ha) and recycled seed plots (455 kg/ha) (Table 6.5). The seed type with the least grain yield per hectare was recycled seed which was also significantly lower than average yield recorded for QDS plots. This relative difference and statistical significance between the grain yields of these three seed types is also observed in the 8 villages where farmer field days and BEA were conducted (Table 6.6)

Table 6.6: Yield of Different Seed Types across Field Experiments

	Harvesting Stage	
Seed type	**Yield kg/ha (N=8)**	**Standard Deviation**
Plot G: Certified Seed	1533.78	337.85
Plot L: Quality Declared Seed	975.09	402.74
Plot M: Recycled Seed	444.67	156.45

Source: Field Experiment data, Ghana-2016

6.2 Results of Bidding Experimental Auction

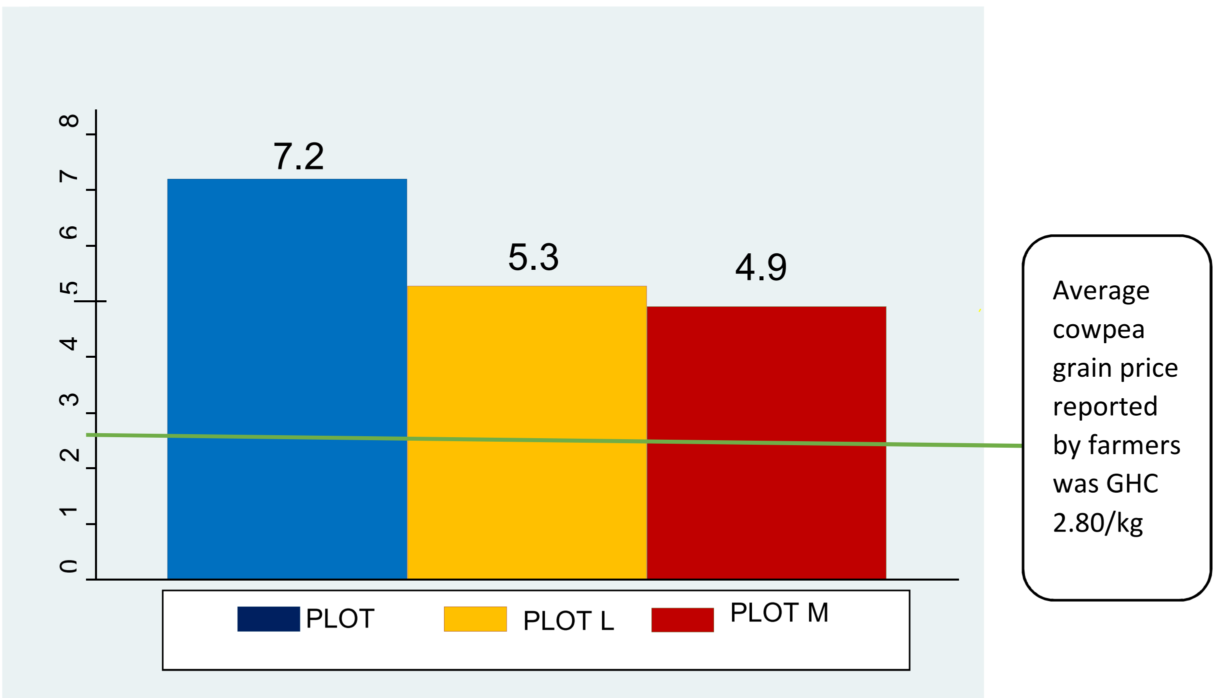
On average, farmers indicated they were willing to pay GHC7.19 for one kg seed of type G, which on average was ranked the best among the three seed types. The WTP for seed type G (certified seed), on average was higher than that of seed type L (QDS) (GHC 5.27) and seed type M (recycled seeds) (GHC 4.90). Differences in the WTP between seed type G and seed types L and M are statistically significant at P=0.01. The difference in the mean prices between seed types L and M is also statistically significant at P=0.01

Table 6.7: Participants Willingness to Pay for Different Seed Types (GHC/kg)

Seed type	Mean	Standard Deviation	N
Plot G: Certified Seed	7.19	2.16	269
Plot L: Quality Declared Seed	5.27	2.11	269
Plot M: Recycled Seed	4.90	2.19	269

Source: Bidding Experimental Auction data, Northern Ghana-2016
Average cowpea grain price =Ghc 2.80/kg

Figure 6.1: Average Bidding Price (Ghana Cedi GHC/kg) for Different Seed Types



Farmers are on average willing to pay a 73% and 20% price premium for best rated seed type G (certified) and seed type L (quality declared), respectively, over seed type M (recycled seed), which was rated ‘worst’ by most farmers during the harvest stage (table 6.8). This implies that farmers are willing to pay higher prices for higher perceived seed quality based on the observed agronomic performance of plants corresponding to the three seed types planted in farmers’ fields.

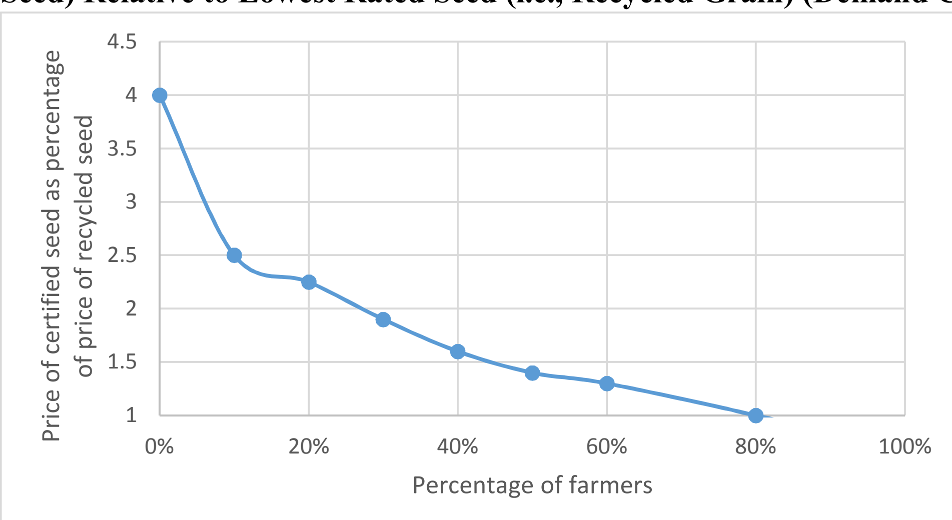
Table 6.8: Average WTP a Premium for Seed Type G (Certified) and L (QDS) over Lowest Ranked Seed Quality (Recycled)

Seed type	Premium farmers are WTP over recycled seed
Plot G: Certified Seed	73.00%
Plot L: Quality Declared Seed	20.14%

Source: author's estimation from BEA data, Northern Ghana-2016

Figure 6.8 presents farmers' willingness to pay for the highest quality seed type rated by most farmers (i.e., certified seed) as a percentage of the WTP for the recycled seed, which was rated the lowest quality seed by most farmers. The WTP a premium for quality seed (i.e., demand curve for seed quality) is plotted against the percentage of farmers that are willing to pay that premium over the price of the recycled seed. As indicated by the downward sloping demand curve in figure 6.2, the percentage of farmers willing to pay a premium for certified over recycled seed declines as the price premium goes up. Conversely, more people are willing to purchase certified seed as the price premium relative to recycled seed goes down. This result is consistent with the demand theory.

Figure 6.2: Distribution of Willingness to Pay for the Highest Rated Seed (i.e., Certified Seed) Relative to Lowest Rated Seed (i.e., Recycled Grain) (Demand Curve)

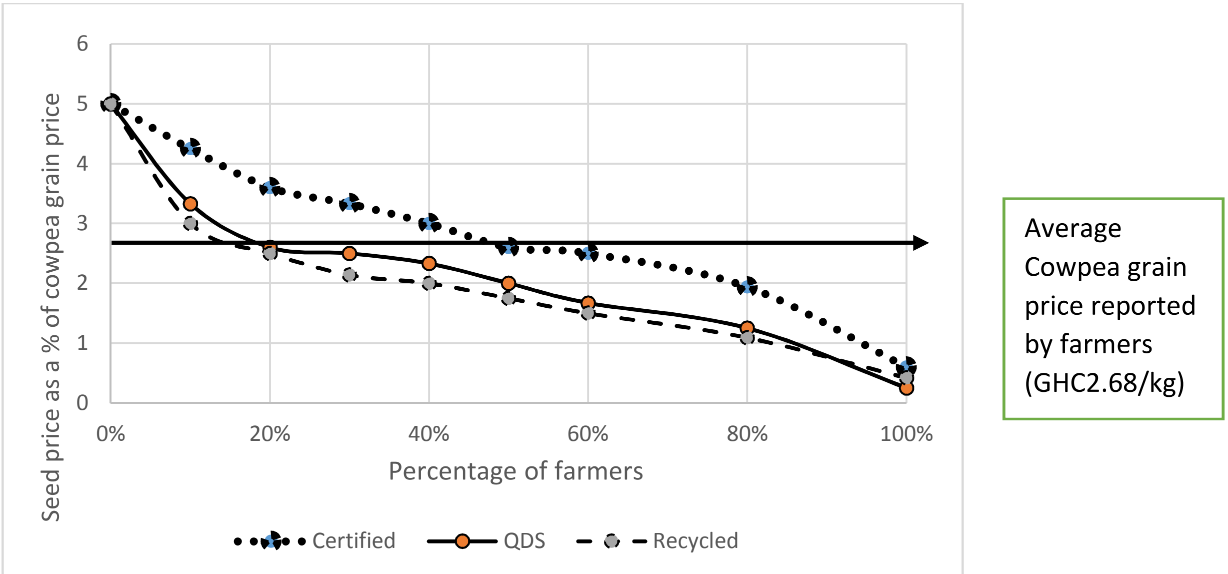


Source: author's estimation from BEA Northern Ghana-2016

Given that cowpea grain is a substitute for 'seed' as a planting material, we estimated the price premium that farmers were willing to pay for different types of seed over the market price for grain that was reported by farmers. This premium was normalized to GHC1 for grain price to express the WTP for different types of seed as a percentage of the grain price.
The downward sloping curves for each of the three seed types (certified, QDS and recycled) in figure 6.3 confirm the inverse relationship between farmers' WTP a premium for perceived quality and the quantity demanded as expressed by the number of farmers, each willing to purchase at least 1 kg of seed of a given type for a given price premium. The downward sloping demand curves indicate that more farmers are willing to purchase seed as the price premium goes down and approaches the grain price. In absolute terms, the WTP for different seed types for about 10-15% of farmers was even below the market grain price. However, in relative terms, even this category of farmers were willing to pay a relatively higher price for higher rated seed (certified) than lower rated seed (QDS and recycled). .

On average, a higher percentage of farmers who participated in the BEA are willing to pay a premium price for higher perceived quality seed. For example, the percentage of farmers indicating their WTP a premium that is double the grain price was 30% for the seed plot planted with recycled seed (type M), 50% for the seed plot planted with QDS (type L), and 80% for the seed plot planted with certified seed (type G). At each level of premium (i.e., points on the Y-axis in Figure 6.3), there are more farmers willing to pay that premium price for certified seed than for QDS seed, and for recycled seed. This shows that farmers' WTP for seed is positively correlated with the perceived quality of seed they observed on the experimental plots.

Figure 6.3: Willingness to pay for seed of perceived different quality as a percentage of cowpea grain price



6.3 Cost of Producing Cowpea Seeds

The estimated total cost of producing a kilogram of certified, QDS and cowpea grain (i.e., recycled seeds) were GHC 5.82, GHC 4.08 and GHC 2.86, respectively (table 6.9). The relative total cost of producing a kilogram of certified seeds is 2.03 times the cost of producing cowpea grain. QDS on the other hand costs 1.4 times to produce compared to the cost of producing a kilogram of recycled seed.

Table 6.9: Relative Cost of Production for Certified and QDS over Recycled Seed

Seed Type	Cost/kg (GHC)	Relative difference
Certified Seed (N=2)	5.82	**2.03** x recycled seed cost
Quality Declared Seed (N=3)	4.08	**1.4** x recycled seed cost
Recycled Seed (N=6)	2.86	--

Source: Cost of cowpea seed production survey, Northern Ghana-2016

In the cost of producing certified seeds, labor cost makes up 77% of the total cost and inputs constituted 15% (table 6.10). Cost of processing, testing and packaging of certified seed (which only applies to this type of seed) was only 8% of the total cost. Labor cost still was the highest expenditure item in the production of QDS (75%) and input cost was 25%. There was no processing and testing cost associated with producing QDS and recycled seeds. This expenditure trend did not change in recycled seed production. Labor and inputs constituted 78% and 22% respectively towards total cost of producing a kilo of recycled seed.

Table 6.10: Total Cost of Production (GHC) for Different Seed Types (average across all producers included in the study), Total Production, and Cost per Kg

Seed type	Input costs	Labor costs	Post-harvest processing costs	Total cost	Total production (kg/acre)	Cost/ kg
Certified Seed (N=2)	229.25 **(15%)**	1196.5 **(77%)**	136.03 **(8%)**	1,561.78	268.34	5.82
Quality Declared Seed (N=3)	122.98 **(25%)**	371.35 **(75%)**	-	494.33	121.15	4.08
Recycled Seed (N=6)	68.69 **(22%)**	240.56 **(78%)**	-	309.25	108.12	2.86

Source: Cost of cowpea seed production survey Northern Ghana-2016
The percentage in parenthesis are with respect to total cost of production

More specifically, pesticide, and seed (input) cost were the major components of total input cost. With respect to labor cost, the cost for weeding and harvesting weighed heavily on total labor cost of producing each seed type. Also, the single most expensive cost item was weeding cost for certified seeds, labor cost for harvesting for QDS and recycled seeds (see Appendix B for a breakdown of production costs by different categories). The absolute cost for inputs, labor and post-harvest were significantly higher for certified seed than for producing QDS and grain. The total output for certified seed was higher than total output from QDS and grain but not as high as the relative cost difference. Thus, the combination of higher relative cost compared to quantity produced contributes to the higher cost/kg for certified seed.

It is worth noting that the two certified seed producers included in the sample did not follow all the requirements of producing 'certified seed.' For example, they reported paying no annual registration fee, which is outlined as one of the requirements for certified seeds producers. This explains why they also did not report any visits by seed inspectors during the growing season. Also, they used certified seeds as planting material instead of foundation seeds, which are more costly, and as per the guidelines should be obtained from the public research station. On both these counts the cost estimation in table 6.10 may be an underestimation of the cost of producing certified seed if all the regulatory requirements are followed. Nonetheless, at the end of the season, the seeds produced by these two producers were sold as 'certified' seeds and thus included as certified seed category in this cost comparison.

CHAPTER 7: DETERMINANTS OF WILLINGNESS TO PAY FOR QUALITY SEEDS

A farmer's decision to purchase a particular seed type depends on the observed, experience as well as the credence attributes of the seed type, according to the Lancaster demand theory. However, Farmers are not able to tell by observation, the experience and credence attribute of a seed type. The field experiment served as a mechanism for farmers to know the experience attribute of the seed before the auction exercise. Again, we eliminated the time factor from our analysis and model because we are interested in the relative performance and WTP differences among the three cowpea seed types. Whether the farmer decides to buy the seed before the planting season or after harvesting does not really matter in our design.

Holding the genetic makeup of the seed, environmental conditions, time, and management practices constant, what influences farmer's WTP for quality seeds? How does perceived seed quality which is formed from observing the differential performance of the seed types, affects farmers' WTP for different quality seed? The purpose of the regression analysis is to explore these questions. The null hypothesis tested is:

> H_o: The relative differences in the WTP for different types of seed products is highly influenced by the perceived differences in seed quality.

We used Ordinary Least Square (OLS) estimation method with and without the household fixed effects to explore the relationship between perceived seed quality and WTP for quality seed. In these models, the dependent variable, WTP by farmer i for seed type G (i.e., certified seed) and seed type L (i.e., QDS) is expressed as a percentage of that farmer's bid for type M (i.e., recycled seeds). In both the regression models standard errors are clustered at the village level. The results are reported in table 7.1.

Table 7.1: Factors that Influences farmers' WTP for Different Types of Seed Products: Model Estimation using Household Fixed Effects (Model 1) and without (Model 2)

Dependent variable=Willingness to Pay for 1 kg seed relative to bid price for seed type M (recycled seed)	**(1)**	**(2)**
Perceived seed quality (1=worst and 3=best)	0.302***	0.302***
	(0.021)	(0.002)
# of years planting cowpea		-0.003
		(0.002)
1=Belongs to a Farmer Based Organization		0.028
		(0.051)
Total land area planted to cowpea		-0.072**
		(0.036)
1=Has attended formal education		0.052
		(0.072)
Farmer's age (Years)		0.0003
		(0.002)
1=Male farmer		0.095*
		(0.049)
1=Early adopter of new technologies (self-reported)		-0.056
		(0.045)
1=Can read/write in English and other languages		0.020
		(0.079)
1=more than 50% of hh income comes from cowpea sales (self-reported)		-0.075
		(0.047)
1=Household has more than 75% probability of living below $1.25/capita/day		0.509***
		(0.142)
Cowpea grain price reported by farmers		0.056
		(0.050)
1=Adopted inputs and new farm practice in the last 3 years (Self-reported)		-0.070
		(0.045)
1=have used certified seeds of any crop in the past		-0.069
		(0.055)
1=Used own saved seeds for planting in the previous season		-0.034
		(0.062)
1=Purchased as seed/grain from market or others in the previous season		-0.052
		(0.066)
Importance of cowpea in terms of purchased inputs devoted for production (self-reported ranking of 3 most important crops)		-0.045
		(0.060)
Cowpea yield per acre in the last season		-0.00002
		(0.0001)
Farmer purchases seed at least every two years		0.016

Table 7.1: cont'd

Dependent variable=Willingness to Pay for 1 kg seed relative to bid price for seed type M (recycled seed)	**(1)**	**(2)**
Farmer purchases seed at least every two years		(0.047)
Household dummies	Yes	No
Constant	0.669^{***}	0.700
	(0.028)	(0.189)
Observations	799	771
R^2	0.18	0.23

Source: Authors' estimation from survey and BEA data in Ghana-2016
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

From the summary statistics in chapter 5, we saw that farmers are willing to pay different prices for different perceived seed quality. Even after controlling for other confounding factors, there is a positive correlation between perceived quality of seed and farmer's willingness to pay for one kg seed of that seed type. As the perceived seed quality increases from a scale of 1=worst to 3=best, farmers are willing to pay 30% more for each incremental quality rating of the seed type relative to their WTP for the recycled seed. These results are robust and statistically significant.

Total area planted to cowpea has a negative and statistically significant effect on WTP for quality seeds. This means that as the total area used to plant increases by an acre, the household is willing to pay 7% less for quality seeds. This could be due to a host of reasons. Quality seeds requires some amount of complimentary inputs like fertilizer and pesticides to realize the full potential of the seed. All these complementary inputs come at a cost to the farmer. This might serve as a disincentive to pay a premium for quality seeds as they increase with the total area planted to cowpea.

Male farmers are willing to pay 9% more premium for quality seeds than female farmers, and this estimate is statistically significant at $p<0.10$. This means that all else equal, male farmers are more willing to pay a premium for perceived higher quality seeds based on their experience of the seed's performance in the FE.

Results also indicate that farmers with a higher probability of being poor are willing to pay more premium for quality cowpea seeds compared to farmers with lower probability of being poor. On average, farmers with a 75% probability of living below the internationally defined poverty line are willing to pay about 50% more premium than their counterparts. Poverty score is estimated based on 10 country-specific indicators of household's demographic and living conditions that can be predictors of the probability of a household's poverty status. Since the poverty score is considered a proxy for household income and wealth status, this result is surprising. However, it may point to the fact that poor farmers may be more seed insecure or lack facilities to maintain quality seed on their farm, and thus value the quality seed and react more positively to the seed quality than their counterparts.

The relationship between farmer group/association membership and the relative price premium for seed type predicted by this model is generally aligned with expectation. Respondents who belong to a farmer based group or association were willing to pay 2.7% more than their counterparts who do not belong to any group, but this positive association is not statistically significant. Mostly, government extension agents and some NGOs consider working with farmer groups in communities as more efficient and cost saving method for promoting technologies and inputs. They are able to reach out to more farmers through such organizations than through individual farmer focused extension. It is through such meetings that new technologies are introduced to farmers. Farmers also get the opportunity to learn from the experiences of other group members.

Farmers who are already investing a significant amount on inputs for cowpea production are willing to pay less for quality seed relative to farmers who currently spend less on purchased inputs. Also, given that most quality seeds of improved varieties require the use of other inputs to realize its full potential, this positive but statistically not significant, correlation between the willingness to pay a higher price (and thus the ability to access quality seed) and the use of other complementary inputs can potentially have a productivity boosting effect.

Surprisingly, farmers who had used certified seeds of any crop in the past were willing to pay 7% less premium for quality seed than farmers who had never used certified seeds. Perhaps, farmers who have used certified seeds in the past might not have had a positive experience with the seed quality. . Their lower relative WTP for quality seed may be because they did not see the claimed seed quality for certified translate into higher yields. Nonetheless, it should be pointed out that his negative relationship is not statistically significant, and thus cannot be considered robust or an evidence in support of this claim.

Age had a positive and insignificant effect on the prices that farmers were willing to pay for quality seeds. Formal education, and years of experience had no effect on the WTP for different types of seeds. Regular seed buyers, source of seed, and the reported grain purchase price also did not have any statistically significant effect on the WTP.

CHAPTER 8: CONCLUSIONS, MAIN FINDINGS, IMPLICATIONS AND NEED FOR FUTURE RESEARCH

8.1 Main Findings

This study has highlighted three important results. First, the three types of cowpea seeds potentially available to farmers as planting material were qualitatively different as reflected in their yield differences and other agronomic performance indicators of plant growth observed on the double blind field experimental plots hosted by cowpea farmers. As expected, certified seed performed better than QDS, which in turn performed better than recycled seeds of the same variety (i.e., Sangotra). Keeping all else constant, on average, plots planted with certified seed yielded 3 times more cowpea than plots planted with recycled seed. This is a large and significant productivity effect from improved seed quality that has not been previously emphasized in the literature.

Secondly, farmers were able to perceive quality differences between the three types of seed plots as reflected in the farmer ratings based on plant performances observed at the flowering and harvesting stages. The perception in relative seed quality differences were highly correlated with the objective measures of relative performance differences recorded by the research staff such as yield, number of plants infected by diseases, number of off-types, and number of plants that survived till harvest. Plots that were ranked as the best plot by most farmers had the highest yield, least number of disease infected plants or off-types, and most number of plants at harvest. These were the plots planted with the certified seed (or seed type G). Similarly, plots that were ranked the worst by most farmers had the lowest yield, highest number of disease infected and off-type plants, and these were the plots planted with the recycled seeds. Higher perceived yield and high seed quality (based on observable traits) were the major reasons why a majority of farmers rated seed type G (certified) as the best plot. Although the results of this study are based on experimental plots established on 10 farms, they are highly encouraging. Sometimes there are concerns that this type of experimental trials are conducted on research stations or managed by researchers, which may not be representative of farmers' conditions. This study was designed to address this concern by setting up experimental plots which were managed by host farmers under their conditions in each village.

Third important finding of this study is that, farmers are indeed willing to pay a price premium for perceived higher quality of seeds. The relative difference in farmers' willingness to pay a premium price for different types of seeds was positively correlated with the relative difference in the farmers' perceived quality ratings (which in turn were correlated with the actual performance differences). On average, farmers in this study were willing to pay 73% more for the highest rated seed (i.e., certified seed) compared to the average bidding price for the lowest rated seed (i.e., recycled seed). Again the whole analysis was based on comparison of relative prices rather than absolute WTP.

Lastly, on the supply side, this study documented the costs involved in producing different quality seeds and found that both in absolute and relative terms it costs more to produce certified seed than QDS, which in turn costs more to produce than cowpea grain (i.e,, recycled seeds). For the sample of seed producers included in this study, the estimated cost of producing one kg seed of certified seed and QDS was, respectively, two and 1.4 times the cost of producing cowpea grain.

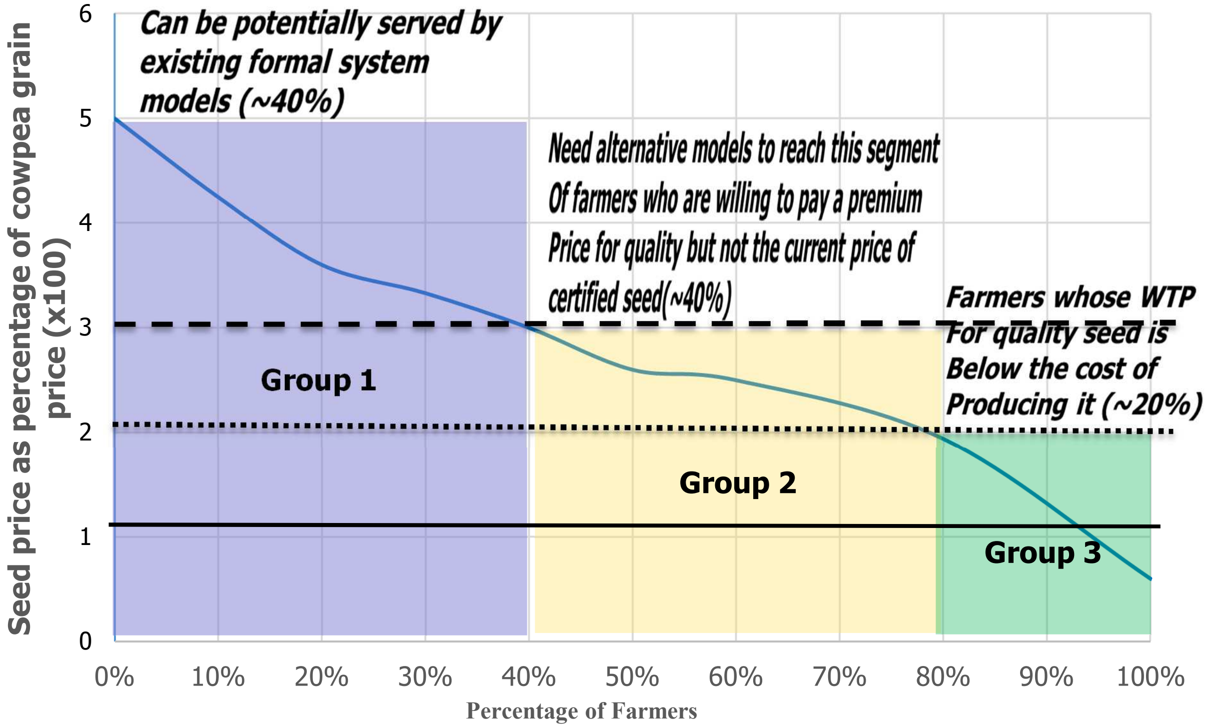
8.2 Implications for Strategies to Make Quality Seeds Accessible to Different Farmers

The findings of this study have important implications for seed dissemination strategies and formal seed sector sustainability. The results from the field experiment, BEA and the cost of seed production survey are brought together in figure 8.1 to highlight these implications. The downward sloping curve represents farmers' WTP for certified seed, which was the highest quality seed rated by them based on the performance of the experimental plots. This is expressed as a percentage of premium farmers are willing to pay over the market price of cowpea grain. This represents the demand side of a potential seed market in the study area.

The three horizontal lines represent three scenarios of potential supply curves in these communities. The solid line in the bottom represents the market price for cowpea grain, the middle dotted line is the estimated cost of producing certified seed (which is approximately twice the cowpea grain price) and the top dashed line is the market price of certified cowpea seed in the study area (i.e., 2.8 times cowpea grain price).

The intersections of these three horizontal lines with the demand curve potentially divides cowpea farmers surveyed for this study into three groups represented by the purple, yellow and green blocks. Farmers within the purple region are willing to pay a premium (relative to the grain price) that is higher than the relative difference between the market price of certified seeds and cowpea grain price. This implies that farmers in this category can be potentially served by formal seed system based on private sector certified seed production and sale. There are approximately 40% of farmers in this study sample in this category.

Figure 8.1: Farmers' Willingness to Pay for Quality Seed Relative to Market Price of Grain, Certified Seed and Cost of Seed Production: Identification of three Groups of Farmers that Require Different Approaches to Meet their Seed Needs



Bottom solid line - Grain market price
Middle dotted line - Estimated cost of producing certified seed (2 x Grain price) Top dash line - Market price of certified seed (2.8 x Grain pr

Farmers in the yellow region are willing to pay a premium that is higher than the cost of producing certified seed but less than the market price of certified seed. This means that the premium they are willing to pay (relative to grain prices) is not enough to attract seed producers to supply quality seeds. About 40% famers in our sample fall in this category. Alternative models are needed to cater the needs of this group of farmers who are willing to pay a premium price for seed that are equivalent in quality as certified seeds included in this study, but not high enough as the market price of certified seed.

The third group of farmers that fall in the green region are farmers (~20%) whose WTP premium price for quality seed is not enough to recover the cost of producing certified seeds. For a subset of this group of farmers the WTP is even lower than the grain price. This group of farmers should be the ideal targets for subsidized or free seed distribution efforts if the goal is to promote the use of quality seeds. The challenge, of course, is to find ways to reach these farmers without undermining the market-led (or alternative non-subsidy based) approaches that may exist to cater the needs of group 1 and 2 farmers.

8.3 Need for Future Research

This study was designed to explore the impact of perceived cowpea seed quality on farmers' willingness to pay a premium for different types of cowpea seed products. The results of this study provides valuable insights for crop improvement and seed system research

One way to make quality seeds accessible to smallholder farmers is to lower the price of certified seed, which in turn implies lowering the cost of seed production. Further research and discussion needs to happen on how to reduce the cost of seed production. Training seed producers in appropriate methods and technology for seed production, processing, storage and marketing that can lower seed losses is critical in increasing seed yields and lowering per unit cost. Seed suppliers and rural shopkeepers must be also provided with basic training in seed business skills and bookkeeping. The effort to train farmers on ways to improve farming practices will require a lot of time investment from farmers. However, it is not clear the extent to which farmers are willing to invest their time for such training. Over the years, researchers have pushed for involving farmers in seed selection and production to produce preferred foundation seeds and farmers' access to these seeds thereafter. This seed accessibility should be complemented with the right recognition of seed breeders for their good work done.

A second issue that needs further research and policy dialogue within Ghana is the regulatory role of the government in building a sustainable seed system. One important question that needs to be addressed is how can farmers be assured of the seed quality (credence attribute) without making the regulatory process costly and cumbersome? How to ensure that the contracts between seed sellers and farmers (as seed purchasers) are honored?

In most developing countries, NGOs play a major role and are a main source for the delivery of legume seeds to smallholder farmers. A key issue with their involvement is sustainability of their efforts, and the negative impact they can potentially have on the survival of for-profit business models. Thus, it is now widely recognized that instead of directly playing a major role in seed delivery themselves, NGOs should be supporting local seed producers and distributors in ways that promote their sales or decrease their costs. However, as shown in this study, NGOs and government led efforts may still be needed to meet the needs of a small target number of farmers who fall on the lower end of the WTP demand curve. For example, about 20% of farmers in our study sample offered bids for seeds (relative to grain price) that were lower than the cost of producing quality seed or even the grain price. This may be a reflection of their lack of affordability or their lack of appreciation for quality seed as a planting material. Hence a seed system that is based 100% on the principle of full cost-recovery might not work if the goal is to reach all types of farmers (including this marginal group of farmers) with quality seeds. A subsidy based approach might still be necessary to reach farmers with low affordability to pay for seed. There is also a need for the public extension programs to increase farmer's knowledge and awareness about the importance of 'quality' seed to increase the demand for seeds.

Although the average WTP for quality seeds was higher than the grain price and also got a favorable ranking for preferences from farmers for quality seeds, it is important to note that there are other ingredients needed to building a sustainable seed system. Factors such as the logistics of seed distribution, distance a farmer will have to travel to get these seeds, how the identity and quality of seed is preserved throughout the value chain may influence the functioning of a seed system. More research that combines farmers' WTP for seed with a host of other supply side factors is needed to better understand the conditioning factors to build a sustainable and efficient seed system.

Finally, it is important to outline a few limitations of this study and the need for future research to address them. First, the fact that farmers did not know the seed type they were bidding for at the time they submitted their bids could partly explain why some farmers were inconsistent with their decisions and choices. Since the main interest in this study was to find the relative price premium/discount associated with the perceived seed quality, the study is not able to say much about the absolute WTP for different seed types. Perhaps, doing incentivized experiments with actual seed types that farmers can buy in the market may be useful in capturing the absolute WTP for each seed type. Second, the BEAs were designed to solicit bids from farmers for one kg of seed, which does not allow the estimation of quantities of seed demanded at that bid. Future studies based on this methodology should also collect data on the quantities farmers are willing to purchase at their bid price and the frequency of purchase to be able to gauge the size of the demand for quality seeds.

Lastly, one of the important contributions of this study is the systematic collection of cost of seed production data across the three types of seed qualities. However, the sample size for estimating these costs of seed production was small. More studies documenting the cost of producing certified, QDS and grain legume seeds in different settings are needed to derive generalizable results and policy implications.

APPENDICES

Appendix A: Comparing Cost of Production for Different Seed Types for same Farmer

Table A1: Comparing Cost of Production for Different Seed Types by Same Farmers

	Total Cost GHC		
Farmer ID	**Certified**	**QDS**	**Recycled**
Farmer 1	8.04	-	7.10
Farmer 2	3.59	-	3.83
Farmer 3	-	2.33	1.73
Farmer 5	-	2.33	1.71
Farmer 6	-	-	4.67
Farmer 7	-	-	1.30
Farmer 8	-	-	2.75
Farmer 9	-	7.13	-
Farmer 10	-	-	1.69
Farmer 11	-	-	2.90

Source: Cost of cowpea seed production survey Northern Ghana-2016
10 farmers producing different seed types were survey during the 2016 major farming season in northern Ghana.

Appendix B: Specific Input Cost as a Percentage of Total Input and Labor Cost

Table B1: Specific Input Cost as a Percentage of Total Input and Labor Cost for Each Seed Type.

	Certified	QDS	Recycled
Input:			
Seed cost	62%	68%	37%
Pesticide	45%	24%	40%
Labor:			
Weeding	36%	24%	25%
Harvesting	30%	35%	48%

Source: Cost of cowpea seed production survey Northern Ghana-2016

Appendix C: Cost of Producing Certified Seeds

Table C1: Cost of Producing Certified Seed

Input	count	min	mean	sd	max
seed cost	2	126.00	141.75	22.27	157.50
fertilizer cost	2	0.00	0.00	0.00	0.00
pesticide cost	2	45.00	87.50	60.10	130.00
herbicide cost	2	0.00	0.00	0.00	0.00
Labor cost					
plowing w animal cost	2	0.00	75.00	106.07	150.00
plowing w tractor cost	2	0.00	75.00	106.07	150.00
planting cost	2	56.00	70.00	19.80	84.00
replanting cost	2	0.00	24.50	34.65	49.00
fertilizer application cost	2	0.00	0.00	0.00	0.00
herbicide application cost	2	0.00	10.00	14.14	20.00
fungicide application cost	2	0.00	0.00	0.00	0.00
pesticide application cost	2	20.00	137.50	166.17	255.00
weeding cost	2	140.00	317.50	251.02	495.00
harvesting cost	2	226.00	311.00	120.21	396.00
threshing cost	2	41.00	52.00	15.56	63.00
winnowing cost	2	24.00	34.00	14.14	44.00
transport cost	2	0.00	25.00	35.36	50.00
drying cost	2	42.00	52.00	14.14	62.00
bagging cost	2	5.00	13.00	11.31	21.00
Post-harvest	0				
Quantity harvested	2	225.00	295.00	98.99	365.00
processing cost	2	36.12	53.22	24.18	70.32
packaging cost	2	15.48	22.81	10.36	30.14
testing cost -- fixed	2	60.00	60.00	0.00	60.00
total cost	2	1312.46	1561.78	352.60	1811.11
total cost per kg	2	3.60	5.82	3.15	8.05
Observations	2				

Appendix D: Cost of Producing Quality Declared Seeds

Table D1: Cost of Producing Quality Declared Seeds

Input Cost	**N**	**Min.**	**Mean**	**SD**	**Max**
seed cost	4	16.00	77.50	98.08	224.00
fertilizer cost	4	0.00	2.50	5.00	10.00
pesticide cost	4	1.92	39.23	36.85	80.00
herbicide cost	4	0.00	3.75	7.50	15.00
Labor cost					
plowing w animal cost	4	15.00	50.00	60.14	140.00
plowing w tractor cost	4	0.00	0.00	0.00	0.00
planting cost	4	8.00	34.25	29.92	77.00
replanting cost	4	0.00	0.00	0.00	0.00
fertilizer application cost	4	0.00	1.50	3.00	6.00
herbicide application cost	4	0.00	2.75	5.50	11.00
fungicide application cost	4	0.00	2.00	4.00	8.00
pesticide application cost	4	0.00	22.50	23.85	56.00
weeding cost	4	8.00	66.25	72.87	162.00
harvesting cost	4	0.00	80.00	110.04	238.00
threshing cost	4	0.00	14.00	28.00	56.00
winnowing cost	4	0.00	7.00	14.00	28.00
transport cost	4	0.00	0.00	0.00	0.00
drying cost	4	0.00	3.50	7.00	14.00
bagging cost	4	0.00	0.00	0.00	0.00
Post-Harvest					
Quantity harvested	4	15.00	141.75	159.79	360.00
processing cost	4	0.00	0.00	0.00	0.00
packaging cost	4	0.00	0.00	0.00	0.00
testing cost -- fixed	4	0.00	0.00	0.00	0.00
total cost	3	107.00	494.33	456.07	997.00
total cost per kg	3	2.34	4.08	2.65	7.13
Observations	4				

Appendix E: Cost of Producing Recycled Seeds

Table E1: Cost of Producing Recycled Seed

Input Cost	**count**	**min**	**mean**	**sd**	**max**
seed cost	10	5.00	28.80	24.59	84.00
fertilizer cost	10	0.00	7.52	10.50	27.00
pesticide cost	10	7.20	28.87	24.72	90.50
herbicide cost	10	0.00	3.50	7.47	20.00
Labor cost	0	.	.	.	.
plowing w animal cost	10	0.00	4.90	11.45	35.00
plowing w tractor cost	10	0.00	28.93	19.50	60.00
planting cost	10	0.00	5.00	15.81	50.00
replanting cost	10	0.00	24.00	16.01	48.00
fertilizer application cost	10	0.00	1.70	3.65	10.00
herbicide application cost	10	0.00	2.50	4.95	15.00
fungicide application cost	10	0.00	3.40	5.58	14.00
pesticide application cost	10	0.00	20.60	19.27	63.00
weeding cost	10	0.00	24.20	33.48	90.00
harvesting cost	10	0.00	69.90	53.52	171.00
threshing cost	10	0.00	16.40	19.95	56.00
winnowing cost	10	0.00	5.30	9.31	28.00
transport cost	10	0.00	4.55	13.04	41.50
drying cost	10	0.00	3.50	5.10	14.00
bagging cost	10	0.00	0.00	0.00	0.00
Post-Harvest Cost	0	.	.	.	.
Quantity harvested	10	3.00	108.55	61.27	195.00
processing cost	10	0.00	0.00	0.00	0.00
packaging cost	10	0.00	0.00	0.00	0.00
testing cost -- fixed	10	0.00	0.00	0.00	0.00
total cost	9	157.20	309.25	131.75	573.50
total cost per kg	9	1.30	2.86	1.27	4.67
Observations	10				

Appendix F: Bidding Experimental Auction Script and Consent Form

WILLIGNESS TO PAY FOR QUALITY COWPEA SEEDS: SCRIPT FOR CONDUCTING BIDDING EXPERIMENTAL AUCTIONS

NOTE: *All text in italics are instructions for the enumerator*. All **text not in italics** must be read to the farmer.

This experiment/survey will be performed at field days in 8 villages in northern Ghana. Each village has 1 field experiment (FE) and the field days will be run in all of these 8 villages. During each field day, 35 farmers (who attended the first field day and were surveyed) will participate in a willingness-to-pay (WTP) auction experiment. A FE consists of one field split into 3 plots. All of the plots contain the same variety of cowpea, but were planted using different qualities of seed – Certified seed (CS) Quality Declared seed (QDS) or recycled Seed (RS). The plots are labeled M, G, and L and farmers and extension agents do not know (and should not be told) which quality of seed was used for which plot.

When signing in farmers, make sure they are one of the 35 chosen and give them a name tag with their number on it. After a brief welcome to the field day and running through the criteria and plot ranking exercise – including a question regarding WTP per kg for each plot (). the attending farmers will be divide into 2 groups (1-17, 18-35)It is required that only one person/household participate. The script below is for the enumerator and helpers running the WTP auctions.

Step 1:Introduction/consent

The enumerator will introduce his or herself and read the consent script to the farmers and record their verbal consents to participate.

CONSENT STATEMENT Hello, my name is (**INTRODUCE YOURSELF**). I am assisting the Savannah Agriculture Research Institute (SARI) from Ghana and Michigan State University (MSU) from the US in conducting a study to document farmers' **willingness to pay for different types of cowpea seed**s. As part of this study, we will be conducting an auction of cowpea seeds in which you will be asked to bid a price you are willing to pay for one kg of cowpea seed of different types. We will explain the rules of this game in detail, and will also play a practice game before we start the seed bidding game. Your participation in this game will not involve any out of pocket cost for you. The game will take approximately **60 minutes**. Your participation is **voluntary**. Your **refusal** to participate or to withdraw from the study **carries no penalty or loss** of any benefits.

The results of your participation in the game will be used to document what cowpea growers are willing to pay for different types of cowpea seed, when available; which will help us to **generate recommendations** that may benefit cowpea production in this region.

Do you have any questions about this study for me?

<Enumerator: pause and respond to any questions raised, then continue with the following statement>.

By continuing to be part of this group, you indicate your **willingness to voluntarily participate** in the bidding game.

Step 2: Overall description of Experiment

ENUMERATOR:

Ok, thank you for being willing to participate. To begin with, let me give you an overall description about what we will be doing. We are interested in getting an idea about how much you would be willing to pay for the seed quality that was used to grow each of the 3 plots that you looked at earlier. To make your decisions more realistic, we are going to give you 10 GHC that you can use to purchase a one kg bag of one of the seeds used to grow one of the plots.

But before we do that, we would like to do a practice auction where we will give each of you 2 GHC in order to bid on purchasing a bar of soap like this one.

Hold up bar of soap

Let's do the practice auction first, and then we will explain more about the seed auction, ok?

Do you have any questions? Should we begin

Step 3: Practice Auction

The enumerator will begin explaining the practice auction.

ENUMERATOR:

Ok, so for this practice auction each of you will be given 2GHC to bid on one bar of soap. Unlike in most auctions, or in auctions you may have participated in in the past, in the type of auction we will be using, it is possible for **everyone** to win and thus everyone might purchase a bar of soap using part or all of their 2GHC.

Let me step through how you bid and how we determine who wins and buys a bar of this soap.

First, we will hand out a bidding sheet like this one.

Hold up bidding sheet.

On this bidding sheet you will write down the maximum amount you would be willing to pay for this bar of soap (in increments of 0.10 GHC). Once everyone has done this, we will collect the bidding sheets and move on to determine how many of you win and buy a bar of soap.

To determine who wins we simply choose a random price between 0 and 2GHC – we will explain how in a moment.

If the price you bid is **greater than or equal to** this random price, then you win, ***BUT*** you pay the random price – not what you bid. This means that if you win, you pay a lower price for the soap than you bid (unless the random price is the same as your bid).

On the other hand, if the price you bid is **less than** this random price, then you do not purchase the soap and you can keep the money.

If you win, we will give you a bar of soap **and** the remaining amount of your 2GHC; that is, 2GHC minus the random price.

For example, if you bid GHC1.30 and the random price is GHC1, then you would pay GHC1 for the soap and get it, along with the remaining GHC1.

If you do not end up buying the soap, you do not spend any of your GHC2 buying soap and we will give you GHC2.

So, for example, suppose that "*name an enumerator1 in the room*" bids 2, I bid 1.7 and "*name an enumerator2 in the room*" bids 0.5. Now suppose that the random price is 1.5…in this case, *enumerator1* would buy the soap, but would pay 1.5GHC, not his /she bid of 2GHC. He/she would get a bar of soap and 2-1.5=0.5GHC. I would also buy the soap and pay 1.50 (my bid was 1.7) so I would also get a bar of soap and 2-1.5=0.5GHC. *Enumerator2* would not buy the soap since his/her bid of 0.5 is less than 1.50 so he/she would just get 2GHC.

Are there any questions?

We will determine the random price as follows

Enumerator: Write on a board two spaces, with a dot in between the first and the second spaces as in:

_____ . _____ _____

The last digit will always be a zero.

The second digit can be be a 0, 1, 2, 3, 4, 5, 6, 7, 8 or 9…we will roll this 10-sided die to determine which it is…the second digit will be whatever is rolled unless a 10 is rolled. If a 10 is rolled the second digit will be a 0.

The first digit can be a 0, 1 or 2. We will roll this 4-sided die to determine which it is…if the die comes up 1 or 2, the first digit will be whatever is rolled. If the die comes up 3, the first digit will be a 0. If the die comes up 4, we will roll again.

Overall, we will end up with one of the following numbers: 0, .10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40, 1.50, 1.60, 1.70, 1.80, 1.90 or 2.00 right?

Are there any questions so far?

Before we hand out the practice round bidding sheets, let me explain the best strategy in this type of auction. The BEST thing to do is to bid the MAXIMUM amount you are willing to pay. This is because it is very likely you will actually pay LESS if you win. However, bidding <u>less</u> than what you would be willing to pay might mean that you miss out on buying the soap at a price lower than you would be willing to pay.

Similarly, bidding <u>more</u> than what you would be willing to pay might mean that you end up having to pay more for the soap than you really want to. For example, if you are willing to pay a maximum of 1 GHC, but you bid 2 GHC and the random price ends up being 1.5 GHC, then you would pay 1.5GHC – more than you were willing to!

Overall, your best strategy is to bid the MAXIMUM amount you are willing to pay.

Ok, let's go ahead and hand out the bidding sheets.

[Hand out bidding sheets]

Ok, go ahead and write down your number (from your name tag – this helps us keep track of who to pay how much) and your bid for a bar of soap. Please do not talk with others until we have collected the bids.

[Collect bidding sheets, making sure that bids and numbers are entered and legible and that the bid is in 0.1GHp increments (i.e., 1.35 is not a valid bid).]

Ok, now let's go ahead and determine the random price.

[Determine random price as outlined above while writing it down on board. A helper should record this number on one of the bidding sheets so we have this information. We can allow farmers to flip coin/role die as long as it is tossed sufficiently to make it

random.]

Ok, so this is the price (*say the random price*) – if you bid more than or equal to this price, you buy a bar of soap at this price (*say the random price*). If your bid was less than this price (*say the random price*) you will not buy a bar of soap, but will receive the 2GHC.

[It might be a good idea to briefly say "if you feel comfortable sharing, raise your hand if you bought a bar of soap. " If they are willing to reveal, they can even say how much they bid.]

Ok, so we will pay you and give you the soap (if you bought one) after we do the seed auction.

Step 4: Seed Auction

The enumerator will begin explaining the seed auction.

ENUMERATOR:

Ok, so hopefully you have a better idea about how this seed auction will operate. It will be very similar to the practice auction you just did, except for a few things:

First, you will be bidding to purchase a one kg bag of the seed that was used to plant the plots in the field experiment you just looked at. Specifically, you will be making 3 bids – one for each plot (labeled G, M, and L). HOWEVER, even though you are bidding for each type, ONLY ONE type will actually have a random price determined and will be bought/sold. You will not know which type is available until after you bid, so you should bid as if each one might be the one chosen.

Second, instead of 2GHC, we are giving you 10GHC to use to bid. Just as before, any amount you do not use to purchase seed, will be given to you after we are done.

Third, the random price can be between 0 and 9.90GHC and will be determined as follows:

Enumerator: Write on a board three spaces with a dot in between the first and second spaces as in:

_____ .______ _____

As before, the last digit will always be a zero.

The second-to-last digit and the first digit can be a 0, 1, 2, 3, 4, 5, 6, 7, 8 or 9. We will roll this 10 sided die….if it comes up 1, 2, 3, 4, 5, 6, 7, 8 or 9, it will be that number, but if it comes up 10, it will be a 0.

Overall, we will end up with a number between 0 and 9.90GHC in 0.10GHC increments?

As before, each number is equally likely.

Are there any questions?

Ok, before we hand out the bidding sheets, let me just remind you that your best strategy is to bid the MAXIMUM amount you are willing to pay for each seed quality.

Remember, since we are only going to determine a random price for ONE of the seed qualities, you do NOT need to try and spread your 10GHC across the three seed qualities – in fact you can bid 10GHC for each quality and not have to worry about spending more than 10GHC.

Any final questions?

As before, please do not talk with others until we have collected the bids.

[Hand out seed bidding sheets.]

Ok, go ahead and write down your ID number (from the card) and bids for all three seed qualities. Remember that this is for a 1 kg bag of the seed quality used to plant the indicated plot (G, M or L). Also, please keep bids to 0.10GhC increments.

[Collect bidding sheets, making sure that bids and numbers are entered and legible and that all bids are in 0.10GHC increments.(i.e., 9.48GHC is not a valid bid)

Ok, so now we will reveal which seed quality was selected for today's auction. For this group, the seed type is *[G, M or L as previously determined]*.

Ok, so now that we know which quality, let's go ahead and determine the random price.

[Determine random price as outlined above while writing it down on board. A helper should record this number on one of the bidding sheets so we have this information. We can allow farmers to flip coin/role die as long as it is tossed sufficiently to make it random.]

Ok, so this is the price – if you bid more than or equal to this price, you won and will buy a 1 kg bag of this quality seed at this price. If your bid was less than this price you will not buy seed, but will receive the 10GHC.

Ok, so we will call you up one or two at a time to give you the seed/soap if you bought them and however much we owe you in GHC.
Thank you and please do not discuss this with the other group of farmers until they have completed the auctions.

Thank you!

Appendix G: Sheet Auction Bidding Sheet

Figure G1: Sheet Auction Bidding Sheet

Seed Auction Bidding Sheet

Number on Participant Card	
Participant Name	

Your Bid for Plot M Seed	**Enter the most you are willing to pay.** **GHC**
Your Bid for Plot G Seed	**Enter the most you are willing to pay.** **GHC**
Your Bid for Plot L Seed	**Enter the most you are willing to pay.** **GHC**

Seed Type Selected: M ☐ G ☐ L ☐ ***Random price:*** ______________________

Village Name		
Village ID		
Name of the farmer hosting this FE		
Participant purchased the seed	*Yes* ☐	*No* ☐
Total Cash Owed	*10 – Random price = GHC*	*10 GHC*
Quantity of seeds willing to buy (kg) at this price		

Appendix H: Seed Quality Analysis for Seed Producers

Table H1: Seed Quality Analysis for Seed Producers

Reference ID	Seed type	M.C %	Pure	Inert	Germination %
005	Grain	8.2	99.9	0.1	0
005	QDS	8.2	99.9	0.1	33
002	Certified	9.8	99.8	0.2	87
001	Grain	10.2	99.9	0.1	0
001	Certified	8.3	99.5	0.5	0
003	QDS	8.3	99	1	11
004	QDS	9	99.8	0.2	24
011	Grain	8.9	99.8	0.2	80
007	Grain	8.8	98.5	1.5	27
010	Grain	8.4	99.3	0.7	21
008	Grain	8.4	99.2	0.8	26
006	Grain	8	99.2	0.8	0

Appendix I: Seed Quality Analysis for Experimental Plots after Harvest

Table I1: Seed Quality Analysis for Experimental Plots after Harvest

Reference community	**Seed type**	**M.C %**	**Purity**		**Germination %**
			Pure seed	**Inert**	
Azumsapelega	Certified	9.5	99.9	0.1	42
Azumsapelega	QDS	9.3	99.9	0.1	80
Azumsapelega	Recycled	9.2	99.9	0.1	24
Tansia	QDS	9.2	99.4	0.6	21
Tansia	Recycled	9.1	99.9	0.1	24
Yalugu	QDS	9.3	99.9	0.1	80
Bansi	Recycled	9.2	99.6	0.4	12
Koluku	Certified	9.2	99.8	0.2	51

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