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Do Farmers Value Seeds of Different Quality Differently? Evidence from Willingness to Pay Experiments in Tanzania and Ghana

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EXECUTIVE SUMMARY

Low effective demand is often cited as a major reason for the lack of private-sector involvement in the seed system for legume crops in developing countries. The viability of these seed systems depends on whether farmers perceive the *seed* product as a quality planting material, and whether they are willing to pay a premium for the seed relative to grain. To evaluate these issues, double blind field experiments and experimental auctions were conducted with more than 500 bean and cowpea farmers in northern Tanzania and northern Ghana. The experiments were designed to gauge the relative demand for three types of seed products: certified, quality declared (QDS), and recycled (i.e., grain saved from previous harvest). These three types of seeds differ in seed input (i.e., which generation of seed is used to produce them), the level of regulatory supervision they receive during production, and the technical conditions under which they are produced. Whether the production cost differential across these types of seeds makes them qualitatively different products as reflected in their perceived or actual performance of the plant, and whether that translates into sufficient price premiums paid by farmers for these better quality seeds are the research questions addressed by this study.

Overall, the results of the field experiments indicate that, all else equal (i.e., the variety and management practices), plots planted with certified seed performed better on measures of objective indicators (i.e., yield, seed quality, and agronomic traits). However, the actual yield difference between the different bean plots in Tanzania was much smaller than the yield differential observed for the cowpea plots in Ghana. Irrespective of the magnitude of the yield differences (or yield deterioration observed over each generation of seed production), an important implication of this finding is that to increase productivity, it is not sufficient to promote only the adoption of improved varieties, but it is likely also necessary to promote the use of higher quality seed as an input.

In both countries, plots planted with certified seeds were perceived, based on the observations of plots at the flowering and harvest stages, to be of the best quality by a majority of farmers. All else equal, farmers were willing to pay a premium for the higher quality seeds. The relative difference in farmers' willingness-to-pay (WTP) for different seed types was highly correlated with the relative difference in their perceived quality. This willingness to pay a premium for quality legume seed by smallholder farmers is encouraging and indicative of the existence of an effective demand for self-pollinated crop seeds (as opposed to recycled grain) like beans and cowpeas.

While a significant portion of farmers in the study (35-40%) were willing to pay a large enough premium to cover the higher production costs of certified seed, across both crop/country case studies, we found the rest of the legume growing farmers' willingness to pay premium for quality seed was below the current local price of certified seed. Indeed, for a sub-set of these farmers in Tanzania (25%), the willingness to pay for quality seed was even lower than the local grain price. The implication of these findings is that there is no one-size-fits-all strategy to meet the seed needs of all the farmers. Current efforts to encourage the private sector to produce and supply certified seeds through agro-dealers can potentially meet the seed needs of at most 35-40% of farmers (if the quality of those seeds is substantially superior to recycled grain, and the seed is of a preferred variety). Clearly, more research and discussion is needed to assess the seed needs of the remaining (majority) farmers whose WTP for quality seed appears to be less than the current market price of certified seed. One avenue of research is to investigate mechanisms to lower the cost of producing quality seed, without reducing the incentives for seed producers, so that quality seed can be provided at prices

closer to that of grain. While cost-reducing strategies through policy, programmatic and technological options should remain a high priority for governments and donor-supported programs such as the Alliance for a Green Revolution in Africa (AGRA), this study also indicates the need for continued support for innovative and smart subsidy-based approaches to meet the needs of the 15-20% of farmers whose WTP for seed is so low that for-profit seed production/marketing models will not work. In drawing this implication, we have not taken in to consideration the varietal preferences of farmers and how their absolute WTP for quality seed might be influenced by the type of variety, which was held constant in the experiments. More research is needed to understand farmers' varietal preferences and their demand for seed that embodies both their preferred traits and quality.

Across the two countries, results indicate that seed quality matters, and that on average certified seeds consistently outperformed both the QDS and recycled seeds. In Ghana, on average the QDS outperformed the recycled seed, but in Tanzania the QDS and recycled seed performed similarly. Community based QDS production and sale is often promoted as a low-cost option for increasing farmers' access to quality seed within a community. However, if the lower cost also comes with lower quality, then the sustainability of QDS seed systems is questionable since farmers may not be willing to pay the price premium required. That said, this study also illustrates that when the advantages of planting better quality seed in place of recycled seed can be demonstrated, a significant portion of farmers appear to be willing to pay more, indicating that private sector seed systems can be viable.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
BDM	Becker-DeGroot-Marschak
BEAs	Bidding Experimental Auctions
CIAT	Impact Assessment Scientist at the International Center for Tropical Agriculture
SARI	Savanah Agricultural Research Institute
FE	field experiments
GHC	Ghanaian Cedi
ISSD	Integrated Seed Sector Development
kg	kilogram
MSU	Michigan State University
NGO	Non-Governmental Organizations
QDS	quality declared seeds
R&D	research and development
TSH	Tanzanian Shilling
USAID	U.S. Agency for International Development
WTP	willingness-to-pay

1. INTRODUCTION

According to the last available estimates, public spending on food and agricultural research and development (R&D) in developing countries totaled about $15 billion in 2009 (Beintema et al. 2012). A significant portion of these investments is devoted to crop research focused on developing improved varieties of staple crops. Farmers can reap the benefits of such crop improvement research only if they plant good quality seeds of improved varieties, where quality is equivalent to seed vigor defined by the ability to germinate, and establish seedlings rapidly, uniformly, and robustly across diverse environmental conditions (Finch-Savage and Bassel 2016). Thus, the returns from investments in crop improvement research depend not only on the genetic improvements embodied in the seed but also on the existence and performance of seed systems that can deliver this improved genetics to farmers in the form of quality seed of high vigor.[1] An effective and well-functioning seed system is therefore critical to ensure that the benefits of billions of dollars of research investments reach the intended farmers.

One of the important factors that determines the existence and success of a market-driven seed system is the *effective demand* for fresh seed (i.e., planting material). Even where farmers have adopted improved varieties, the low volume and frequency of seed demand for that variety is often cited as a major reason for the lack of private sector involvement in seed provision. This is especially true for self-pollinated legume crops like beans (Almekinders, Louwaars, and de Bruijn 1994), groundnuts, cowpeas, pigeon peas, etc. Since self-pollination produces progenies that are more uniform than those that result from outcrossing, it is easier for farmers to save some grain from their own harvest to use as seed in future seasons, unless there are effective plant breeders' rights or contract law which is rarely the case (The World Bank 2006). Moreover, the transaction costs in seed markets can be usually high for both buyers and sellers. For example, farmers incur the costs of acquiring reliable information about new varieties. They also face the moral hazard of being sold poor quality seed, which can become apparent only after the seeds are planted and it is too late to rectify the damage or to seek redress from the seed vendor. Suppliers, on the other hand, also encounter high costs of information in discovering farmers' preferences. They have to also take up the risk of potentially unsold inventory, storage, and wastage costs, and logistical costs of providing multiple varieties of seed in small amounts at the right time to buyers located in geographically dispersed, and often remote areas. In addition, they need to carry stocks sufficient to meet uncertain and fluctuating demand, including the occasional emergency needs stemming from previous poor harvests (Wiggins and Cromwell 1995).

Thus, the market for seed of improved varieties provided by formal sector organizations is markedly imperfect. The low effective demand is often cited as a major reason for the lack of availability of seeds, as it discourages private-sector involvement in the seed system, which in turn results in low availability and high prices of seeds. The end result of this viscous loop is that farmers in developing countries continue to grow crops using low quality planting material, which lowers crop productivity. In most cases, the only way seeds of improved varieties reach smallholder farmers is through government-, donor-, and NGO-funded initiatives, which raise the question of long-term sustainability of such a strategy.

[1] Note that it is also critical to ensure the seed system is delivering improved varieties that meet local preferences in terms of traits demanded for consumption, processing, and trade.

To break from this viscous cycle of low effective demand and lack of private sector involvement, requires the coexistence of the following demand and supply side conditions. First, keeping the genetics constant, the demand side conditions depend on whether the farmers are able to perceive the seed product as a higher quality planting material than grain, and that they are willing to pay a premium for the seed compared to grain. On the supply side, the required conditions are that the price farmers are willing to pay is high enough to recover the cost of producing quality seed, and that the quantity and frequency of seed demanded (i.e., seed replacement) at that price is large enough to attract suppliers to produce and sell seeds.

There are no rigorous studies that have examined these demand and supply side conditions and requirements in a systematic manner (Kugbei 2002). This study is an attempt to understand these conditions, at least from the demand side, by conducting field experiments and experimental auctions to assess farmers' willingness-to-pay (WTP) for quality cowpea seeds in Ghana and bean seeds in Tanzania. Bean farmers in Tanzania and cowpea farmers in Ghana potentially have access to three types of planting materials: certified seeds, quality declared seeds (QDS), and recycled seeds (i.e., grain) from previous harvest.[2] These three types of seeds differ in seed input (i.e., the generation of seed used to produce them), the regulatory supervision they receive (or not in the case of recycled seed), and the technical conditions under which they are produced. These types therefore vary in not only quality, but also the cost to produce them. Specifically, seeds that are sold as certified or quality declared, cost more to produce and come with some assurance of genetic quality (i.e., variety name and identity) and seed quality in terms of germination, purity, disease-free, etc. Grain or recycled seed on the other hand are produced with no regulatory or technical supervision, and thus, have lower production costs than certified or QDS, but also come with no genetic or quality assurance and are typically lower quality than certified or quality declared seed.[3]

These cost and quality differences among different seed products are reflected in their price differentials. In most developing countries, certified seeds are sold at 2 to 3 times the price of grain. Depending on demand and seed scarcity, the price of QDS is often the same or just below that of certified seed. However, only a fraction of these high quality seeds is sold directly to farmers. In most developing countries, the primary buyers are government- and donor-supported NGOs and projects who then distribute the seed to farmers either for free or at highly subsidized prices. As efforts to promote private sector-led seed sector growth intensify, several important questions need to be addressed: Are farmers willing to pay two to

[2] Note that in Ghana, QDS is not a legally recognized seed product available in the market. It refers to the seed produced by farmers under the supervision of researchers or field technicians through seed dissemination projects with an objective of training farmers in rural communities to become community registered seed growers or to be linked with registered seed companies as their out-growers. The main objective of the community seed production is to ensure availability of improved seeds to farmers at the rural and sub-rural areas who are not able to access improved seeds from agro-dealers who are mostly located in the district capitals and bigger towns within the districts. Until these farmers are well trained and are registered as certified seed growers or linked to seed companies, the use of the quality declared seeds produced by these farmers are restricted to be sold within the communities. In Tanzania, QDS are also produced by a farming community or a group of farmers under close surveillance and advisory service of the Seed Certifying Organization in collaboration with a breeder or researchers. The seed has to be qualified and declared good quality by the Tanzania Official Seed Certification Institute before it can be sold or distributed as seed. Also, in the case of Tanzania, the sale or distribution of the QDS is restricted to the district where it was produced. In both the countries, the objective of introducing QDS production was to circumvent the stringent and costly mandatory certification system. It is identified as a strategy to increase the availability of quality seed for the agricultural communities.

[3] Grain and recycled seed are terms used interchangeable in this document.

three times more for a product that they consider a close substitute of the grain they grow?[4] Are the extra costs of producing QDS or certified seed justified in terms of the actual or perceived performance differences? If so, how does that translate into differential price farmers are willing to pay for these seeds? These are empirical questions rarely addressed in the literature.

To fill this evidential gap, this study specifically focuses on the following two research questions:

- For a given improved variety (i.e., keeping the genetics constant), what is the actual and perceived difference in the performance of the crop across the three seed types—certified, QDS, and recycled grain, when the seeds are planted and managed by farmers under their own conditions? and
- How does the observed differential performance translate into farmers' willingness to pay (WTP) for these different seed types?

As a preview of our results, we find significant differences in the perceived quality of seed products evaluated, and the corresponding differences in farmers' WTP for their higher rated seed relative to their lower rated seed product. However, for a majority of farmers the magnitude of the premium they are willing to pay for a higher quality seed is less than the current price differential between the highest quality seed available in the market (i.e., certified seed) and grain. Moreover, the magnitude of the premium farmers are willing to pay depends on the higher rated seed product performing significantly better than the lower rated seed, on quality indicators such as yield, plant health, and vigor.

The rest of this paper is organized as follow. We first describe the methodology and data used to address the research questions in the two case study countries and crops—Tanzania for beans and Ghana for cowpeas. Following that, we present the results, and discuss the implications and need for further research.

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[4] For example, from 2006 to 2016 the Alliance for a Green Revolution in Africa (AGRA) had reportedly spent $100 million in seed companies. In 2016 they announced intensifying their investment by $500 million over the next five years to promote the efforts by agricultural seed companies and governments in seed production (Bloomberg 2016).

2. METHODOLOGY

Double-blind field experiments (FE) were established in 12 villages in the Hai and Karatu districts (northern Tanzania) and in 10 villages in Binduri district in Upper East Region of Ghana. The fields were used to demonstrate the characteristics of the three types of seed quality of bean variety (*Jesca*) in Tanzania and cowpea variety (*Songotra*) in Ghana. These are improved varieties released by the research programs through their respective national variety registration systems and commonly grown by farmers in the study areas. For a given variety, the seed types included in the FEs were certified, quality declared, and recycled seeds.[5] These three types of seeds represent different seed quality grades as reflected by their vigor (i.e., germination rate, disease free) and purity—desired traits that contribute to the uniform and successful establishment of healthy seedlings that emerge from the seeds planted. Certified seed is produced using basic (or foundation) seed as planting material and is grown using more stringent agronomic and post-harvest practices to meet the quality standards required by the country's seed certification agencies. QDS is also produced using basic or foundation seed, but is grown by farmers (trained by research organizations) to use production standards similar to certified seed, but without the *certification* from the government. Recycled seed is the seed that is produced by the farmer as grain (mostly for consumption at home or sold in the market) and saved for use in the following season as planting material or procured from the market as grain. The quality of this type of seed varies greatly as there are no seed quality standards imposed during the production or post-harvest processing stage for this type of seed. For this study, certified seeds of the same variety were procured from agro-dealers or directly from certified seed producers, QDS from community seed growers, and recycled seed from farmers who had previously purchased seeds of a given variety or from the market. For all three types of seeds, the variety was confirmed by the breeder based on visual characteristics (i.e., seed color, size, texture). The recycled cowpea seed used in the experiments in Ghana was previously recycled for three seasons. However, in the case of Tanzania, it is unknown for how many years the *recycled* bean seed was recycled as these seeds were procured from the bean vendors in the market.

FEs were hosted by farmers and planted using farmers' own land and management practices. Each seed type was procured by the researchers and equal quantities of seeds of each type were given to the host farmers to plant on 10x10m plots (in Tanzania) and 10x20m plots in Ghana. Plots were labeled by letters (e.g., A, B, C and D in the case of Tanzania for certified 1, certified 2, recycled and QDS seed, respectively; and G, L, and M in the case of Ghana for certified, QDS and recycled seed, respectively;). Neither the farmers nor the extension agent who helped in the technical supervision knew which seed type was associated with which letter. Making the FEs double blind reduced any systematic bias on the part of the technical staff or the farmer managing the plot towards or against any pre-conceived higher and lower quality seed type (Hawthorne effect). In addition, the double blind nature of the FEs reduced any bias farmers as observers may have towards a specific seed type based on their prior personal experience or hearsay. In Tanzania, FEs were established in the 2015 short rain season (July-September) in the Hai district, and in the 2016 long rain season (March to July) in the Karatu district. In Ghana, the FEs were conducted in all the villages in the 2016 cowpea growing season (July-September).

[5] In Tanzania, two categories of certified seeds representing seeds produced in the most recent season (certified 1) and seeds carried over from the previous season (certified 2) were included in the field experiments. Ghana did not have a similar dual categories of seed stocks and thus we include only one type of certified seed (those produced in the most recent season).

Two field days were held in 12 villages in Tanzania and 8 villages in Ghana where farmers from those villages were invited to observe the bean and cowpea plots around flowering stage (Field day 1) and around harvest stage (Field day 2).[6] During the field days, each farmer was asked to evaluate the performance of the seed plots based on characteristics they considered important, and rate one plot (i.e., seed type) as the best (both field days) and one as the worst (field day 2 only).

Once farmers had learned how different types of seeds performed in the field, WTP auctions were carried out during Field Day 2 to elicit information about how much they were willing to pay for these seeds based on the observed differences in their performance. We followed the Becker-DeGroot-Marschak (BDM) (Becker, DeGroot, and Marschak 1964) method, where participants do not bid against other people, but only against themselves. The WTP elicitation mechanism is typically performed using one of two methods—a full bidding or an endow-upgrade method.[7] In both these auctions each participant receives a cash endowment at the beginning with which to either pay for a good (i.e., full bidding method) or to upgrade (i.e., endow-upgrade method). 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. Thus, in this study we used the full bidding method, whereby farmers participated in three auctions (e.g., one for certified seed, one for QD seed, and one for recycled seed). Farmers were asked to *bid* their maximum willingness to pay for one kilo of seed for a given type of seed (referred to by the letter labels) knowing that one of the three or four auctions would be chosen randomly and the bid for that seed would then be compared to a randomly drawn price (from a given revealed range).[8] If the bid was greater than or equal to the randomly drawn price, then the farmer purchased that seed for the randomly drawn price (not their bid). The difference in the bids between the three/four auctions reveals the premium (or discount) due to the different quality attributes as perceived by the farmer.

Approximately 20-40 farmers from each village (only one per family) that had attended both the field days were given local currency equivalent of about $1.85 (in Tanzania) and $2.6 (in Ghana) as their initial endowment (so they did not have to bid using their own money). These amounts for the initial endowments were equivalent to about 20% more than the market price of one kg of certified (i.e., highest quality) seed in Ghana, and about 33% more than the market price of one kg of certified seed in Tanzania. Prior to the seed BDM auction, a practice BDM auction experiment was conducted with a bar of soap (a product that has a readily apparent valuation) to make sure farmers understood the auction mechanism. An additional small amount of cash ($0.25-0.5) was given to farmers for this practice BDM auction.[9]

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[6] Due to budget constraints, two villages in Ghana were excluded from the field demonstration days and bidding experimental auctions.

[7] 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 a participant's true WTP.

[8] The revealed price range for bean seeds in Tanzania was 0 to 3950 Shillings (TSH, and farmers were allowed to bid at an increment of TSH 50, up to TSH 4,000), and the price range for cowpea seeds in Ghana was 0 to 9.90 Cedi (GHC, and farmers were allowed to bid at an increment of GHC 0.10, up to GHC 10).

[9] In Tanzania, farmers were given TSH 4000 as endowment for the seed BDM and TSH 500 for the practice BDM. In Ghana, farmers received GHC 10 as endowment for the seed BDM and GHC 2 for the practice BDM. The exchange rate from 1 US$ to local currency at the time of these experiments was about 2,100 Tanzanian Shillings and 3.8 Ghanaian Cedi.

3. DATA

A total of 247 bean farmers in northern Tanzania and 269 cowpea farmers in northern Ghana participated in both the field days and the WTP experiments. Data from the two field days (i.e., flowering and harvesting stages) where farmers ranked the seed plots based on visual characteristics were used to gauge the perception of seed quality differential across the three seed types. Data from the WTP auctions on field day 2 were used to estimate the relative WTP for each type of seed. After the fields were harvested, the extension agents collected the yield data from each plot. In the case of cowpea, experiments in Ghana, the seeds used for planting in the FEs and the seeds harvested from these plots were subjected to seed quality tests at a seed testing laboratory. The yield data (for both Tanzania and Ghana) and the seed quality test results (in the case of Ghana) both serve as objective measures of the relative performance of each seed type, and are used to compare with the relative difference in quality as perceived and reported by farmers through their subjective rankings.

Data were also collected from all the participating farmers using a structured questionnaire to understand the household and farmer characteristics, and agricultural practices, including their use and experience with different types of seeds. These data were used to understand the socio-economic and demographic characteristics of the farmers who participated in the experiments.

4. RESULTS

4.1. Sample Characteristics

Table 1 reports farmer and household characteristics of the respondents from Tanzania and Ghana who participated in the field experiments and experimental auctions. The average age of the respondents was 42 years in both the countries and they had 16-18 years of farm experience. About 30% of respondents in both the countries belonged to a farmer organization and 90% belonged to male headed households. The respondents were majority men (60%) in Tanzania and majority women (60%) in Ghana. Illiteracy rate among respondents was 10% in Tanzania and 70% in Ghana. About 40% of respondents in Ghana and 80% of respondents in Tanzania identified themselves as early adopters of a new technology.

Average household size was 5.6 members in Tanzania and 8.9 members in Ghana. On the measure of total poverty score based on 10 country-specific indicators of poverty (with the probability of being poor decreasing with the total score), households in Ghana had on average 30 points and households in Tanzania scored 48 points. Sampled households in Tanzania and Ghana had an average of 2.2 and 5.6 acres of land, respectively. The average bean/cowpea yield per household was estimated to be about 400 kg/acre in Tanzania (for beans) and 230 kg/acre in Ghana (for cowpeas). In Ghana, about 15% of respondents had purchased or used certified cowpea seeds in the past 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 in Ghana. However, in the case of Tanzania, none of the respondents reported ever using certified or quality declared seeds of beans before; although a high percentage of respondents (80%) had used certified seed of other crops.

Among Ghanaian respondents, 29% of the farmers reported that they had used their own saved cowpea 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 NGOs and government support programs. For Tanzania, most farmers reported purchasing the seed from the market either from seed vendors (60%) or grain vendors (30%). About 20% of respondents reported using saved seed from previous harvest in the last bean season.

Bean/cowpea was reported as the most important crop in terms of area planted, input used, and source of income by 30, 30, and 40 percentage of respondents, respectively, in Tanzania, and 10, 20, and 70 percentage of respondents, respectively, in Ghana. On average, a respondent’s household in Tanzania reported selling 60% of annual bean harvest. Ghanaian respondents on average reported selling about 50% of cowpea harvests in a typical year. Lastly, about 30% of Tanzanian participants had reported planting the bean variety that was included in the field experiments (i.e., Jesca), and only 3% reported growing Songotra variety, which was a relatively new *striga* resistant variety that was included in the experiments.

Table 1. Farmer and Household Characteristics of Participants in the Field Experiments and Experimental Auctions in Tanzania and Ghana

	Tanzania		Ghana	
Number of observations	247		269	
Legume crop focused in this study	Common bean		Cowpea	
	Mean	sd	Mean	sd
Farmer characteristics				
Age (years)	42.0	13.7	42.0	14.1
Gender (1=male)	0.6	0.5	0.4	0.5
1=Respondent is head of the household	0.6	0.5	0.5	0.5
Number of years of education completed	7.1	2.4	3.1	4.7
1=Cannot read or write in any language	0.1	0.2	0.7	0.6
Number of years of experience growing beans/cowpeas	15.6	12.1	17.9	14.5
1=Member in a farmer organization	0.3	0.5	0.3	0.5
1=Self-reported early adopter of new technologies	0.8	0.4	0.4	0.5
Household characteristics	--	--	--	--
1=household head is male	0.9	0.3	0.9	0.3
Household size	5.6	2.2	8.9	4.9
Poverty score (0-100)	48.2	13.2	29.8	11.3
1=household has used certified seeds of any crop	0.8	0.4	0.2	0.4
1=household has used certified bean/cowpea seed before	0.0	--	0.2	0.4
1=household has used QDS bean/cowpea seed before	0.0	--	0.3	0.5
1=purchases bean/cowpea seed at least every other year	0.7	0.5	0.7	0.4
1=Last time purchased bean/cowpea seed less than 4 years ago	0.8	0.4	0.6	0.5
Source of bean/cowpea seed planted in the last season:				
1=Saved from own harvest	0.2	0.3	0.3	0.5
1=Purchased as grain from market/others	0.3	0.5	0.1	0.3
1=Purchased as seed from market/others	0.6	0.5	0.5	0.5
1=Received from NGOs/government	0.01	0.1	0.1	0.2
Average yield of bean/cowpea in the last harvest (kg/acre)	403	396	230	170
Total land area owned (acres)	2.2	3.1	5.6	3.7
Bean/cowpea reported as most important crop in terms of: (% of HHs)				
Area planted	0.3	0.5	0.1	0.2
Inputs used	0.3	0.5	0.2	0.4
Source of income	0.4	0.5	0.7	0.4
Percentage of bean/cowpea harvest sold in a typical year	0.6	0.3	0.5	0.2
1=Farmer reported growing *Jesca* variety in the last bean season	0.3	0.5	--	--
1=Farmer reported growing *Songotra* variety in the last cowpea season	--	--	0.03	0.2

Source: Farmer surveys in Tanzania (2015-16) and Ghana (2016).

Next, we present the results of the field experiments and the WTP auctions. Recall that the study is double blind in nature, meaning that the farmers did not know the identity of the seeds when they were rating the plots or bidding for the seeds. Hence, the seed types in all the tables and figures are referenced by their plot IDs (i.e., A, B, C, D for Tanzania, and G, L, M for Ghana) as a reminder of what farmers were actually bidding for or rating.

4.2. Results of the Field Experiments

Table 2 presents the results of farmers' rating of the best seed plot at the flowering stage, and the best and worst plot at the harvest stage. In both countries, the plots planted with certified seeds (i.e., plot A in Tanzania and plot G in Ghana) received the highest rating by a majority of farmer participants in Field day 1 (flowering stage) and Field day 2 (harvest stage). For example, at flowering stage, close to 60% of farmers in Tanzania and 90% of farmers in Ghana rated plots A and G (planted with certified seed) as the best. Plots planted with seed type B (certified 2), type D (QDS), and type C (recycled) in Tanzania received the best plot rating by 27%, 8%, and 6% of farmers, respectively. In Ghana, 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 and at this stage there was a clear distinction between the plots planted with different quality seeds, resulting in more farmers rating plot A (for Tanzania) and plot G (for Ghana), which were planted with certified seed, as the best. The relative ranking of other seed types (i.e., QDS, recycled) remained the same at the harvest stage as it was at the flowering stage. At this stage, in both the countries, plots planted with recycled seed received best plot rating by the least number of farmers—4% in the case of Tanzania and less than 1% in Ghana (see Table 2).

At the harvest stage, farmers were also asked to rate the worst plot. In Ghana, 78% of participants rated plot M (recycled) as worst with 22% rating plot L (QDS) as worst. Less than 1% rated plot G (certified) as the worst plot (Table 2). In the case of Tanzania, less than 5% rated plot A (certified 1) as the worst. However, the opinion on which of the remaining three plots was the worst was not as decisive as in Ghana. About 35% rated plot B (certified 2), 34% rated plot D (QDS), and 27% rated plot C (recycled) as the worst. Clearly, in both the countries farmers were confident about rating certified seed (plot A and plot G) as the best and least worst. In the analysis presented later on in the paper, we use this subjective rating on seed quality at the harvest stage to explain how much the perceived seed quality influenced farmers' willingness to pay for different types of seeds.

Farmers were asked to select the main reason for rating a plot as the best or worst based on their field observations. These reasons for the harvest stage are categorized in Table 3 and include, yield, grain quality, how plants looked in terms of overall health and seed density in the pods. In Ghana, a majority of farmers (69%) rated a plot as best because of good yield. Other characteristics selected as the main reason for rating a plot as the best were grain quality (15%), filling of pods (9%), and plant health (7%). Unhealthy appearance of plants and lower yields were the major reasons given by famers for rating a plot as worst. In Tanzania, the latter were also the top two reasons for rating a plot as worst. However, the reasons for best rating among Tanzanian farmers were split between good yield (36%) and seed density in pods (35%). About a quarter of farmers in Tanzania also rated a plot as the best because of how healthy the plants looked (Table 3).

Table 2. Farmers' Perception of Quality Differences: Ratings of Best Plots at Flowering Stage, and Best and Worst Plot at Harvest Stage—Results from Tanzania and Ghana Field Experiments

Plot (Seed type)	Flowering stage	Harvest stage	
	Best plot	Best plot	Worst plot
		Percentage of farmers	
Tanzania (beans)	N=282	N=245	N=245
Plot A: Certified 1	59.2	73.1	4.5
Plot B: Certified 2	26.6	15.5	34.7
Plot D: Quality Declared	7.8	7.8	33.5
Plot C: Recycled	6.4	3.7	27.4
Ghana (cowpeas)	N=269	N=269	N=269
Plot G: Certified	89.9	95.2	0.4
Plot L: Quality Declared	7.9	4.1	21.9
Plot M: Recycled	2.2	0.7	77.7

Source: Field experiment data, Tanzania 2015-16; Ghana-2016.

Table 3. Characteristics Cited As a Reason for Rating a Seed Type Best or Worst at Harvest Stage: Results for Tanzania and Ghana

Reasons for rating a plot BEST	% of farmers	Reasons for rating a plot WORST	% of farmers
Tanzania-Beans (N=247)			
Good yield	36%	Plants look unhealthy	45%
Pods have filled nicely	35%	Lower yields	26%
Plants look healthy	26%	Pods have not filled nicely	20%
Good grain quality	4%	Poor grain quality	7%
		Other	2%
Ghana-cowpeas (N=245)			
Higher yield	69%	Plants look unhealthy	39%
Good grain quality	15%	Lower yields	38%
Pods have filled nicely	9%	Pods have not filled nicely	15%
Plants look healthy	7%	Poor grain quality	8%

Source: Farmers' ratings recorded on Field Day 2, Tanzania (2015-16), Ghana-2016.

The subjective ratings of the performance of different quality seeds in the field experiments and reasons given by farmers are highly correlated with the objective indicator of performance as measured by plot yields (Table 4).[10] In the case of Ghana, a relatively more decisive reason given for rating a seed plot as best was good yield, which is reflected in the estimated yield differential between the three seed quality types. On average, across all eight villages where farmer field days and WTP auctions were conducted, certified seed plots recorded significantly higher grain yield per hectare (1,533 kg/ha) than yields on both QDS (975 kg/ha) and recycled seed plots (445 kg/ha) (Table 4).

[10] Note that the plots were not harvested when the farmers participated in the second field day and the bidding auction experiments. The yield and other agronomic data were collected by field technical staff independent of any field days and were not revealed to the farmers.

Table 4. Grain Yield as a Measure of Performance of Bean and Cowpea Experimental Plots Planted with Different Quality Seeds

	Mean yield (kg/ha)[*a]	Std.dev.
Tanzania-beans (N=12)		
Plot A: Certified 1	1,484	1,154
Plot B: Certified 2	1,475	1,266
Plot D: Quality Declared	1,321	1,311
Plot C: Recycled	1,345	1,180
Ghana-cowpeas (N=8)		
Plot G: Certified	1,533 [a]	337.9
Plot L: Quality Declared	975 [b]	402.7
Plot M: Recycled	445 [c]	156.5

Source: Field experimental data, Tanzania (2015-16) and Ghana (2016).
Note: *a. Numbers with different letters denotes differences in yield estimates are statistically significant at $p<0.01$. Numbers with no letters denotes no statistically significant yield differences.

In Tanzania, certified 1 seed plots, on average recorded the highest yield (1,484 kg/ha), followed by plots planted with certified 2 seed (1,475 kg/ha), recycled seed (1,345 kg/ha), and QDS (1,321 kg/ha) (Table 4). Unlike in Ghana, none of the yields in Tanzania was statistically significantly different from each other. The relatively close yield performance in Tanzania may, in part, explain the closer subjective ratings of worst plot given by farmers to certified 2, QDS and recycled seed. Additionally, it may also explain why yield was not cited as the main reason for best plot more frequently than in Ghana (Table 3).

In Ghana, other objective measures of seed quality, such as moisture content, germination rate and purity, and agronomic performance during the growing season were also recorded as reported in Table 5. On all measures, certified seed performed significantly better than QDS, which in turn performed better than recycled seeds. Certified seed had the highest germination rate and plant density two weeks after planting and at harvest, and lowest number of plants affected by root rot disease or off-type plants (Table 5). In Tanzania, the researchers had conducted seed health and quality tests, but there was no significant difference in the seed health indicators across the four seed types. For the two seed quality measures—germination rate and vigor, the results are presented in Table 5. On both these measures of quality, certified seeds rated slightly higher than QDS and recycled seeds. These measures are good predictors of plant health and overall plant performance observed during the growing season, and highly correlated with harvested yields, as confirmed by the actual crop yield data reported in Table 4, and reflected in farmers' perceived quality ratings and reasons reported in Tables 2 and 3.

Across all the communities in Ghana, at two weeks after planting, all the seed types recorded over 90% establishment, which is considered a good germination rate. 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 total number of plants that survived till the time of harvesting ranged from 304 (plot M) to 400 (plot G) plants per 25 square meters. When the number of plants at harvest are expressed as a percentage of plants that were established two weeks after planting, certified seed plot recorded 99% survival, QDS had 93% survival rate, and plots with recycled seeds had only 77% of plants survive 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*), compared to the off-types recorded in the certified and QDS plots (Table 5).

Table 5. Measures of Seed Quality and Agronomic Performance of Three Types of Cowpea Seeds Included in the Field Experiments in Ghana and 4 Types of Bean Seeds Included in the Field Experiments in Tanzania

Ghana	Plot G	Plot L	Plot M	
Seed type planted	Certified	QDS	Recycled	
Variety	Songotra	Songotra	Songotra	
Seed quality test results (pre-planting)				
Moisture content (%)	9.9	9.5	9.9	
Germination (%)	98	92	88	
Purity (%)	99.9	99.9	99.8	
Agronomic parameters observed during the growing season				
Plant density at 2-weeks after planting (number/25m^2)	403	403	394	
Plants affected by root rot (number/25m^2)	3.5	30	90	
Plants at harvest (number/25m^2)	400	375	304	
Number of off-type plants (25m^2)	1	2	26	
Tanzania	**Plot A**	**Plot B**	**Plot C**	**Plot D**
Seed type planted	Certified 1	Certified 2	Recycled	QDS
Variety	Jesca	Jesca	Jesca	Jesca
Seed quality test results (pre-planting)				
Germination (%)	93	95	84	87
Vigor	90	93	80	85

Source: Field experimental data, Ghana (2016) and Tanzania (2015-16).

Overall, the results of the field experiments indicate that, all else equal, plots planted with certified seed not only performed better on measures of objective indicators (i.e., yield, seed quality, and agronomic traits), but were also perceived to be the best quality by a majority of farmers based on the observations of plots at the flowering and harvest stages. There are, however, differences in the degree of consensus on perceived quality of different seed types among participants who observed the cowpea experiments in Ghana and those that observed the bean experiments in Tanzania. Also, the actual yield differential among bean plots in Tanzania was much smaller than the yield differential observed for cowpea seed plots in Ghana. Although, the purpose of this study is not to do a comparative analysis across crops and countries, these differences in the degree of perceived and actual quality differences in seed types can help explain whether and to what extent these perceived differences in the performance of a crop across different seed types translate into farmers' willingness to pay for different quality seeds. We turn to this research question in the next section.

4.3. Results of WTP Experimental Auctions

In this section, we present the results of the Becker-DeGroot-Marschak WTP experiments conducted during the second field day. The experiments occurred after the farmers had rated the seed plots and took place approximately one week before harvest. Table 6 shows the mean values of the bids. On average, farmers in Tanzania indicated their willingness to pay TSH 2,093/kg for the seeds used to plant plot A (certified 1), TSH 1,804/kg for plot B (certified 2), TSH 1,594/kg for plot D (QDS), and TSH 1,605/kg for plot C seeds (recycled). The WTP for these different types of seeds are all statistically significantly different (at $p<0.01$), except for plots C and D. To put these expressed WTP values in context, the mean

Table 6. Farmers' Willingness to Pay (WTP) for Different Seed Types: Results of the Bidding Auction Experiments

Seed type [*a]	Mean WTP	Std.dev.
Tanzania-beans (TSH/kg) (N=247) [*b]		
Plot A: Certified 1	2,093 [a]	1,166
Plot B: Certified 2	1,804 [b]	1,149
Plot D: Quality Declared	1,594 [c]	1,088
Plot C: Recycled	1,605 [c]	988
Ghana-cowpeas (GHC/kg) (N=269) [*c]		
Plot G: Certified	7.19 [x]	2.16
Plot L: Quality Declared	5.27 [y]	2.11
Plot M: Recycled	4.90 [z]	2.19

Source: Authors' estimation from experimental auctions, Tanzania (2015-16) and Ghana (2016).
*a Note that seed types planted on different plots were not known to farmers at the time of bidding experiments. Average grain price reported by Tanzanian bean farmers at the time of experiment was TSH 1,577/kg (median was 1,500/kg) and by Ghanian cowpea farmers was GHC 2.80/kg (median was 2.66/kg).
*b Numbers with different letters denotes that differences in WTP are statistically significant at p<0.01.
*c Numbers with different letters denotes that differences in WTP are statistically significant at p<0.05.

bean grain price per kg reported by farmers in the study area at the time of the survey was TSH 1,577. The mean bean seed price per kg paid by the farmer participants was TSH 1,761.[11] In terms of comparison, the average bid price for the lowest rated seed (plot D) is very similar to the average grain price reported by farmers, and the average bid price for the highest rated seed (plot A) is statistically significantly higher (at p<0.01) than the price of bean seed paid by farmers in their last purchase.

In Ghana, participants bids indicated an average willingness to pay of GHC 7.19 for one kg seed of type G (certified seed), which was higher than their WTP for seed type L (QDS) (GHC 5.27) and seed type M (recycled seeds) (GHC 4.90). Differences in the WTP between seed type G, seed type L, and type M are statistically significant at p<0.05. Again, to put these WTP values in context, the mean cowpea grain price per kg reported by farmers in the study area was GHC 2.80. The mean cowpea seed[12] price per kg paid by the farmer participants in their seed purchase was GHC 4.66. The average bids for all three seed types expressed by the farmers in the case of Ghana are significantly higher (p<0.01) than the farmer reported grain price. Also, the average bid price for the highest rated seed (type G) was significantly higher than the reported price of cowpea seed paid by farmers in their last seed purchase.

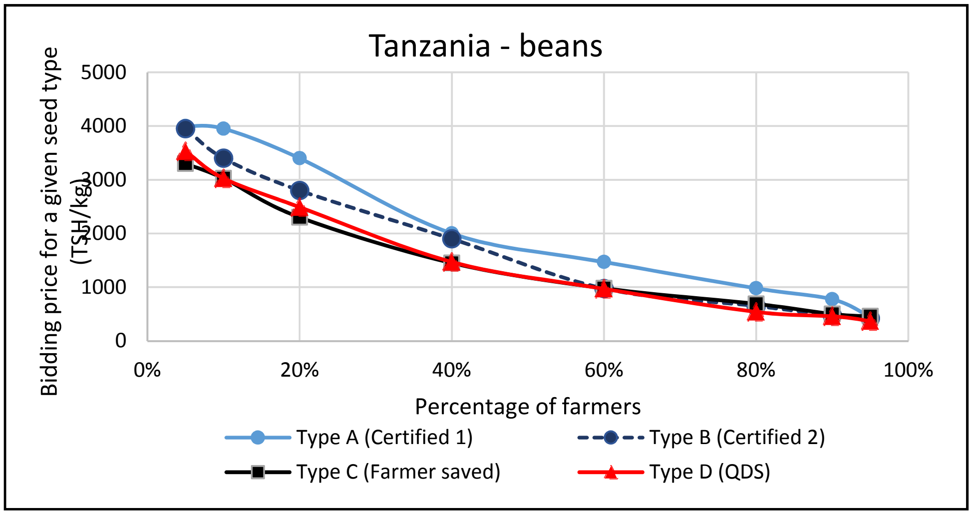
For both Tanzania and Ghana, the WTP for different quality seeds were highly correlated with the rank order in which participants had rated the seed plots. For example, the WTP for seeds planted on plots A and G (i.e., certified seed) was highest, which on average was ranked the best plot by a majority of participants in each country. Similarly, the WTP for seed type C and M (i.e., recycled seed) was the lowest in case of Ghana, and second lowest, but not significantly different from the lowest bid price, in the case of Tanzania, with the corresponding low percentage of participants rating it as the best seed plot in each country.

[11] Most of the reported purchase of seed came from seed vendors in the market and came with no label or a seed package and are, thus, not equivalent to certified seed.

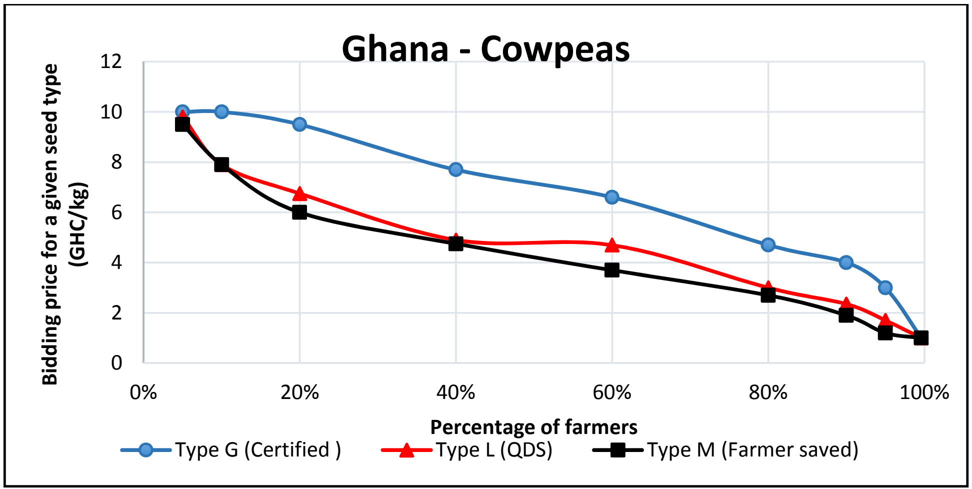
[12] The same was reported as seed sources in Ghana as Tanzania. Most of these seed products were purchased from seed vendors in the market and came with no label or package.

The distribution of WTP for different quality seeds, cumulative across all the farmers who participated in the auctions, is depicted in Figure 1. The downward sloping WTP curves indicate that more people are willing to pay a lower price, and fewer people are willing to pay a higher price for a given seed type. If we keep the quantity demanded per person as a constant (e.g., one kg/person, as was the case in the auctions), then the WTP line graph for a given seed type can be interpreted as a demand curve showing the inverse relationship between price and quantity demanded. The difference is the inclination at which these curves slope downward represents the price elasticity of demand for seed. In general, the demand for lower quality seeds (recycled and QDS) is less elastic than the demand for higher quality seed (i.e., certified seed) across both countries. However, the demand curve for quality seed is relatively more elastic (i.e., price sensitive) in the case of Ghana than in the case of Tanzania.

Figure 1. Farmers' Willingness to Pay for Seeds of Different Quality Types: Results of the Bidding Auction Experiments from Tanzania for Beans and Ghana for Cowpeas



Source: Authors' estimation from experimental auctions, Tanzania (2015-16).



Source: Authors' estimation from experimental auctions, Ghana (2016).

The vertical distance between the *demand* curves for any two seed type denotes farmers' willingness to pay different prices for different quality seeds. For example, the WTP for certified seed across all the farmers is above the WTP curve for certified 2, QDS and recycled seeds in the case of Tanzania, and is significantly above the WTP curves for QDS and recycled seeds in the case of Ghana. Similarly, the WTP for recycled seed is lowest across all the participants in both the countries. In the case of Tanzania, the WTP for recycled seed is not significantly different from the WTP for QDS seed as shown by the almost overlapping curves for seed types C and D (Figure 1).

In fact, the experimental auctions were designed to get a sense of this vertical distance between the demand curves of different seed types. In Table 7, we express this distance between the overall lowest rated seed type (i.e., recycled) and other types of seeds as the premium farmers are willing to pay for higher seed quality. This is expressed both in the form of; a) an average amount per kg (in local currency) a farmer is willing to pay above his/her willingness to pay for recycled seed and b) the mean percentage relative to the willingness to pay for recycled seed.

For Tanzania, relative to the overall lowest rated seed type (i.e., recycled), on average farmers were willing to pay (per kg) an additional TSH 490 or about 30% more for the highest rated seed plot (i.e., certified 1), and about TSH 200 (or 12%) more for the second highest rated seed type (i.e., certified 2). For the third best rated seed type (i.e., QDS), farmers were on average not willing to pay a premium over and above the lowest rated seed type. In fact, there was a small but insignificant amount of negative premium (i.e., discount) of TSH 11 associated with plot D (i.e., QDS) relative to plot C (i.e., recycled seed).

In relative terms, the premium for highest rated seed type in Ghana was significantly more than that found in Tanzania. On average Ghanaian farmers were willing to pay an additional GHC 2.3 or 73% more for one kg of the overall highest rated seed type (i.e., certified seed) than what they were willing to pay for the overall lowest rated seed type (i.e., recycled).

Table 7. Average Premium Farmers Are Willing to Pay for Higher Ranked Quality Seeds over the Lowest Ranked Seed Quality

Seed quality ranking (across the sample)	Seed type	Average premium farmers are WTP for a given seed type relative to the bidding price of the overall lowest ranked seed type	
		Amount[*b]	%
Tanzania-beans (N=245)[*a]			
Highest	A: Certified 1	487.45	130%
Second	B: Certified 2	198.79	112%
Third	D: Quality Declared Seed	-10.53	99%
Lowest	C: Recycled seed	–	–
Ghana-cowpeas (N=269)			
Highest	G: Certified	2.29	173%
Second	L: Quality Declared Seed	0.37	120%
Lowest	M (Recycled seed)	–	–

Source: Authors' estimation from experimental auction data, Tanzania (2015-16) and Ghana (2016).
*a Farmers' best-worst plot rating is missing for 2 farmers.
*b In Tanzanian Shillings for Tanzania and Ghanaian Cedis for Ghana.

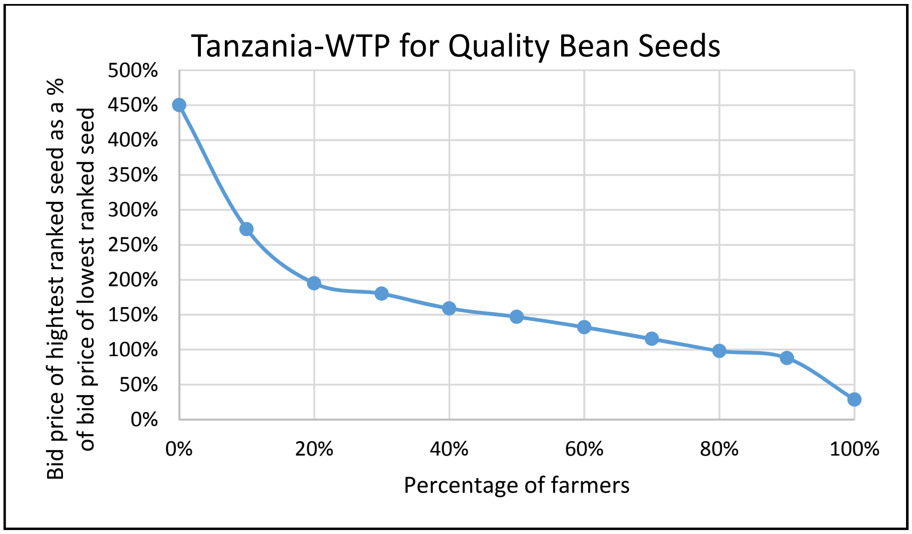
The premium for the second best rated seed type (i.e., QDS) was GHC 0.37 or 20% more than the WTP for the lowest rated seed. Recall that the actual yield difference between the highest and lowest rated seed was significantly more in Ghana than in Tanzania. Consequently, this is reflected in a higher magnitude of premium farmers were willing to pay for quality seed in Ghana than in Tanzania.

4.4. Farmers' Willingness to Pay for Seed Relative to Perceived Quality

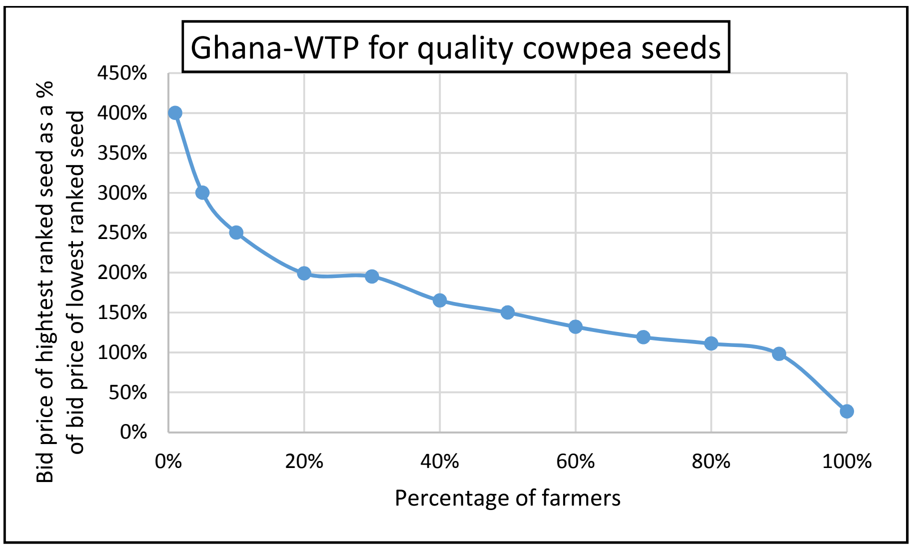
The average premiums noted in Table 7 are estimated based on the overall best or worst rated plots for the whole sample. One could argue that a true measure of the average WTP for quality seed should be the mean of the premium each farmer is willing to pay for the highest rated seed relative to the lowest rated seed type based on his/her own quality perception. In Table 8, we present the mean and median values of the premium farmers are willing to pay based on their perceived quality difference between the best and the worst seed plots, and in Figure 2, we show the distribution of farmers' willingness to pay a premium for their best rated plot relative to the bid for their worst rated plot. The y-axis in Figure 2 represents the price premium for the best rated plot expressed as a percentage of the same farmers' WTP for the worst rated plot, and the x-axis represents the percentage of participants who are willing to pay a given percentage premium. A premium of more than 100% implies that a farmer is willing to pay a positive amount for the best rated plot above and beyond the WTP for the worst rated plot. For example, the maximum premium some farmers in Tanzania and Ghana were willing to pay for their best rated plot is, respectively, 450% and 400% (i.e., 4.5 and 4 times more than the bid price for their worst rated plot). About 50% of the farmers in both the countries were willing to pay at least 50% more for their best rated seed plot than their bid price for the worst rated plot (i.e., 1.5 times the bid price of worst rated seed type).

In Figure 2, 100% on y-axis implies that a farmer is willing to pay the same for his best rated plot as his worst rated plot. Similarly, a less than 100% premium implies that a farmer is willing to pay less for his best rated plot than his worst rated plot. As indicated in Figure 2, close to 20% of participants fall below this 100% threshold line. Since this scenario of negative WTP in relation to plot rating seems illogical, in Table 8 we present the mean and median estimates for three sub-sample of participants. Sample 1 includes all the observations, except a few outliers (2 for Tanzania and 6 for Ghana) for whom the estimated premium for best rated seed over the worst rated seed was more than the mean plus 3 times the standard deviation. Sub-samples 2 and 3 progressively excludes observations with bids that seem unreasonable and perhaps reflect participants' inabilities to understand the BDM exercise. For example, sample 2 excludes observations where the farmer's bid for the best rated plot was lower than his/her bid for the worst rated plot (i.e., observations below 100% threshold), and Sample 3 further excludes observations where the bids for best and worst rated plots were the same (i.e., observations that fall on the 100% threshold). We present the mean and median values for these three sub-samples to gauge the sensitivity and bias in estimated premium price that could be due to the inclusion of unreasonable bids in relation to plot ratings.

Figure 2. Distribution of Farmers' Willingness to Pay for Their Highest Rated Seed Relative to Their Lowest Rated Seed



Source: Authors' estimation from experimental auctions, Tanzania (2015-16).



Source: Authors' estimation from experimental auctions, Ghana (2016).

Table 8. Premium Farmers Are Willing to Pay Based on Their Perceived Quality Differences between the Best and the Worst Rated Seed Types: Mean and Median Values for Tanzania and Ghana for Three Sub-Samples

		Premium farmers are willing to pay for their highest rated seed type as a percentage of the bidding price of their lowest rated seed type	
Country-Crop	N	Mean (s.d.)	Median (s.d.)
Sample 1: All the observations (excluding outliers[*a])			
Tanzania-beans	243	166.8% (92.3)	146% (62.8)
Ghana-cowpeas	263	160.0% (63.9)	143% (50.2)
Sample 2: Excludes farmers with bid price for the best rated seed type less than the bid price for the worst rated seed type			
Tanzania-beans	216	179.5% (89.9)	153% (61.7)
Ghana-cowpeas	240	169.0% (59.9)	150% (47.2)
Sample 3: Excludes farmers with bid price for the best rated seed type less than or equal to the bid price for the worst rated seed type			
Tanzania-beans	189	190.8% (90.7)	160% (61.9)
Ghana-cowpeas	220	175.3% (58.7)	166% (46.2)

Source: Authors' estimation from experimental auction data, Tanzania (2015-16) and Ghana (2016).
*a. outliers defined as values more than mean plus 3 times the standard deviation.

As indicated in Table 8, in the case of Tanzania, for sample 1, bean farmers on average were willing to pay 66.8% more for their perceived highest quality seed than their perceived lowest quality seed type. The median value of this price premium was 46% for Tanzania. As we progressively exclude observations with unreasonable bids relative to the plot rating, the estimated mean premium farmers in Tanzania were willing to pay increased from 66.8% to 79.5% for sub-sample 2 and 90.8% for sub-sample 3. Similarly, the median value increased from 46% to 53% for sub-sample 2, and 60% for sub-sample 3.

For Ghana, the estimated mean willingness to pay a premium for best rated plot over and above the bid for the worst rated plot ranges from 60% for sub-sample 1, 69% for sub-sample 2, and 75.3 % for sub-sample 3. The median willingness to pay a premium for best rated plot is 43% for sub-sample 1, and increased to 66% for the sub-sample that excludes any observations with the ratio of bids for the best to worst seed type less than or equal to 1 (Table 8).

It is clear from the results presented in Figure 2 and Table 8 that there is a positive association between farmers' perception of seed quality (based on observations of plant performance in the experimental plots) and their willingness to pay for a seed type. Of course, there could be other factors that can also influence farmers' willingness to pay, such as income, prior use and experience with non-recycled seeds, farm characteristics, and personal characteristics such as education, age, gender, innovativeness, risk attitudes, etc. This relationship between willingness to pay for different types of seed (of a given variety) and other factors can be specified as,

$$WTP_{ij} = \alpha + \beta Q_{ij} + \gamma Z_i + \varepsilon_{ij} \qquad (1)$$

where, WTP_{ij} represents farmer i's willingness to pay (or bid) for seed type j; Q_{ij} represents the perceived seed quality rating for seed type j by farmer i, Z_i is a vector representing farmer and household characteristics such as demographic, socio-economic, and behavioral variables, and ε_{ij} are idiosyncratic error terms. Given that for each farmer who participated in the auctions, we have the WTP for different seed types, we can use the farmer fixed effect to control for the farmer and household characteristics (including the unobservable confounding factors). Thus, we use Ordinary Least Square (OLS) estimation method with household fixed effects to explore the relationship between perceived seed quality and WTP for quality seed as specified in equation 2.

$$WTP_{ij} = \alpha + \beta Q_{ij} + \delta_i + \varepsilon_{ij} \quad (2)$$

Where, δ_i is the fixed effect for farmer i. In this model, 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). The model estimations are presented in Table 9 for the three sub-samples defined in Table 8.

The statistically significant values for the perceived seed quality variables confirm that after controlling for other potentially confounding factors, there is a positive correlation between perceived quality of seed and farmers willingness to pay for one kg seed of that seed type. Relative to seed plots that were rated worst, bean farmers in Tanzania were willing to pay on average TSH 611 more for 1 kg seed of their highest rated seed and on average TSH 144 more for 1 kg of the seed type they rated neither best nor worst (referred as medium quality in Table 9).

Table 9. Influence of Perceived Seed Quality on Farmers' Willingness to Pay for Bean Seed in Tanzania and Cowpea Seed in Ghana: Model Estimation Using Household Fixed Effects

	Tanzania WTP for bean seed (TSH/kg)			Ghana WTP for cowpea seed (GHC/kg)		
	(1)	(2)	(3)	(1)	(2)	(3)
Perceived Seed quality:						
Highest	611.11***	790.97***	903.96***	2.19***	2.60***	2.84***
	(98.697)	(85.376)	(80.454)	(0.275)	(0.160)	(0.126)
Medium	144.34***	224.88***	294.44***	0.40	0.58**	0.66**
	(43.864)	44.111	35.152	(0.250)	(0.159)	(0.263)
Lowest *a	–	–	–	–	–	–
Farmer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2900.05***	2814.82***	2751.79***	3.14***	2.94***	2.83***
	(42.941)	(38.420)	(32.729)	(0.159)	(0.111)	(0.103)
R-square	0.8296	0.8634	0.8622	0.7153	0.7706	0.7670
N	972	864	756	789	720	660

Source: Authors' estimation from field experimental and experimental auction data, Tanzania (2015-16) and Ghana (2016).
Standard errors are in the parenthesis. Robust SE are clustered at the village (or field experiment level). ***=p<0.01, **=<0.05.
Model 1 includes all the observations (sample 1). Model 2 excludes farmers with bid price for the best rated seed type less than the bid price for the worst rated seed type (sample 2). Model 3 excludes farmers with bid price for the best rated seed type less than or equal to the bid price for the worst rated seed type (sample 3).
*a. Excluded variable in all the models.

The average value of this premium goes up as the sub-sample is restricted (specifications 2 and 3). For Tanzania, the results are robust and statistically significant across all sub-samples for both seed quality ratings.

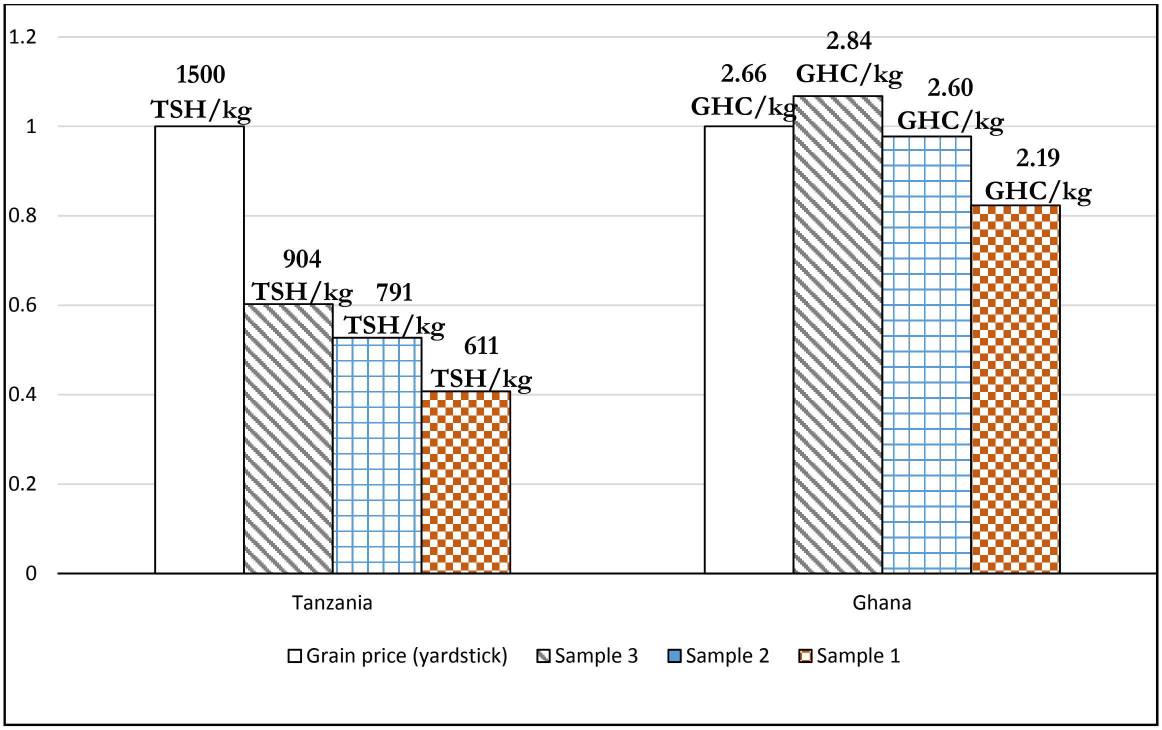
In the case of Ghana, results suggest that on average, cowpea farmers were willing to pay between GHC 2.2 to 2.8 per kg for the highest rated seed quality relative to the lowest rated seed type, depending on the sub-sample used for model estimation. For the medium quality rated seed, farmers were willing to pay an average GHC 0.4 to 0.66 per kg across the three sub-samples. The results for Ghana are robust and statistically significant across all sub-samples for the premium estimated for the highest quality seed, and for sub-samples 2 and 3 estimates are also statistically significant for medium quality rated seed (Table 9).

To put these estimated premiums in context and for comparison purpose, we show in Figure 3 how these values for the highest rated seed quality in the two case study countries compare with the median gain price reported by the farmers for the respective crops in the study area. The estimated premium a bean farmer in Tanzania was willing to pay for his/her highest rated seed quality relative to his/her lowest rated seed quality was in the range of 40-60% of the bean grain price.[13] For Ghana, the estimated premium a farmer was willing to pay on average for his/her highest rated seed quality relative to his/her lowest rated seed quality was in the range of 80-110% of the cowpea grain price. Thus, relative to a common yardstick of grain price, cowpea farmers in Ghana expressed WTP a significantly higher premium compared to bean farmers in Tanzania.

To further illustrate the cross-country differences in the magnitudes of WTP premiums relative to a common yardstick of grain price, in Figure 4 we show the distribution of the predicted values from model 3 (the most restrictive sample) of farmers' WTP for the best and worst rated plot relative to the grain price. In Ghana, all farmers in sample 3 were at least willing to pay for the best rated seed type a price greater than the grain price; although for about 15% of farmers the WTP for their worst rated seed type was below the grain price. In Tanzania, there is a substantially greater proportion of participants (about 25%) with a maximum WTP price for the best rated seed below the grain price. Since the cost of producing good quality seed is likely to be significantly more than producing grain, the supply curve for the best rated seed type will certainly be above the grain price. Using the existing market price for certified seed as a proxy for the supply curve for quality seed, we show that in both the countries, only about 40% of sample 3 farmers' WTP for highest quality seed is above the market price of certified seed (Figure 4). In other words, for about 60% of farmers in the study area, the current market price of certified seeds in not affordable. The implication of this and other results presented in this section are discussed next.

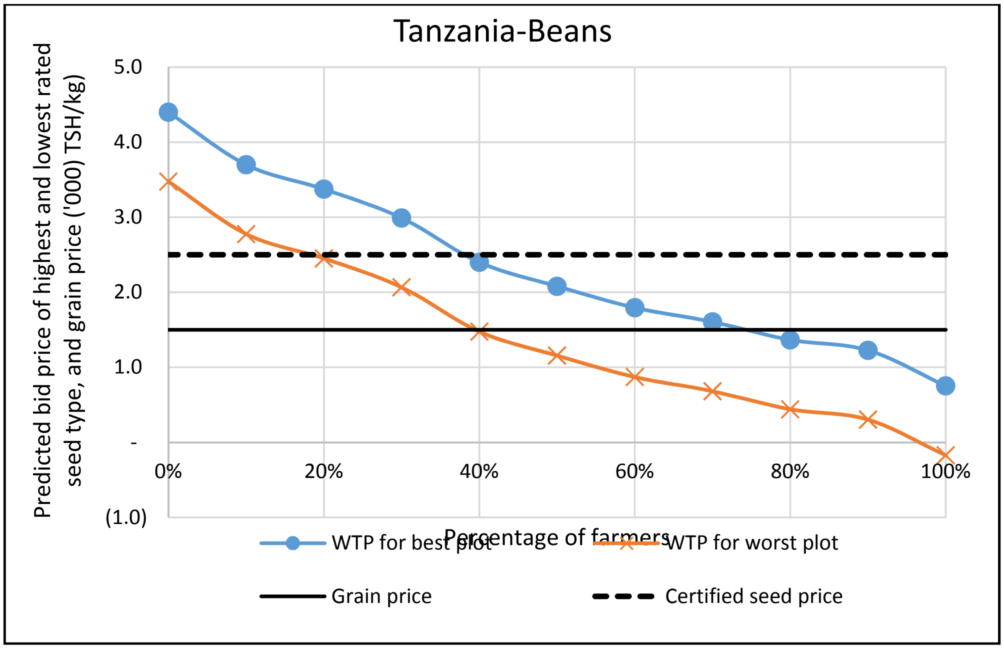
[13] Note that the BEAs were conducted around the harvest time, when the grain price is typically lower than the price at planting. The estimated percentage premium would be different if the grain price at planting season is used as a yardstick. However, it is also possible that the estimated WTP for different seed types could have been also different if the BEAs were conducted just before planting. This is an interesting hypothesis, which this study was not designed to test. We thus use the grain price at the time of BEAs as the reference period for this comparison against a common yardstick.

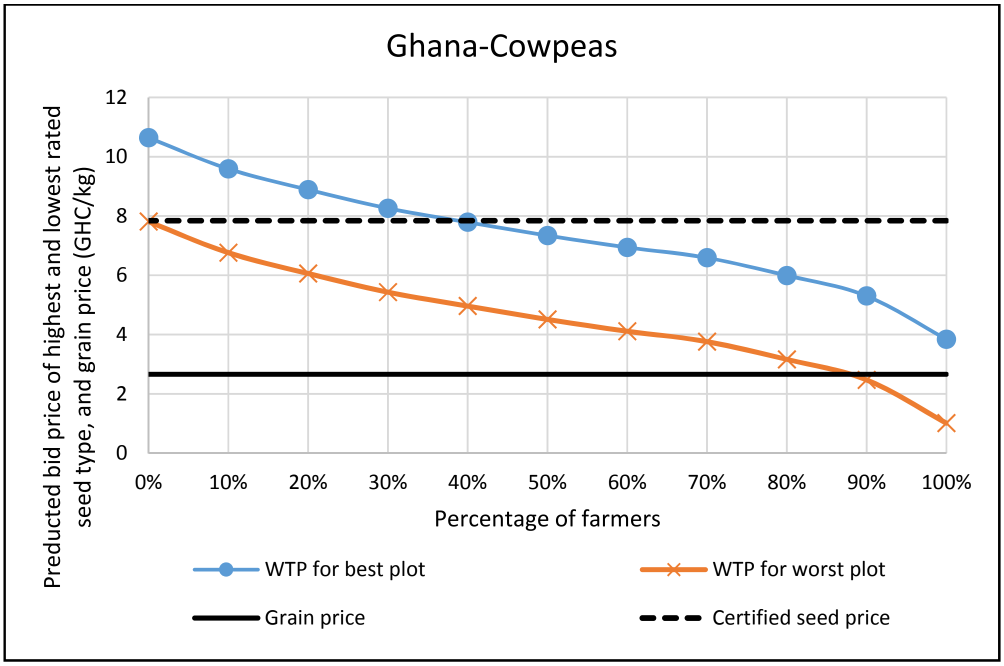
Figure 3. Farmers' Willingness to Pay Premium for Highest Quality Bean/Cowpea Seed over the Lowest Quality Seed Relative to Median Grain Price: Model Results for Tanzania and Ghana for Three Sub-samples



Source: Authors' estimation based on Model 1, 2 and 3 results, Table 9.

Figure 4. Farmers' Willingness to Pay for Best and Worst Rated Seed Relative to Grain and Certified Seed Price: Predicted Values from Model 3 for Tanzania and Ghana





Source: Authors' estimation based on Model 3 results.

5. DISCUSSION OF RESULTS AND IMPLICATIONS

Overall, the experiments conducted in Tanzania and Ghana point to several interesting results, some of which challenge conventional wisdom. First, at least in these two case studies, quality seeds did perform better in terms of important characteristics (i.e., germination rate, yield, etc.) relative to recycled grain. The performance was relatively better for cowpea field experiments in Ghana than the bean seed experiments in Tanzania. This finding that seed quality does matter under farmers' growing conditions, challenges the long-held notion that for self-pollinated crops, farmers do not lose much if they recycle seeds for multiple generations. Irrespective of the size of the yield differences (or yield deterioration over generation of seed production), an important implication of this finding is that to increase productivity, it is not sufficient to promote only the adoption of improved varieties, but also the adoption of improved quality seed as an input. Too much focus in the scientific community has been devoted to evaluating different genetic materials through varietal trials. However, surprisingly, there are very few studies that evaluate the performance of different generations of legume seeds of the same variety under farmers' conditions as was done here.[14] There is a need for more experimental evidence on productivity differences in seed types across legume (and other self-pollinated) crops and countries to confirm or challenge the notion that self-pollinated crops such as beans and cowpeas do not suffer from significant yield loss as a result of seed quality deterioration that impacts the seed vigor due to recycling seeds for multiple generations.

A second important finding of this study is that it shows that farmers are able to perceive quality differences in planting material and are willing to pay a premium for higher quality seed. In the case of Ghana, the average premium farmers were willing to pay for one kg of higher quality seed was equivalent to the price of grain prevalent at the time of harvest. This willingness to pay such a significant premium for quality legume seed by smallholder farmers is encouraging and indicative of an effective demand. However, this study was not designed to estimate the quantity of this potential seed demand. Further research is needed to assess the quantity of seed farmers would be willing to buy at a premium price and at what frequency. This information will help gauge the size and scope of the demand for quality seed and to assess if there are local, regional, or national entrepreneurial opportunities for someone to fill this demand gap.

A third finding this study points to is that although the auction experiments reveal that about a third of the farmers' WTP for quality seed in Ghana, and about a quarter of the farmers' WTP for quality seed in Tanzania was above the price of certified seed, in practice farmers' use of purchased certified seeds or QDS is much lower. In fact, a majority of farmers reported buying seed every year or every 2-5 years, but from specialized vendors who have no credentials and sell bulk seed with no label or quality assurance (i.e., the so called informal seed system). Further research is needed to investigate whether the low (actual) use by farmers of quality seed products acquired from the formal sector is a trust and perception issue (i.e., counterfeit or inferior seed sold in the name of certified and QDS), the availability

[14] Few examples we found in the literature all relate to potato. For example, the study by Rahman et al. (2010) report the experiments conducted on experiment stations to compare the performance of different generation potato seed in the presence of two types of viruses. The study by Crissman et al. (1990) compared two generation of seedling tubers, and farmers' own seed tubers in farmers' fields. Similarly, Demo et al. (2015) present on-farm yield trial results comparing different generations and types of potato seeds (certified, clean) relative to typical farmer saved seed. But in both these studies it is not clear if the genetics of these different materials was the same or varied.

issue (i.e., supply side constraint), or both.[15] If most farmers are acquiring seeds from the informal system, there is also a need for more research and systematic investigation on what the true quality is of these seeds acquired from the informal system and how much the quality varies from vendor to vendor. Given the role these vendors play in the current system, it may pay to investigate how to link them to the formal system to increase farmers' access to legitimate quality seed products (McGuire and Sperling 2016).

Fourth, across both the crop-country case studies, we find that there are a significant proportion of legume growing farmers (about 60%) whose willingness to pay a premium for quality seed is much lower than the existing certified seed to grain price ratio in the study area. For a sub-set of these farmers in Tanzania (25%), the willingness to pay for quality seed is even lower than the grain price. One of the implications of these results is that, if the objective is to increase yields across all farmers, there will need to be a multi-pronged approach in order to get high quality seed into the hands of all the farmers across this spectrum of WTP. Current efforts to entice the private sector to produce and supply certified seeds through agro-dealers can potentially meet the seed needs of at most 35-40% of farmers (if the quality of those seeds is substantially superior to recycled grain). More research and discussion will be required to address the seed needs of those farmers whose WTP for quality seed is below the price at which certified seeds are sold in the market. For example, research is needed on how to lower the cost of producing quality seed so that per unit cost can be brought closer to grain price, while still providing a sufficient profit motive for seed producers. One possibility is to develop training and support capacity building of seed producers that can deliver and support the development of new innovative technologies in seed production and quality assurance monitoring systems that can both lower the cost of quality assurance system and reduce the rejection of seeds that do not meet quality standards, can increase the seed yield, and thus lower the cost per unit of seed produced. In the case of Ghana, the high price elasticity of demand for quality seed observed in this study implies that lowering the price of good quality certified seed can substantially increase the revenues for seed producers from increased demand. Thus, from a policy perspective it makes economic sense for governments to invest in programs that lower the cost of seed production and increase the supply of quality seeds.

Recall that farmers' choice of which seed plot was the best and which one was the worst was more decisive in the case of Ghana than in the case of Tanzania. This higher degree of agreement or consensus among participants in Ghana on the perceived best and worst seed is reflected in a higher average premium across all the farmers. This was confirmed by the significant differences in the yield and other objective measures of quality observed for different seed plots in Ghana, but not in Tanzania. The results are thus indicative of the important role perceived yield advantages of different quality seeds play in influencing the size of the price premium farmers are willing to pay. For crops and in settings where the significant advantage of planting good quality seed compared to recycled seed can be

[15] In many developing countries, including Tanzania and until recently, in Ghana, the multiplication of early generation seeds (i.e., foundation/basic seed) of public varieties is controlled by the public sector. The high cost of seed multiplication and the limited capacity of the public sector to produce early generation seeds of legume crops such as beans and cowpeas is often cited as the major constraint for the formal sector to produce and supply certified seeds in adequate quantities to meet the demand. Recent estimates suggest that for cowpea, the formal seed system in Ghana has the capacity to produce certified seeds that can be planted on at most 1% of cowpea area in the country (AGRA/USAID 2017). In the case of Tanzania, the quantities of certified bean seeds produced in the country was reported to be 80 MT (in 2008/09), which was enough to meet at most 0.2% of the total quantities of seed needed to plant the bean area in the country (ASARECA/KIT 2014). A more recent assessment estimates that the formal bean seed system in Tanzania can meet the seed need for 1-5% of total bean area in the country (AGRA/USAID 2016).

demonstrated (i.e., where one can really show product quality differentiation between grain and seed), it is possible to see a higher willingness to pay, and thus a higher demand for fresh seed, which can stimulate more private sector investments in the seed system.

6. CONCLUSION

This study was designed to explore the impact of perceived seed quality on farmers' willingness to pay a premium for different types of bean and cowpea seed. Three types of seed products were evaluated—certified seeds, quality declared seeds, and recycled grain. Auction experiments were conducted with more than 500 bean and cowpea producing smallholder farmers in two countries to elicit their willingness to pay for seed types based on their performance in the fields, and not on the seed product label (to avoid any bias from pre-conceived notion of seed quality associated with those seed categories). Results indicate that seed quality matters, and on average certified seeds consistently outperformed QDS and recycled seeds. In the case of Ghana, QDS outperformed recycled seed, but this was not the case in Tanzania. Community based QDS production and sale is often promoted as a low-cost option for increasing farmers' access to quality seed within a community. However, if the lower-cost also comes with lower-quality, then farmers may not be willing to pay the price premium reflected in the price of QDS. The results of this study thus raise questions regarding the viability of promoting QDS as a substitute for certified seeds if the seed quality is significantly compromised. As the formal system moves towards a decentralized seed multiplication and marketing model embodied in the QDS system, it is important that proper quality assurance mechanisms are also put in place to ensure quality control. Weak quality assurance processes can damage farmers' trust and discourage them from purchasing quality seed of improved varieties.

The relative difference in farmers' WTP for different seed products was found to be highly correlated with the relative difference in their perceived quality. Results also confirmed the downward sloping demand curve for quality seed, with the number of farmers who are willing-to-pay a premium price for quality seed declining as price of seed increased. For the highest rated seed, the demand was more elastic for cowpea seeds on Ghana than for the bean seed in Tanzania. The implication of these findings is that there is no one-size-fits-all strategy to meet the seed needs of all the farmers (Louwaars, de Boef, and Edeme 2013; ASARECA/KIT 2014). Policies and programs are needed to increase the availability of qualitatively better performing (i.e., higher germinating, disease-free, and non-mixtures) seed products to smallholder farmers that are within the range of price premium farmers are willing to pay. Lowering the cost of producing higher quality certified seed to no more than 1.5 times the cost of grain production is key to getting quality seed products for crops like beans and cowpeas into the hands of more farmers, and thus increasing their effective demand and sustaining a more vibrant seed system. While cost-reducing strategies through policy, programmatic and technological options should remain a high priority for governments and donor-supported programs such as AGRA, this study also indicates the need for continued support for innovative and smart subsidy-based approaches to meet the needs of 15-20% of farmers whose WTP for seed is so low that for-profit seed production / marketing models will not work.

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