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ORIGINAL PAPER

Farmer demand for certified legume seeds and the viability of farmer seed enterprises: Evidence from Myanmar

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Abstract
Legume seed systems in many developing countries are characterized by low availability of certified seeds because the private sector is often absent, and the public sector has limited capacity to produce such seeds. Farmer seed enterprises (FSEs) are therefore increasingly promoted as alternative suppliers of certified and in some instances, quality declared and truthfully labelled seeds. In this study, we assess the commercial viability of FSEs that produce chickpea and green gram certified seeds by comparing average seed production cost, inclusive of opportunity costs and expected profits, with consumers' willingness to pay (WTP) price. The cost of seed production data come from a survey of 63 FSEs and the data on WTP are from the Becker, DeGroot, Marschak (BDM) bidding experiments conducted with 512 farmers from the Central Dry Zone of Myanmar. We find that the post-harvest storage cost during the 7–8 months between harvest and the next planting season contributes significantly to the total cost of producing seeds. Forty-seven percent of chickpea farmers and 53% of green gram farmers were willing to pay equal to or higher than the average minimum cost of producing certified seeds. which is as an upper bound estimate of potential market share for FSEs' certified seeds. This potential customer base of FSEs can be further increased by reducing the cost, especially post-harvest and labor costs. What role government, private companies, and NGOs could play in reducing the cost and increasing the demand for certified seed are important policy research questions discussed in the paper.

Keywords Quality seed · Willingness to pay · Cost of production · Farmer seed enterprise · Legume seed demand · Myanmar

1 Introduction

The use of quality seeds of improved varieties is critical for agricultural productivity growth and poverty reduction (Evenson & Gollin, 2003; Awotide et al., 2013). Yet, in many developing countries, the low capacity of the public sector and the limited role of the private sector in the seed system restrict the availability of certified seeds that go through a quality assurance process of meeting standardized thresholds of seed quality in terms of germination rate, viability, purity, and varietal identity. This is especially the case for self-pollinated crops like legumes and vegetatively propagated crops like potatoes and cassava. Most smallholder farmers thus rely on recycled seeds from the informal sector—i.e., farm-saved seeds, exchanges with other farmers, or purchases from other farmers/grain markets—where quality is signaled through reputation and branding (David, 2004). Although, seeds from the informal sector are purposively selected and managed as seed and are thus better quality than harvested grain destined for consumption, they don't undergo any physical or physiological quality testing. The quality of recycled seed is thus unknown or generally perceived to be of varying quality (Biemond, 2013; van Gastel et al., 2002).

In Myanmar, legumes are the second major crop category after rice. A representative survey in the Central Dry Zone of Myanmar in 2018 found that chickpea significantly contributed to the income of 73% of households and green gram to the income of 46% of households (Boughton et al.,

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2020). Despite their importance, yields for those crops are extremely low in Myanmar. One of the reasons for low yields is the low use of high-quality seeds of superior varieties (Broek et al., 2015; World Bank, 2016). Farmers rarely use certified seeds in Myanmar because the supply is limited. Other forms of locally produced seeds that signal high quality such as quality declared or truthfully labelled seeds are mostly unavailable (Boughton et al., 2020; Cho et al., 2017; Mather et al., 2018; World Bank, 2016). Thus, how to increase the supply of quality seeds has remained an important policy issue in Myanmar as it has been in other developing countries.

The literature on the smallholder seed system highlights both supply and demand-side constraints in limiting the rise of a thriving market-based private seed sector for legumes and other self-pollinated crops. Self-pollination produces progenies that are more uniform than those from outcrossing, making it easier for farmers to save some of their harvests to use as seeds for the next season without losing much genetic quality. Seed demand for such crops is thus low (Almekinders & Louwaars, 2002; David, 2004; Maredia et al., 2019). Additionally, the demand is fragmented by diverse agro-ecological zones and consumer preferences. Low and unpredictable demand lower the economic incentives for private sector involvement in seed production and limit the role of the formal system in supplying quality seeds of improved varieties of self-pollinated crops.

Given this reality, many researchers and practitioners have called for approaches that promote seed production at the local level (Almekinders & Louwaars, 2002; Bishaw & Gastel, 2008; David, 2004; Jones et al., 2001; Louwaars & de Boef, 2012; Louwaars et al., 2013; Sperling et al., 2014; Thijssen et al., 2015). These efforts include community seed banks, seed exchange schemes, farmer seed enterprises (FSEs), community-based seed enterprises, and local seed businesses to produce quality declared seeds (QDS).

Even though it is not proven, some researchers believe that FSEs have the potential to be more sustainable given their business orientation and profit motivation (David, 2004; Srinivas et al, 2010). Indeed, recent years have witnessed a proliferation of NGO and donor projects supporting this kind of local-level seed production in many developing countries, including Myanmar.

Despite this proliferation, there exists little evidence on the viability of FSEs as commercial enterprises. Earlier studies had raised concerns of sustainability of FSEs, especially after the end of the donor and NGO support (Cromwell et al., 1993; Cromwell, 1997; Tripp, 2001; and Tripp & Rohrbach, 2001). However, a few recent studies have argued that they could be profitable and sustainable with careful implementation, monitoring, strategic marketing, and better institutional linkages with research and formal institutions (Afari-Sefa et al., 2015; Amsalu et al., 2015; Bishaw & Niane, 2015; Srinivas et al., 2010; Katungi et al., 2011; and Witcombe et al., 2010). However, there remains a gap in the literature on assessing the viability of FSEs from both supply (i.e., the profitability of FSEs) and demand (i.e., willingness to pay price for seeds produced by FSEs) perspectives. We address this gap by doing a case study of FSEs in Myanmar that produce certified seeds of chickpea (*Cicer arietinum*) and green gram (*Vigna radiata*).

Our focus on the assessment of the viability of FSEs is timely for two reasons. First, contrary to the conventional wisdom, the role of retained legume seeds from the previous harvest as the most important source has been declining. In the case of Myanmar, free exchange and distribution of seeds are also rare. Instead, there is a vibrant seed system that already exists, and farmers are accustomed to purchasing seeds from their neighbors, traders, vendors, and the government. The study by Boughton et al. (2020) conducted in the same region as this study, found that more than 50% of the seeds planted by legume farmers were purchased either from the informal (45%) or the formal sector (10%). This characteristic is not unique to Myanmar. A recent study in African countries also found that more than 50% of legume seeds were purchased and majority of those purchases were from the informal sector (McGuire & Sperling, 2016; Sperling et al., 2021).

Second, even though demand for legume seeds is robust, this demand is diverse and fragmented across different agro-ecological zones and consumer preferences, which prevents large-scale seed producing companies to benefit from specialization and economies-of-scale. Grassroots level seed production models like FSEs are better suited to meet this diverse and fragmented seed demand due to their local presence (Rubyogo et al., 2007). Together, these two characteristics of legume seed system—presence of the vibrant informal seed market system and diverse/fragmented demand–offers a potential business opportunity for FSEs, if they can produce quality seeds at a cost lower than the price most farmers are willing to pay. Investigating the potential of this possibility is thus an important research question and the focus of this study.

This study was conducted in the Central Dry Zone of Myanmar, a major chickpea and green gram producing region, and where the NGO-supported Integrated Seed Sector Development (ISSD) program had started promoting quality seed production based on the FSE model. We conducted the cost of production (CoP) survey of 63 FSEs that produced chickpea and green gram certified seeds under the ISSD program. For demand estimation, we conducted the Becker et al. (1964) mechanism (BDM) to elicit willingness to pay for different types of seeds, including certified seeds produced by FSEs. The BDM experiments were conducted with 512 farmers, selected from 11 villages in the area where FSEs operate. Bringing both the demand and supply side perspectives to address the commercial viability of a seed business model is a unique contribution of this study. This study also contributes to the ongoing policy debates on the legume seed sector development to promote the adoption of quality seeds and draws some generalizable lessons on the role of local seed production models which have been advocated by the development community in many other countries.

The study finds that on the demand side, 47% of chickpea farmers and 53% of green gram farmers were willing to pay a price equal to or higher than the actual average cost of FSE certified seed in BDM experiments. These percentages provide a theoretical maximum or an upper bound estimates of potential market share of FSEs' certified seeds. On the supply side, a major contributor to the cost of seed production is the post-harvest cost such as financing, storage, and labor associated with long storage time (7–8 months between harvest and next planting season). Together, these post-harvest costs contribute 39% to the total cost of producing seeds and is a key challenge for FSEs' commercial viability. Thus, how to bring down post-harvest seed handling costs and risks associated with the long storage time so that the price of seed is brought below the price most farmers are willing to pay remain important issues to be addressed by policy makers and future research.

The rest of the paper is organized as follows. In Section 2, we describe the current seed system in Myanmar. In Section 3 we discuss the research method and data, followed by descriptive statistics in Section 4 and the presentation of results in Section 5. We conclude with discussions and implications in Section 6.

2 Current seed system in Myanmar

Myanmar's current seed sector can be classified into three major systems—the informal, the formal, and the semi-formal. These three systems differ in their target crops, the quality of seeds, variety type, and distribution channels (Broek et al., 2015). The informal seed system includes farm-saved seeds, grains purchased as seeds in the local market, and grains purchased as seeds from other farmers. Seeds from the informal sector are not certified and thus come with no formal quality assurance even though there might be some form of social assurance through reputation and trust that come from repeated transactions. Seeds are often identified by local names and mostly represent landraces and recycled improved varieties.

The formal seed system includes the government and the seed companies. For many agricultural activities including seed supplies and development of new varieties, the government mostly focuses on rice, the major staple crop, and to some extent sunflower and black gram due to food security and political reasons (Boughton et al., 2020). Even for rice, the public sector supplied less than 5% of the paddy seed requirement in 2013–2014 (Broek et al., 2015). The public seed supply is even lower for non-paddy crops; for instance, less than 0.8% of the green gram seed requirement in 2013–2014 was fulfilled by the public sector.[1] The private sector involvement is minimal and limited to producing hybrid seeds of exotic and improved vegetables, maize, and hybrid rice. For instance, out of 43 companies active in seed production in Myanmar, 39 are producing seeds of hybrid maize and vegetables (MoALI, 2016).

Two main reasons for the limited involvement of the private sector in Myanmar are stringent seed laws and regulations, and the unfriendly business climate. Foreign investment in the seed sector is one of the restricted sectors where 100% foreign ownership is not allowed for the import, production, and multiplication of seeds (Broek et al., 2015). As a result, many foreign companies are operating through local Myanmar agents to sell imported seeds. The law which guarantees intellectual property rights such as breeder rights is yet to be enacted in Myanmar (World Bank, 2017). Myanmar ranked 34th out of 62 countries in terms of having an enabling environment for plant breeding, variety registration, and seed quality control. In addition, the business climate is not conducive enough to attract the private sector due to social and political unrest. Myanmar ranked 171st out of 190 countries, according to the World Bank's Ease of Doing Business Indicators in 2019.

The semi-formal system of producing quality declared seeds and truthfully labeled seeds at the local level through community-based seed enterprises and seed banks, which are increasingly popular and important in other developing countries, are not yet common in Myanmar. The ISSD program of Wageningen University, which was initiated in 2018 comes closest to a semi-formal system in Myanmar but with a focus on producing certified seeds. ISSD provides registered seeds purchased from the Department of Agriculture (DOA) to their trained local farmers who operate as FSEs. It provides technical assistance on seed production, packaging, and marketing to FSEs. It also plays a coordinating role between FSEs, the government, and farmers. The advantage of this system is that FSEs are trained to produce quality seeds, so the seed quality is higher than the informal system. Since only certified seeds are recognized under the current seed law, FSEs can only sell seeds that are inspected and certified by the government. The question for this type of system is their commercial viability—i.e., the ability to

[1] In 2013-2014, the government produced 82.63 tons of certified seed for green gram (Broek et al., 2015). The total green gram sown area for that year was around 1.2 million hectares according to the Myanmar Central Statistical Organization 2016 data, so if we assume at the seed rate of 8 kg/hectare, only 0.8% of the green gram seed requirement were fulfilled by certified seeds produced by the public sector.

sell seeds at a price that can cover the production cost and earn them enough profit to survive as a business enterprise.

With the minimal level of private sector involvement, the low capacity of the public sector, and the limited development of the semi-formal system, the supply of seeds that have gone through formal or semi-formal quality assurance is limited in Myanmar. Myanmar's farmers thus heavily rely on recycled seeds, i.e., grains specifically saved/exchanged/sold as seeds.

3 Methods and data

3.1 Study region and timing

Chickpea and green gram are mainly produced in Mandalay, Sagaing, and Magway regions of Myanmar's Central Dry Zone. In 2015–2016, about 60% and 96% of the total cultivated area for green gram and chickpea, respectively, were in this region (Myanmar's Central Statistical Office, 2016). We conducted the CoP survey in 2018 for green gram and in 2020 for chickpea. Our sample for the cost of production (CoP) survey includes all chickpea and green gram FSEs working with ISSD at the time the study was conducted. They were based in Madaya, Patheingi, and Kyaukse townships of the Mandalay region, and Chaung-U, Myinmu, and Monywa townships of the Sagaing region.[2] In total, our sample has 15 green gram FSEs and 48 chickpea FSEs.

Typically, these two crops are cultivated once a year in both regions, but at different times. The CoP survey for green gram covered the growing season for the crop from April-June 2018 in Mandalay and from July–September 2018 in Sagaing. This was the first year the ISSD program had supported the production of green gram seed in these two regions. They similarly initiated their support for chickpea seed production in the November 2019-February 2020 season in both Mandalay and Sagaing. The CoP data for chickpea corresponds to this 2019–20 season. In this cost of production survey, we captured the detailed cost information for each farm activity. This includes the disaggregated level data on the cost of inputs, seed, labor, draft animals, mechanization, storage, and inspection. About 46% of sampled FSEs for chickpea and 67% for green gram also produced grains to sell for consumption in the same season as certified seed production (Table 2). For those FSEs, we also collected similar cost information for grain production to calculate the opportunity cost. Other additional information we collected are yields from both types of production, and market prices for the sale of their harvested products.

We conducted BDM experiments in eleven villages in Kyaukse and Myit Thar townships of the Mandalay regions. Our selection of villages was purposive and based on a list of villages obtained from another study conducted in the previous year to estimate farmer demand for quality seeds for eight crops including green gram and chickpea (Boughton et al., 2020). Their survey was representative of six townships in the Central Dry Zone.[3] We used the listing information from this survey to identify major chickpea or green gram growing villages and contacted their village heads to seek their help in organizing the proposed exercise.

Eleven villages, all in the Mandalay region, were selected based on their availability to participate within the timeframe we had planned to do data collection. Of these eleven villages, eight villages grew chickpea, ten grew green gram, and seven grew both crops. For our BDM experiments, we targeted 250 farmers for each crop. With this aim, we contacted village heads to invite on average about 25 farmers per crop to participate in our experiments prior to implementing the BDM mechanisms. On average, about 25 farmers participated for chickpea and 30 farmers for green gram in each experiment. For those villages growing both, we conducted BDM experiments two times—one for each crop. If farmers grew both crops and they were willing to, we allowed them to participate in both experiments. 37% (190 farmers) participated in both experiments. For those villages where we implemented two experiments, we randomized the crop order of the experiments to avoid order effects. We show the sample size by location in detail in Supplementary Information E.

Table 1 compares the timing of BDM experiments vis-à-vis the cultivation season for the two crops in the Mandalay region. BDM experiments for both crops were implemented in August 2018. Relative to the crop growing season, the timing relative to harvesting and planting seasons for these two crops is different. For chickpea, the BDM experiments were implemented 2 months before the planting season (or five months after the harvest season) and for green gram, it was implemented 7 months before the planting season (or one month after the harvest season). This timing issue has important implications for the storage and interest costs as well as WTP prices when we later compare the CoP for seed and the WTP price to estimate the demand for certified seed.

3.2 Becker-Degroot-Marschak (BDM) experiment design

We elicited farmers' willingness to pay for different types of seeds using Becker et al. (1964) mechanism (BDM), a

[2] Myanmar is divided into 14 provinces/7 states and 7 regions. States/regions are then subdivided into townships.

[3] They include the townships of Myinmu and Monywa in Sagaing Region, the townships of Magway and Pwint Phyu in Magwe region, and the townships of Madaya and Kyaukse in Mandalay region.

Table 1 Crop cultivation season for chickpea and green gram and the timing of BDM implementation in Mandalay

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
Chickpea growing season	×	×	×	×								
Green gram growing season						×	×	×				
BDM implementation										×		

method used by several studies to assess WTP for seeds of grain crops (Maredia et al., 2019; Mastenbroek et al., 2021; Morgan et al., 2020) and vegetatively propagated crops (Maredia & Bartle, 2022). BDM is, by design, incentive compatible, as people are put in a well-simulated market environment with real money, goods, and market information (Lusk & Shorgen, 2007).

There are two commonly used methods in BDM: an endow-upgrade method and full bidding. In an endow-upgrade method, participants are endowed with a good A and then asked to bid to exchange the endowed product with another good B. On the other hand, in full bidding, participants are bidding both good A and good B simultaneously. The literature finds that full bidding is more suitable if similar products are readily available in the market (Alfnes, 2009; Lusk & Shogren, 2007). Thus, we used the full bidding approach in this study.

Each of our BDM experiments includes two rounds of biddings and quality ratings, and a structured survey. In both rounds, we presented products representing the same variety—Yezin 14 for green gram and Yezin 6 for chickpea. The choice of these varieties was based on local familiarity and popularity, which was assessed through findings from the previous larger household survey by the Food Security Policy Project in the same region in 2018, and discussions with farmers and ISSD (Boughton et al., 2020). Round 1 included five products, two-grain items representing the informal seed system—1) grain produced, selected, and managed by a farmer as seed and 2) grain purchased from the market that was specifically sold as seed, and three certified seed (CS) products representing the formal and the semi-formal seed systems—3) CS from the government, 4) CS from the private company, and 5) CS from the farmer-based seed enterprise (FSE).[4] We chose to include only these products because they are the most common types of seeds available to farmers. As noted earlier, quality declared or truthfully labeled seeds are not produced or available for sale in Myanmar.

[4] We would like to emphasize that the two grain seed products were distinct from grains sold in the market for consumption. We sought to purchase the grain seeds from a local farmer who had the reputation of selling his harvested grain specifically selected for planting purpose, and thus claimed to be better quality than grain for consumption. Indeed, we paid higher price for these 'grain seed' (MMK 1563 for chickpea and MMK 3000 for green gram) than the prevailing market price for grain (MMK 938 for chickpea and MMK 1563 for green gram).

In Round 1, we displayed all five items in bulk and provided information on the type of seeds (grain vs. CS) and the information on where the seeds were sourced and who were the producers. In Round 2, we included product variations with additional information on packaging and quality lab test labeling to address some other research questions that are not part of this study. In the following sections, we focus only on the results from Round 1.

We procured products 1 and 2 from a grain-producing farmer (that had the reputation of selling grain as planting material) in one of the non-experiment villages located in the study region, product 3 was procured from the government– Department of Agricultural (DoA) township office, located in Madayar township, Mandalay region, and products 4 and 5 from the FSEs working with the ISSD. At the time we conducted the BDM, there was no private company providing certified seeds for either green gram or chickpea. So, we used the seeds procured from an FSE to display as company seeds (i.e., product 4). Since products 1 and 2 were essentially from the same source and products 4 and 5 were also from the same source, the experiment was designed to measure is the effect of the quality signaling conveyed in the information about the source of seeds (i.e., a grain farmer, CS from the government, CS from a company, and CS from FSE).

BDM could be either conducted at individual level or in a group setting (Lusk & Shogren, 2007). All our experiments were conducted by the experimenter in a local language in a group setting as it was more convenient in terms of logistics and time. The experimenter followed a script to make sure the information shared with farmers was consistent across all the experiments (see Supplementary Information A for a copy of the script). The participants were allowed to ask questions, but the experimenter reiterated the points from the script in responding to the questions.

The experiments proceeded as follow. As farmers arrived at a meeting location they were registered and assigned an ID number. As an introduction, the experimenter explained to farmers the general purpose of the study and the overview of the study protocol. After the consent process, a practice round of BDM was conducted using a toothpaste. This was followed by the first Round of biddings for the five seed products displayed in containers that could hold one pyi of seed.[5] The experimenter introduced each seed product

[5] One Pyi is the local unit commonly used in Myanmar and is approximately equal to 2 kg.

in terms of whether it was grain or certified seed and who the producer was (i.e., farmer, government, company, or FSE).[6] Participants were allowed to touch and inspect the seeds. Each participant received a bidding sheet to record their individual bids for the five seed products. They were discouraged from discussing their bids with other farmers. After collecting the bid sheets, farmers were asked to complete the quality ratings of each seed product.

Farmers were free to bid from zero to as much as they would like to pay for one pyi of seed with an increment of 50 kyats.[7] Our data has less than 1% with bids of zero value so censoring, which comes from participants transforming their negative WTP to zero price, may not be an issue in our sample.

We provided participants a participation fee equal to MMK 8,000 for green gram and MMK 7,000 for chickpea.[8] These amounts were slightly more than double the price of one pyi of certified seeds for the respective crops paid by the researchers to procure the seeds for the experiments. This participation fee ensured that farmers had cash at hand to pay for the product if their bids were higher than the random price (explained below). In general, the literature finds mixed evidence on the provision of cash endowments, i.e., farmers may not perceive the participation fee as their own, which may compel them to make riskier decisions and may not take into consideration trade-offs they normally consider in a real-life situation (List & Rondeau, 2003). However, a participation fee is still widely used in experiments, especially when the major focus is to estimate incremental value (or premium) a participant is willing to pay for a new product (i.e., CS in this case) relative to a base product (i.e., grain seed) whose market value is well established (Loureiro et al., 2003; Maredia et al., 2019).

Even though farmers made bids on all five products in each round, only one product was selected for sale, a rule that was explained to farmers in the introduction. For logistical reasons, the highest quality seed—procured from FSE—was pre-selected as the binding product. This was conveyed to the participants at the end of the two Rounds. A coin was tossed to select the binding round. For random price selection, one participant was asked to come forward and press a key on the computer which was programmed to generate a random number between 0 and the price of the highest quality seed we had paid to obtain the seed. This upper range was not revealed to the farmers at any time. Farmers whose bids for the binding product (in the selected Round) was greater than or equal to the random price purchased one pyi of seed at the random price and received the difference between their participation fee and the random price. Those with bids less than the random price received the full amount of their participation fees. As a final step, the enumerators conducted the survey interview with each farmer to collect information on farmer and household characteristics and chickpea/green gram production and seed use practices.

4 Results

4.1 Characteristics of BDM participants and seed producers

Table 2 presents the summary statistics of seed producers included in the CoP survey. Most of our seed producers (90%) were male with an average age of 48 years.[9] The educational attainment of producers was quite high with an average of 8.5 years. On average, producers devoted about 1.65 hectares to chickpea seed production, 3.06 hectares to chickpea grain production, 0.82 hectares for green gram seed production, and 1.49 hectares for green gram grain production.[10]

Table 2 also shows the characteristics of our farmers who participated in BDM experiments. The sample was almost equally split between men and women. Participants were mostly smallholder farmers with an average land holding of 2.32 hectares for chickpea and 2.39 hectares for green gram. An average participant in our study belonged to a household with 5 members, was 50 years old, was literate, and had 5 years of education. Slightly more than half of participants identified themselves as the head of their households.

Even though it is not a pre-condition to participate in the experiments, we encouraged main decision-makers to

[6] Note that under the Myanmar seed law, only certified seed can be labeled and sold as 'seed' by a non-farmer. To comply with the law, we did not label the two informal sector seed products as 'seed' but referred them as 'grains.' Also, as per the local custom and common understanding, the term 'seed' is equated to 'certified seed', which in Myanmar language translates to "quality seed." Other than certified seed, the only other type of 'seed' is 'grain for planting purpose,' which farmers understand as 'grain from previous harvest that is saved specifically for the purpose of using it as seed'.

[7] We asked the farmers to bid at an increment of 50 kyats because it is hard to find the currency notes or coins lower than 50 kyats. Moreover, sale prices of most of the products start at minimum 50 kyats in Myanmar.

[8] 1$ was approximately equivalent to MMK 1,400 in 2018 when the study was conducted.

[9] Seed production is a 'business enterprise' with a higher expected return and requires more land and capital investment. In many developing countries, large-scale, commercial, and business-oriented farms tend to be owned/managed by men rather than women. It is thus not surprising that 90% of managers/decision makers of FSEs we interviewed were men.

[10] FSEs differentiated different plots for seed and grain production as seed production is more management intensive and requires higher level of inputs and labor.

Table 2 Characteristics of BDM participants and seed producers

	Seed producers			
	Chickpea (N = 48)		Green Gram (N = 15)	
	Mean	SD	Mean	SD
Producers' characteristics				
1 = Male	0.9	0.31	1	0
Age (Years)	48.81	11.02	48.33	8.65
Highest level of education attained (including 0)	8.45	3.33	8.93	3.28
Household characteristics				
1 = Produced grain in the same season as seed production	0.46	0.5	0.67	0.49
The total area of seed cultivation (hectares)	1.65	1.95	0.82	0.44
	Chickpea (N = 22)		Green Gram (N = 10)	
Total area of grain cultivation (hectares)	3.06	5.75	1.49	1.39
	BDM Participants			
	Chickpea (N = 254)		Green Gram (N = 258)	
	Mean	SD	Mean	SD
Participants' characteristics				
1 = Male	0.54	0.49	0.52	0.50
Age (Years)	48.24	11.46	48.79	11.69
1 = Able to read and write	1	0	1	0
Highest level of education attained (including 0)	4.88	2.97	4.88	2.93
1 = Household head	0.59	0.49	0.55	0.49
1 = Main decision-maker of chickpea/green gram cultivation	1	0	1	0
1 = Self-identified as an early adopter of a new technology	0.24	0.43	0.25	0.43
1 = Belongs to a farmer group	0.06	0.23	0.09	0.77
Household characteristics				
Household Size	4.30	1.52	4.31	1.50
1 = Access to irrigation	0.75	0.43	0.88	0.33
Total agricultural land owned (hectares) (including 0)	2.32	1.87	2.39	1.79
Distance to the nearest paved road) (including 0)	3.35	4.25	3.07	3.88

Source: FSE and farmer surveys conducted by authors

participate in the BDM as they are more familiar with different quality of seeds and making seed purchasing decisions. All participants were main decision-makers of chickpea or green gram cultivation. About a quarter of the participants self-assessed as early adopters of new technology. Only a small percentage of participants (6% for chickpea and 9% for green gram) belonged to any farmers' group. Most participants had access to irrigation, and on average, lived about 2 miles away from the paved road.

As expected, most participants had used recycled grain as seed (Table 3). Only a small share of participants had experience using certified seeds from either the formal or the semi-formal sector. Seeds from the government (8% for chickpea and 12% for green gram of participants) were the most common formal system seed sources. Only a negligible percentage of participants had used CS from a private sector—i.e., a company or FSEs.

4.2 Average willingness to pay and quality ratings

On average, BDM participants were willing to pay a premium for the perceived quality difference between certified seeds and grains. The average WTPs of three CS products for chickpea was MMK 2,855/pyi compared to the average WTPs of MMK 2,151/pyi for two non-CS products whereas for green gram, it was MMK 2,993/pyi for CS products and MMK 2,280 for non-CS products respectively. In terms of percentage, farmers were willing to pay a 33% premium for chickpea CS products and a 32% premium for green gram. Table 4 shows the average WTP prices and quality ratings of different seed products. Participants expressed the highest WTP for the seed labeled as company seed, followed by the seeds from FSE, the government, farmer grains, and market grains.

Table 3 Seed related experience

	Chickpea (N = 254)		Green Gram (N = 258)	
	Mean	SD	Mean	SD
1 = Has used saved seeds	0.73	0.44	0.69	0.46
1 = Has used grain from other farmers as seed	0.54	0.50	0.61	0.49
1 = Has used grain from the market as seed	0.72	0.45	0.60	0.49
1 = Has used seed from at least one of the above three sources	0.99	0.11	0.97	0.16
1 = Has used CS from the government	0.08	0.27	0.12	0.33
1 = Has used CS from a company	0.02	0.14	0.03	0.17
1 = Has used CS from FSEs	0.02	0.12	0.02	0.15
1 = Has used CS seed from any source	0.09	0.29	0.17	0.37

Source: Farmer survey conducted by authors

The results of the pair-wise t-test in Table 4 indicate that WTP prices of certified seed products, in general, were statistically significantly higher compared to the two grain products. We also find that bids of FSEs were nominally higher (but not statistically significant) than the WTP price of the government seed. Even though farmers expressed a slightly higher WTP for the company seed (MMK 2,699 vs MMK 2,582 for chickpea and MMK 3,333 vs MMK 3,273 for green gram), the difference between the two sources was not statistically significant. As a reminder, the seeds labeled as company seeds were actually FSE seeds. They were displayed as company and FSE seeds to test whether the source information generated any differential quality signal to the farmers. The non-significant differences in the WTP prices of company and FSE seeds suggest that there are no differential quality signaling effects between the company and the FSE CS; farmers trusted the quality of both company and FSE seeds similarly.

The pattern of perceived seed quality rating farmers submitted was similar to the rank order of bids for different seed products. Company seeds were ranked the highest, followed by the FSE seeds, the government, farmer grains, and the market grains. This suggests that farmers were bidding according to the quality they perceived visually.

There are several other factors such as individual and household characteristics that could affect the WTP price, and without controlling them, the results presented in Table 4 could be biased. To correct for this, we estimate WTP premiums using econometric models described in Supplementary Table B1. Overall, the coefficients from pooled OLS and fixed effects estimates are similar and confirm the pattern described in Table 4.

4.3 Cost of producing seeds

The cost of seed varies from the cost of grain in terms of field production cost (inclusive of early generation seed, additional labor and inputs, and costs of crop inspection), storage costs up to the time of sale, opportunity cost of foregone revenues from grain production, and higher expected returns to investment. The storage and opportunity costs depend on the time of sale. We consider three scenarios of seed sale time to estimate the cost of production—seed is sold at: 1) harvest 2) in the month the BDM experiments were conducted, which was one month after green gram harvesting season and 5 months after the chickpea harvesting season, and 3) at next planting, which was 7 and 8 months after harvesting for chickpea and green gram, respectively.

Table 4 Mean WTP and quality ratings of different seed types

	Chickpea (N = 254)		Green gram (N = 258)	
	WTP (MMK)	Quality rating (1 = Worst 5 = Best)	WTP (MMK)	Quality rating (1 = Worst 5 = Best)
Market grain	1963.53[a] (1254.26)	2.65 (1.04)	2462.98[a] (1302.63)	2.82 (0.95)
Farmer grain	2021.65[a] (1359.63)	2.89 (0.93)	2408.33[a] (1181.36)	2.93 (0.99)
Certified seed-Govt	2435.5[b] (1554.84)	3.89 (1.05)	3212.79[b] (1683.11)	4.17 (0.87)
Certified seed-Company	2699.3[b] (1601.74)	4.28 (0.92)	3333.92[b] (1444.68)	4.22 (0.88)
Certified seed-FSEs	2582.09[b] (1645.28)	4.02 (0.95)	3272.29[b] (1463.77)	4.08 (0.86)

Source: Authors' calculation

Standard deviations are reported in parenthesis

For a given crop, mean WTP values identified by different letters in the superscript are statistically significantly different at $p < 0.01$

To compare farmers' WTP estimates with the cost of production, it is thus important that they both correspond to the same time frame. Later when we make a comparison between the demand and supply of seeds produced by FSEs, we, therefore, focus on Scenario 2. Detailed budgets for grain and seed cost of production are presented in Supplementary Information C.

The difference in field production cost at the harvest time is more pronounced for green gram; the labor and input costs are more than double for seed production than grain production (Supplementary Table C.1). If FSEs were to sell their seeds at the time the BDM experiments were conducted (Scenario 2), they would incur the additional post-harvest costs of storage bags as well as financing and drying costs, which would increase the total cost for chickpea by 30% and for green gram by 8% more compared to costs incurred till harvest time.[11] If FSEs were to wait till next planting (Scenario 3), for both crops, the post-harvest storage cost (inclusive of material, labor, and interest costs) adds about 39% to the total field production costs.[12]

Next, we calculate the break-even prices for seeds under the 3 scenarios by considering gross margins (GM) on grain production and interest fee on foregone GM as opportunity costs of producing seed. The break-even price is estimated to be 1,502 MMK/pyi for chickpea and 2,364 MMK/pyi for green gram if FSEs were to sell their seed production soon after harvest (See Supplementary Table C.2 for details). The break-even prices go up with each additional month of holding the seed inventory, such that in the month we conducted the BDM experiments (scenario 2) the break-even price is 1,890 MMK/pyi for chickpea and 2,525 MMK/pyi for green gram. If FSEs were to wait till the next planting season (i.e., scenario 3), the break-even price further increases to MMK 2,030/pyi for chickpea and MMK 3,243/pyi for green gram. Compared to the harvest time, these break-even prices at the next planting season are 33% higher for chickpea and 38% higher for green gram (Supplementary Table C.2).

Seed production business requires more investment both in terms of time and money and is thus considered riskier than grain production. FSEs would thus have higher expected returns on their investment in a seed enterprise than reflected in the gross margins of grain production. The estimated minimum acceptable prices reported in Supplementary Table C.2 do not account for these additional returns FSEs would expect on their investment in a seed enterprise. Therefore, we adjust the break-even prices to include additional returns to investment that FSEs would expect from their seed entrepreneurship and estimate the minimum acceptable price for seed under the same 3 scenarios. We use the actual price FSEs sold their seed inventory in the following planting season and estimate the realized profits or returns on investment. FSEs in our sample reportedly received MMK 2,500/pyi for chickpea and MMK 4,000/pyi for green gram when they sold their seeds at the beginning of the next planting season. This represents about 23% return on investments for both chickpea and green gram (Table 5).

We apply this same rate of return to investment to estimate the minimum acceptable price if FSEs were to sell their seed in the month when we conducted the BDM experiments (Scenario 2) or soon after harvest (Scenario 1). To earn the same return on investment (i.e., 23%), we estimate that FSEs would expect to sell their seed at minimum MMK 2,334/pyi for chickpea and MMK 3,113 for green gram under Scenario 2, and at minimum MMK 1,849/pyi for chickpea and MMK 2,914/pyi for green gram under Scenario 1 (Table 5).

Next, we bring the supply and demand-side estimates together and compare the minimum acceptable prices with farmers' WTP for FSE seeds and draw implications for the commercial viability of FSEs for the two crops.

4.4 Comparing demand and supply

We expect the WTP price expressed by farmers in the BDM mechanism that occurred a few months before the planting season to be reflective of the opportunity costs of storing seeds. We focus on Scenario 2 in this comparison between the demand and supply of seeds produced by FSEs to align the time frames between farmers' WTP estimates and cost of production.

Figures 1 and 2 present demand curves showing the percentage of farmers willing to pay a given price for FSE seeds, and two supply curves—1) if FSEs were willing to sell the seed at the average break-even price that would recover the input, material, interest, and opportunity cost but not provide any additional returns to investment (depicted by dash lines), and 2) the price that additionally provides FSEs an opportunity to earn a profit at the same rate as what they reportedly earned by selling seeds at planting (depicted by dotted lines). About 63% of farmers were willing to pay equal to or greater than the break-even price for chickpea whereas 67% were willing to pay equal to or greater than the break-even price for green gram. If we use the minimum acceptable price that would earn FSEs the reported returns on their investment, the percentage of farmers who are willing to pay that price is 47% for chickpea and 53% for green gram. We consider these farmers whose WTP price is greater than or equal to the dotted line in Figs. 1 and 2 as potentially having an 'effective' demand. Next, we examine the determinants of this effective demand.

[11] We only included the cost of hermetic storage bag in calculating the storage bag cost. It costed around $1 per bag which could be used for 48 kg of seed. We excluded the cost of normal storage bag for transportation, which was negligible.

[12] The storage cost does not include any cost for physical space or building as this cost was incurred by ISSD for each FSE group.

Table 5 Cost and realized returns on investment by FSE at planting, and minimum acceptable price to earn the same level of returns at harvest and the month when BDM occurred (MMK/pyi)

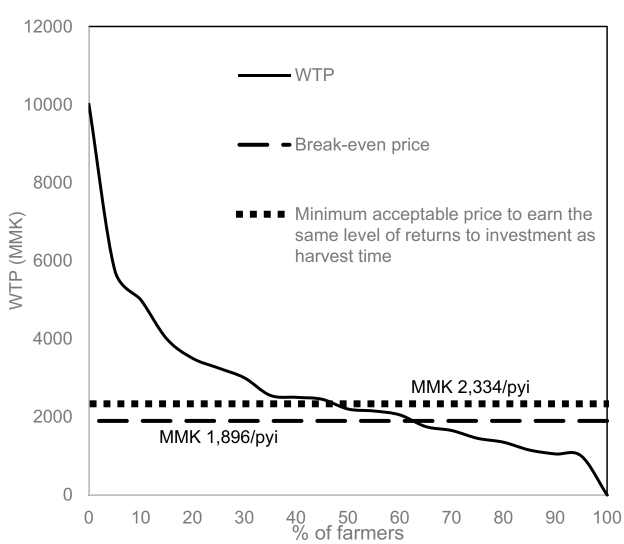
	Chickpea	Green gram
Cost and realized returns at planting time (Scenario 3)		
a. Cost of production \a	2,031	3,243
b. Price sold the seed (reported by FSEs)	2,500	4,000
c. Profits earned (b-a)	469	757
d. Returns to investment [(c/a)*100]	23.10%	23.30%
Cost and minimum acceptable price at the time BDM occurred (Scenario 2)		
e. Cost of production \a	1,896	2,524
f. Expected profits on investments (e * d)	438	589
g. Minimum acceptable price to earn the same level of returns to investment (e + f)	**2,334**	**3,113**
Cost and minimum acceptable price at harvest (Scenario 1)		
h. Cost of production \a	1,502	2,363
i. Expected profits on investments (h * d)	347	551
j. Minimum acceptable price to earn the same level of returns to investment (h + i)	**1,849**	**2,914**

Source: Authors' calculation

\a See Supplementary Information C (especially, Table C.2) for details on how this is estimated

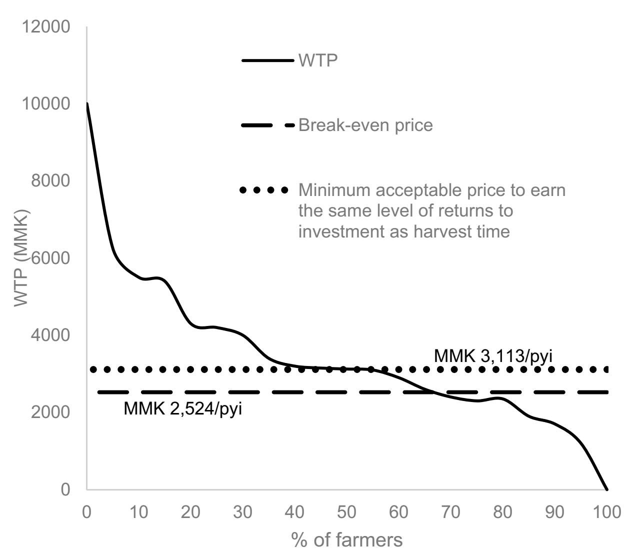
4.5 Determinants of effective demand

Commercial viability of FSEs depends on the size of the effective market demand for seed. To understand the determinants of this effective demand for FSE seeds, we estimated the linear probability model (LPM) with the dependent variable = 1 if farmer's WTP price is equal to or higher than the minimum acceptable price (i.e., MMK 2,334/pyi for chickpea and MMK 3,113 for green gram), and 0 otherwise. Past literature has shown that socio-economic characteristics, demographic characteristics, and institutions (for example, extension, input supply market, etc.) are critical factors in influencing the adoption of quality seed and improved varieties (Negatu & Parikh, 1999). Some of these factors identified in the literature include the role of education (Gerhart, 1975), land size and ownership of favorable land type (Ghimire et al., 2015), access to seed Ghimire et al. (2012), and the availability of extension services and on-farm field trials (Kaliba et al., 2000). Based on the past literature, we included some of the important



Source: Authors' estimates

Fig. 1 Demand curve for chickpea at different acceptable prices in the Central Dry Zone of Myanmar in 2019 from BDM experiments comparing with Cost of Producing Data



Source: Authors' estimates

Fig. 2 Demand curve for green gram at different acceptable prices in the Central Dry Zone of Myanmar in 2019 from BDM experiments comparing with Cost of Producing Data socio-economic factors (i.e., gender, education, age, wealth, etc.) and institutional factors (i.e., access to irrigation, distance to road, membership of farmer groups, etc.), which could possibly influence farmers' willingness to pay more than/equal to the minimum acceptable prices (MMK 2,334 for chickpea and MMK 3,113 for green gram). The socio-economic and institutional information we used in this model are not exhaustive as they are limited to what we had collected in the post-auction survey.

Results are shown in Supplementary Information D. An overwhelming result is that very few characteristics differentiate between farmers with effective demand (i.e., WTP at or above the dotted line) from those with ineffective demand (i.e., WTP below the dotted line). For example, none of the indicators of wealth that would be commonly associated with seed demand—i.e., landholding size, asset index, and tropical livestock units owned are statistically significant. Also, belonging to a farmer group or self-assessed early adopters, both considered indicators of progressive farmers, are uncorrelated with effective demand. The only variables positively correlated with effective demand for chickpea seeds are access to irrigation ($p < 0.05$) and education ($p < 0.1$). For green gram, men had lower WTP, and thus 24% less likely ($p < 0.01$) to be in the effective demand territory than their women counterparts. In contrast to chickpea, having access to irrigation was negatively associated with WTP price for green gram seed ($p < 0.1$). Since both crops are not irrigated, the opposite signs on the correlation between access to irrigation and WTP price could reflect the effect of the timing of the cropping season relative to the practice of irrigation.

5 Discussion and implications

Overall, the demand and supply-side analyses for two legume crops presented in this paper point to the potential viability of FSEs as commercial seed enterprises to increase the availability of quality seeds in Myanmar; albeit with proper policies and supports in place. There are several specific insights that underlie this overall result that have important implications for Myanmar's legume seed system development.

First, farmer demand for certified legume seed is high and robust as reflected in farmers' willingness to pay a significant premium for certified seeds produced by the government (10% for chickpea and 15% for green gram), the private sector (18% for chickpea and 20% for green gram), and the FSEs (16% for chickpea and 20% for green gram) relative to the recycled seeds commonly purchased from other farmers or the market. Second, the WTP premium for seeds produced by FSEs is slightly higher (but not statistically significant) than the WTP premium for the government seed, which is traditionally the supplier of certified legume seeds in Myanmar. This suggests that farmers trust FSEs as credible sources of quality seeds, as much as the government. Together, these two findings point to the existence of market demand for certified seeds that commercial suppliers like FSEs can potentially meet.

But the commercial viability of FSEs depends on two conditions—1) whether the price of seed they are willing to sell is within the reach of what farmers are willing to pay; and 2) how many of these farmers will actually purchase FSE seeds when different quality seeds are available in the market at varying prices. Towards the first condition, an important analysis we undertook in this paper is to estimate the cost of producing seeds by FSEs. We estimated two levels of selling prices—1) the break-even price for FSEs to recover all the field production costs (from planting to harvesting), opportunity cost of foregoing grain production, and post-harvest costs inclusive of the storage material cost, and the interest cost for financing the seed inventory; and 2) the minimum acceptable price that additionally includes a 23% rate of return on their total investment.

We find that about two out of three farmers are willing to pay equal to or greater than the break-even price of MMK 1,360/pyi ($0.97/2 kg) for chickpea and MMK 2,410/pyi ($1.72/2 kg) for green gram. This represents a significant effective market demand for legume seeds if seeds are sold at break-even prices. However, few FSEs would be willing to enter into a seed business if they can earn zero profit. Thus, a more realistic selling price is the minimum acceptable price, which we estimate to be MMK 2,334/pyi ($1.7/2 kg) for chickpea and MMK 3,113/pyi ($2.2/2 kg) for green gram corresponding to the time of the BDM experiment. The percentage of farmers willing to pay equal to or more than these minimum acceptable prices is 47% for chickpea and 53% for green gram. This is still within a decent positive range of effective demand, which is a third key finding of our analyses.

However, the level of effective demand in the range of 47—53% estimated in our analysis should be considered a theoretical maximum or an upper bound estimate of potential market share for FSE seeds due to the second condition mentioned above. These numbers may or may not translate into actual purchase decision for FSE seeds because in the real-world market scenario, different quality seeds compete on the basis of price. Ultimately, the purchase decision by a farmer depends on the relative difference in producer surpluses across all the products. In this scenario, it is possible that a farmer who falls on the higher end of the demand curve for FSE seed (i.e., above the supply price) may still end up purchasing a lower quality grain seed at a lower price if the difference in the WTP and price of that low quality product is greater than the difference in the WTP and price of FSE seed. We lack data to estimate these relative differences in producer surplus across all the products to parse out how many of these farmers whose WTP for FSE seeds is above the supply price would actually purchase FSE seed when also offered a lower quality seed at a much lower price. Given this limitation, we consider our estimates of 'effective demand' as an upper bound estimate.

Fourth, our results indicate that this theoretical maximum effective demand for FSE seed is uncorrelated with most of the household characteristics we included in the determinant analysis model. This does not mean that WTP price is not determined by any household characteristic. What it means is that it is not associated with characteristics that we included in the analysis, some of which are often associated with economic status and thus ability (and willingness) to pay such as education, land holding, asset index, and number of TLU owned. We are thus not able to identify farmer characteristics that could be targeted to promote FSE seeds. Future studies should collect more data or expand the sample size to better detect and understand the correlates of WTP for certified legume seeds produced by FSEs.

Based on the detailed cost analysis, we identify two cost components that could be targeted by programmatic and policy interventions to bring down the cost. First is the post-harvest component. Since chickpea and green gram are one-season crops and farmers tend to buy seeds at planting time, FSEs need to wait about 7 months for chickpea and 8 months for green gram to sell their products as seeds. The post-harvest cost, inclusive of storage materials, financing, and labor contributes significantly—about 30%–to the total cost of producing seeds. Second is the labor cost component. The field production costs (from pre-planting to harvesting) of producing seeds and grains are very similar for chickpea but for green gram, the seed production cost is 45% higher than the cost of producing grains. This is because more labor and inputs are required for producing green gram seeds compared to grains. The labor and input costs for green gram seed production are approximately 3.5 times and 2.6 times higher than producing grains, respectively.

How to bring down these post-harvest cost and labor costs is an important policy question. We offer four possible policy options that the government and NGOs could consider. First, the government can play an important role in providing financing at a lower interest rate to reduce the cost of storing seed inventory. The Myanmar government provides seasonal loans to farmers through Myanmar Agricultural Development Bank (MADB) at 8% annual interest. These loans target smallholder crop production and provide about $100/acre for paddy farmers and about $35/acre for non-paddy farmers for up to 10 acres. Since the size of these loans is quite small to use for both grain and seed production, the government should increase the loan amounts for seed production or consider FSEs as small-and-medium enterprises (SMEs) that can qualify for low-interest SME loans from commercial banks. This could reduce the cost of capital, which is currently sourced from the informal sector at an annual rate of up to 48%, and significantly bring down the opportunity cost of holding the seed inventory for 7–8 months post-harvest.

The storage cost in our calculation does not cover any cost for renting a physical space or constructing a storage facility as these costs were incurred by ISSD for each FSE group. However, many FSEs expressed the importance of upgrading the traditional and basic storage facility built in the backyard to an air-tight storage facility to minimize seed quality degradation. This implies even higher cost for storage if FSEs will need to bear these costs at the end of the project. Thus, our second recommendation is that the government and NGOs should consider supporting the FSEs through upgraded community level seed storage system or providing subsidies to construct such community storage facilities.

Third, even though there is currently no input subsidy programs in Myanmar, NGOs or the government could consider providing input subsidy, especially for green gram seed producers. Finding a way to replace labor with machinery and subsidizing the cost of machinery purchase or rental services could be a good strategy to reduce high labor cost. Mechanization as well as machinery rental services for small-scale farmers in Myanmar is widespread, but the current available machinery such as combine harvesters are not suitable for the harvesting of legume crops (Win et al., 2020). Thus, more research and innovations are needed to make mechanization adaptable to legume crops.

Other ways the government and NGOs can assist FSEs is to provide them training and extension services to build their technical capacity to produce seeds that meet the quality standards. The goal of such training should be to reduce seed rejection rate, increase the seed yield, and lower the cost per unit of seed produced. Our findings also point out that the remaining one out of two farmers were not willing to pay more than the average cost of producing FSE seeds but expressed their willingness to pay more for the seeds by the private businesses. This highlights the need for the government and NGOs to support FSEs in strategic marketing approaches to expand their market size by changing the perception of farmers and reducing the information asymmetries embedded in producer identity and by sensitizing farmers on the importance of quality seeds to increase their demand. Another important role the government can play to promote FSEs is to increase the supply of quality foundation seeds and making them accessible to FSEs.

The fact that farmers trusted the seeds produced by the private businesses more than FSE seeds by expressing the highest WTPs for the company seeds shows the presence of the demand for the private sector, and thus a role they could play in the legume seed system in Myanmar. However, seeds produced by private companies could be more expensive than the FSEs due to higher sunk costs, i.e., building, land, and processing infrastructure. This indicates the importance of future research focusing on assessing the profitability of the legume seed production by the private sector. The government should also focus on building a better enabling environment such as relaxing seed laws and regulations, and business registration requirements to attract more private sector investment in the seed system and to encourage the possible collaboration between FSEs and seed companies.

Lastly, we would like to add a few caveats to our findings and discuss the implications for further research. First, the implications of the 7–8 months gap between harvest and the next planting season on farmers' WTP price needs further investigation. In this study, to make the demand and supply side estimates coincide with the same time frame, we adjusted the cost of production to match the timing of the BDM mechanism. However, since farmers typically purchase seeds just before planting, future research should aim at conducting the BDM at the time when farmers typically purchase seeds. One of the implications of failing to conduct the BDM during the peak season is the underestimation of WTP values, i.e., farmers' absolute willingness to pay values in off-seasons may be lower than the values they would pay in the peak season. This could lead to inaccurate determination of the market size, i.e., the lower percentage of farmers who are willing to pay equal to or above the average seed price. However, off-season WTPs are still relevant in estimating the relative WTP differences among products.

Second, like many seed demand studies in the past, our analysis only measures demand at one time for one pyi of seeds. This study did not capture the quantity of seeds farmers would be willing to buy at their WTP prices and how often they would purchase the seeds (Maredia & Bartle, 2022). To estimate the potential market size in terms of quantity of seed demand, future research studies should also collect these two pieces of information to estimate total market size for legume seeds.

6 Conclusion

In many developing countries, including Myanmar, there is low availability of certified seeds for self-pollinated crops like legumes. This is due to the limited capacity of the public sector to produce certified seeds and the limited involvement of the private sector. To fill this void, NGOs and other development partners have promoted seed production at the local level through community-based approaches. Among them, FSEs are considered more sustainable due to their business orientation. To assess the commercial viability of FSEs in supplying certified seeds of chickpea and green gram, we conducted BDM experiments to estimate the effective demand or farmers' willingness to pay for certified seeds produced by FSEs and compared them with the cost of production. In Myanmar, free seed exchange and distribution are rare, and a vibrant informal market exists. This case study thus offers an ideal setting to learn about the potential growth of local seed businesses (Boughton et al., 2020).

We find evidence of high and robust demand for certified seeds by smallholder legume farmers. Our results indicate that 50% of farmers were willing to pay a price that would allow an average FSE to recover all its cost and earn a 23% rate of return. This sizable effective demand, albeit an upper bound estimate, suggests that the government should focus on relaxing the seed laws and regulations and building a better business climate to attract more private sector investment and encourage their collaboration with FSEs. However, to make the certified seeds accessible to more farmers, and the seed business profitable to most FSEs, this study highlights the importance of bringing down the cost of producing seeds, especially the post-harvest and labor costs, and the important role government, NGOs, and the private sector need to play in making this happen.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

Afari-Sefa, V., Karanja, D. K., Rajendran, S., Chagomoka, T., Samali, S., Katunzi, A., Mtwaenzi, H., Kimenye, L., & Kessy, R. (2015). Farmer-led seed enterprises as a strategy for improving smallholder income through private contracting and community seed production of traditional vegetables in Tanzania. In C.O. Ojiewo., S.Kugbei., J.C. Rubyogo.(Eds), *Community Seed Production* (pp. 71–79). FAO & ICRISAT.

Alfnes, F. (2009). Valuing product attributes in Vickrey auctions when market substitutes are available. *European Review of Agricultural Economics, 36*(2), 133–149.

Almekinders, C. J., & Louwaars, N. P. (2002). The importance of the farmers' seed systems in a functional national seed sector. *Journal of New Seeds, 4*(1–2), 15–33.

Amsalu, A., Borman, G., Subedi, A., Abay, F., Mohammed, H., Nefo, Kedir., Nefo, Kedir., Dechassa, N., & Dessalegn, T. (2015). Integrated seed sector development in Ethiopia: Local seed business development as an entrepreneurial model for community-based seed production in Ethiopia. In C.O. Ojiewo., S.Kugbei., J.C. Rubyogo.(Eds), *Community Seed Production* (pp. 88–97). FAO & ICRISAT.

Awotide, B. A., Karimov, A., Diagne, A., & Nakelse, T. (2013). The impact of seed vouchers on poverty reduction among smallholder rice farmers in Nigeria. *Agricultural Economics, 44*(6), 647–658.

Becker, G. M., Degroot, M. H., & Marschak, J. (1964). Measuring utility by a single response sequential method. *Behavioral Science, 9*(3), 226–232.

Biemond, P. C. (2013). *Seed quality in informal seed systems*. [Doctoral dissertation, Wageningen University]. https://edepot.wur.nl/259025

Bishaw, Z., & Gastel, A. J. (2008). ICARDA's seed-delivery approach in less favorable areas through village-based seed enterprises: Conceptual and organizational issues. *Journal of New Seeds, 9*(1), 68–88.

Bishaw, Z., & Niane, A. A. (2015). Are farmer-based seed enterprises profitable and sustainable? Experiences of VBSEs from Afghanistan. In C.O. Ojiewo., S.Kugbei., J.C. Rubyogo. (Eds), *Community Seed Production* (pp. 55–64). FAO & ICRISAT.

Boughton, D., Makhija, S., Maredia, M., Mather, D., Megill, D., Ortega, D. L., Payongayong, E., Plataroti, L., Spielman, D. J., Thijssen, M., & Win, M. (2020). *Variety Adoption and Demand for Quality Seed in the Central Dry Zone of Myanmar*. Department of Agricultural, Food, and Resource Economics, Michigan State University.

Broek, J. V., Subedi, A., Jongeleen, F., & Oo, N. (2015). *Pathways for Developing the Seed Sector of Myanmar: A Scoping Study.* Wageningen: Wageningen University: Centre for Development Innovation.

Cho, A., Belton, B., & Boughton, D. (2017). *Crop production and profitability in Ayeyarwady and Yangon*. Department of Agricultural, Food, and Resource Economics, Michigan State University.

Cromwell, E. (1997). Local-level seed activities: Opportunities and challenges for regulatory frameworks. In R. Tripp (Ed.), *New Seed and Old Laws: Regulatory Reform and the Diversification of National Seed Systems.* Intermediate Technology Publication.

Cromwell, E., Wiggins, S., & Wentzel, S. (1993). *Sowing beyond the state: NGOs and seed supply in developing countries*. Overseas Development Institute.

David, S. (2004). Farmer seed enterprises: A sustainable approach to seed delivery. *Agriculture and Human Values, 21*(387–397).

Evenson, R. E. & Gollin, D. (Eds.) (2003). *Crop Variety Improvement and its Effect on Productivity: The Impact of International Agricultural Research*. Wallingford, U.K.: CABI Publishing. http://sherekashmir.informaticspublishing.com/453/1/9780851995496.pdf

Gerhart, J. (1975). *The diffusion of hybrid maize in Western Kenya.* Mexico: International maize and wheat improvement center.

Ghimire, R., Huang, W. C., & Shrestha, R. B. (2015). Factors affecting adoption of improved rice varieties among rural farm households in Central Nepal. *Rice Science, 22*(1), 25–43.

Ghimire, S., Mehar, M., & Mittal, S. (2012). Influence of sources of seed on varietal adoption behavior of wheat farmers in Indo-Gangetic plains of India. *Agricultural Economics Research Review, 25*, 339–408.

Jones, R., Audi, P., & Tripp, R. (2001). Dissemination of modern varieties. The example of Pigeonpea from a semi-arid area of Kenya. *Experimental Agriculture, 37*(4), 539–548.

Katungi, E., Karanja, D., Wozemba, D., Mutuoki, T., & Rubyogo, J. C. (2011). A cost-benefit analysis of farmer based seed production for common bean in Kenya. *African Crop Science, 19*(4), 409–415.

Kaliba, A. R., Verkuijl, H., & Mwangi, W. (2000). Factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones of Tanzania. *Journal of Agricultural and Applied Economcs, 32*(1), 35–47.

List, J. A., & Rondeau, D. (2003). The impact challenge gifts on charitable giving: An experimental investigation. *Economics Letters, 79*(2), 153–159.

Loureiro, M., Umberger, W. J., & Hine, S. (2003). Testing the initial endowment effect in experimental auctions. *Applied Economics Letters, 10*, 271–275.

Louwaars, N. P., & de Boef, W. S. (2012). Integrated seed sector development in Africa: A conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement, 26*, 39–59.

Louwaars, N. P., de Boef, W. S., & Edeme, J. (2013). Integrated seed sector development in Africa: A basis for seed policy and law. *Journal of Crop Improvement, 27*, 186–214.

Lusk, J. L., & Shogren, J. F. (2007). *Experimental Auctions: Methods and applications in economic and marketing research*. Cambridge University Press.

Mather, D., Aung, N., Cho, A., Naing, Z., Boughton, D., Belton, B., Htoo, K., & Payongayong, E. (2018). *Crop production and profitability in Myanmar's Dry Zone*. Department of Agricultural, Food, and Resource Economics, Michigan State University.

Maredia, M. K., Shupp, R., Opoku, E., Mishili, F., Reyes, B., Kusolwa, P., Kusi, F., & Kudra, A. (2019). Farmer perception and valuation of seed quality: Evidence from bean and cowpea seed auctions in Tanzania and Ghana. *Agricultural Economics, 50*.

Maredia, M. K., & Bartle, B. (2022). Excess demand amid quality misperceptions: The case for low-cost seed quality signalling strategies. *European Review of Agricultural Economics*. https://doi.org/10.1093/erae/jbac019

Mastenbroek, A., Sirutyte, I., & Sparrow, R. (2021). Information Barriers to Adoption of Agricultural Technologies: Willingness to Pay for Certified Seed of an Open Pollinated Maize Variety in Northern Uganda. *Journal of Agricultural Economics, 72*(1), 180–201. https://doi.org/10.1111/1477-9552.12395

McGuire, S., & Sperling, L. (2016). Seed systems smallholder farmers use. *Food Security, 8*, 179–195.

Ministry of Agriculture, Livestock and Irrigation (MoALI). (2016). *Road Map for Myanmar's Seed Sector: 2017–2020.* Naypyitaw: Ministry of Agriculture, Livestock and Irrigation (MoALI).

Morgan, S., Mason, N., & Maredia, M. K. (2020). Farmer Valuation of Improved Bean Seed Technologies: Real Auction Evidence from Tanzania. *Food Policy*. https://doi.org/10.1016/j.foodpol.2020.101955

Myanmar Central Statistical Organization (CSO). (2016). *Statistical Year Book 2016.* Naypyitaw: Ministry of Planning and Economic Development.

Negatu, W., & Parikh, A. (1999). The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda (district) of Ethiopia. *Agricultural Economics, 21*(2), 205–216.

Rubyogo, J. C., Sperling, L., & Assefa, T. (2007). A new approach for facilitating farmers' access to bean seeds. *Leisa Magazine, 23*(2), 27–29.

Sperling, L., Boettiger, S., Barker, I. (2014). *Integrating seed systems*. Planning for scale brief #3: AgPartnerXChange. https://seedsystem.org/wp-content/uploads/2014/03/Integrating-Seed-Systems-.pdf

Sperling, L., Gallagher, P., McGuire, S., & March, J. (2021). Tailoring legume seed markets for smallholder farmers in Africa. *International Journal of Agricultural Sustainability, 19*(1), 71–90.

Srinivas, T., Bishaw, Z., Rizvi, J., Niane, A., Manan, A. R., & Amegbeto, K. (2010). ICARDA's approach in seed delivery: Technical performance and sustainability of village-based seed enterprises in Afghanistan. *Journal of New Seeds, 11*(2), 138–163.

Thijssen, M. H., Borman, G., Verhoosel, K., Mastenbroek, Astrid., Heemskerk, W. (2015). Local seed business in the context of

Integrated Seed Sector Development. In C.O. Ojiewo., S.Kugbei., J.C. Rubyogo.(Eds), *Community Seed Production* (pp. 39–45). FAO & ICRISAT.
Tripp, R. (2001). *Seed Provision and Agricultural Development*. James Currey.
Tripp, R., & Rohrbach, D. (2001). Policies for African seed enterprise development. *Food Policy, 26*, 147–161.
van Gastel, T. J. G., Gregg, B. R., & Asiedu, E. A. (2002). Seed Quality Control in Developing Countries. *Journal of New Seeds*, 117–130.
Win, M., Belton, B., & Zhang, X. (2020). Myanmar's Rapid Agricultural Mechanization: Demand and Supply Evidence. In X. Diao, H. Takeshima, & X. Zhang (Eds.), *An Evolving Paradigm of Agricultural Mechanization Development: How much can Africa learn from Asia?* (pp. 263–283). International Food Policy Research Institute.
Witcombe, J., Devkota, K., & Joshi, K. (2010). Linking community-based seed producers to markets for a sustainable seed supply system. *Experimental Agriculture, 46*(4), 425–437.
World Bank. (2016). *Myanmar: Analysis of farm production economics.* Washington, DC.
World Bank. (2017). *Increasing the impact of public spending on agricultural growth.* Washington, DC.

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