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**Yielding Profits? Low Adoption of an Improved Mung Bean
Seed Variety in Southern Bangladesh**

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Abstract

Agricultural technology adoption is an important driver of rural poverty reduction. We study take-up of a specific technology: BARI-Mung 6 (BM6), an improved mung bean seed variety, among smallholder farmers in the southern region of Bangladesh. In contrast to agronomic studies on BM6 performance under highly controlled conditions, we focus on performance of this variety for farmers who are growing outside of the context of an agronomic field trial. We find no evidence of higher performance in this uncontrolled environment: we do not observe statistically significant differences in output or yields between farmers planting BM6 and those planting local varieties. We do, however, observe a significant positive association between BM6 use and yields among farmers who report applying seeds within recommended guidelines. Using a simple model, we illustrate that modest uncertainty around the required quantity of seed per unit area of land can substantively impact the profitability of BM6 seeds for smallholders in our study context. Our findings highlight the importance of providing adequate extension information along with improved technologies to encourage adoption and ultimately improve farmer welfare.

Keywords: Market systems, technology adoption, uncertainty, Bangladesh

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1. Introduction

Market systems interventions have been proposed as a means of achieving sustainable impact on development outcomes at scale (Campbell 2014). Advocates of a market systems approach to agricultural development argue that interventions should strive to address the root causes of constraints that hinder markets from working well for the poor, which will help facilitate trade and improve transactions for the poor and non-poor alike. Market systems interventions for agricultural development are necessarily indirect, targeting non-farming actors' business practices and product marketing to facilitate technology adoption instead of directly promoting the technologies by working with farmers (Osorio-Cortes and Lundy 2018). Such interventions aim to improve the way markets work by attempting to align incentives among actors within the system, which advocates argue, induce changes that are more sustainable.

While many market systems interventions have been implemented, there is limited empirical evidence of their effectiveness in reducing poverty. Moreover, it is unclear whether any impacts supported by market systems interventions have been sustained, which is the main rationale behind the approach. Conroy and Kessler (2019) point out 150 “evidence documents” that exist on market systems development interventions, but their review suggests there are very few impact evaluations of market systems interventions, whether *ex ante* or *ex post*. A challenge is the adaptive nature of market systems thinking or interventions, which requires an adaptive approach to evaluation (e.g. Pasanen and Barnett, 2019), in contrast to what can be considered ‘static’ intervention designs used in most rigorous causal analyses.¹ This may, at least, in part explain the lack of rigorous impact evaluations around market systems interventions: a gap which this study aims to help fill.

In this paper, we consider the potential gains derived from a component of a market systems intervention in the southern delta region of Bangladesh. The goal of the intervention was to increase the take-up of an improved seed variety for mung bean, BARI-Mung 6 (BM6), among

¹ Kasy and Sautmann (2020) suggest and analyze a method of conducting an adaptive experimental design; although they suggest an example hiring extensionists in India, it is not clear that their approach can sufficiently generalize to be feasible in most implementation settings.

producer households, but the intervention was found not to have attributable impacts on the adoption of BM6 (de Brauw et al. 2019).²

The paper has two primary goals. First, we aim to descriptively explore why the intervention did not have stronger effects on BM6 adoption; that is, why farmers may not have taken up this technology, despite its strong performance in agronomic trials. Our data demonstrates that farmers generally did not apply seed at the recommended rate, which could explain why we do not observe yield gains among adopters. To demonstrate how deviations from recommended seed practices might lead to low take-up of the technology, we construct a simple model to demonstrate that in the presence of uncertainty about the seeding rate, adoption may not be optimal for all farmers.

A second objective is to estimate the potential gains of the intervention. Using parameters estimated from survey data, we apply our model with uncertainty about the seeding rate to understand how much added value an intervention in mung beans could potentially provide in project areas if yield gains were realized, and technology adoption was much higher. As we only estimate maximum additional revenues among retailers and do not make assumptions about costs, our estimates represent an absolutely upper bound for overall benefits to such an expansion. Since market systems proponents suggest such scale-up should occur naturally after the intervention, understanding maximum potential benefits in an *ex post* manner can speak to future cost effectiveness of such interventions.

Having positive impacts while minimizing negative ones is only one component of a successful intervention; as with other interventions, market systems interventions should be cost effective as well. From a private perspective, investments are often necessary to create demand in new products. Such investment is not prudent if the stream of private benefits to the technology will be lower than the costs. From a public perspective (in this case, from a donor agency or government perspective) it can be argued that subsidizing the demand creation for such technologies is worthwhile if the stream of total benefits (e.g. the combined benefits to the private firm and to users of the product, in this case farmers) exceeds costs. These public benefits could be (for example) in terms of poverty reduction or in advancing other public goals. However, in considering a public-private partnership such as this one, if after an initial period of public

² We define adoption as any use of the variety in the most recent agricultural season for the purposes of this paper.

investment costs must be borne by the private sector (which is one way to characterize market systems interventions); they may abandon such investments if the future stream of benefits will not exceed costs. Many realistic assumptions about benefits in this context suggest they are quite small, implying they will be unlikely to exceed costs, and hence private sector engagement is unlikely to be sustained.

The paper proceeds as follows. First, we provide background about the project, on the performance of BM6 relative to other mung bean seeds, and on the economics of technology adoption. Second, we provide details on sampling, and how the data used in the paper was collected. The third section presents our results, including the simulations showing that uncertainty about seeding rates can explain low adoption, and the estimates of potential gains from the intervention if such uncertainty were resolved. The fourth section provides a discussion and conclusion.

2. Background

2.1 The Feed the Future Bangladesh AVC project

In the analysis, we use data from a survey conducted among households that reside in a region targeted by the Feed the Future Bangladesh Agricultural Value Chain (AVC) project, a USAID project implemented by Development Alternatives International (DAI). AVC adopted a market systems approach to strengthen agricultural value chains with the objective of improving agricultural productivity, food security, and nutrition. The project was undertaken in the southern delta region of Bangladesh, encompassing twenty districts in the Barisal, Dhaka, and Khulna administrative divisions, and targeted crops from eight different value chains. Our analysis focuses on one of these crops, mung bean, using data collected as part of an impact evaluation of a range of market systems interventions implemented by the AVC project.

Within the mung bean value chain, the goal was to foster links between input retailers and mung bean farmers to promote the adoption of BM6 seeds marketed and distributed by a large seed supplier in Bangladesh: Partex Ltd. To promote these mung beans, the market systems intervention combined informational activities for farmers with support to seed retailers to develop a marketing and promotional strategy, with a goal of growing the market for improved seeds (DAI 2015).

The intervention was primarily implemented by supporting Partex in an expansion of its network of input retailer loyalty clubs in mung bean producing areas within the targeted districts within the

Barisal division. The intervention combined this expansion with complementary services to farmers. As part of these complementary services, Partex organized a series of Agri-fests targeting mung bean farmers, which combined sales and promotions of improved inputs as well as information sessions and one-on-one consultations with farmers. The objective was to broaden access to improved varieties and associated inputs, while providing information both on how to apply those inputs and on complementary agricultural practices.

2.2 Yield Performance of BARI-Mung 6 seeds

Improved varieties of mung bean seed have been the subject of several agronomic studies within Bangladesh (Table 1). This literature is broadly supportive of the hypothesis that BM6 seeds are higher yielding than other varieties. Biswas et al. (2018) construct a theoretical crop model of the production of mung bean under a variety of scenarios calibrated for local growing conditions in Bangladesh, estimating yield rates in the range 0.8-1.6 tons per hectare (T/Ha) for BM6 seed under different climatic, soil and other conditions. This represents a significant potential increase over local varieties, which have an estimated yield range of 0.5-0.6 T/Ha (Islam, et al. 2016).

Agronomic studies carried out within Bangladesh generally provide support for an expected yield for BM6 around the lower bound of the model estimate. Hossain et al. (2017) estimate a yield of 0.79-0.82 T/Ha. for BM6 in a trial with other mung bean seed varieties. Similarly, Mahbub and Shizary (2016) estimate a yield of 0.77 T/ha under controlled conditions. Work by Mainul et al. (2014) tests BM6 yields under different degrees of fertilizer application, estimating a yield range from 0.5 (with no application of fertilizers) to 1.1 T/ha (under a productivity-maximizing allocation). An exception to these results is a field study conducted by Islam and co-authors (2018) which reports a somewhat lower yield range for BM6 (0.49-0.66 T/Ha).

While these studies are conducted under controlled growing conditions, there is some evidence to suggest that similar yields can be achieved by smallholders in practice. Observational studies by Islam et al. (2011) and Islam, Miah and Rahman (2013) report an average yield of 0.8 T/Ha. and 0.78 T/Ha. respectively among producer households in southern Bangladesh, though neither paper provides detailed documentation about project implementation, so it is unclear to what extent additional support services such as extension and complementary inputs, including fertilizers, were provided.

2.3 Heterogeneity and technology adoption

Understanding agricultural technology adoption and barriers to technology adoption have long been a subject of research among development economists.³ Many seemingly promising technologies are not adopted by large numbers of smallholders in developing countries (e.g. Jack, 2011). One explanation is that the returns to those technologies are uncertain from the individual farmer perspective; if so, the uncertainty can hinder adoption and between initial decisions about whether to adopt and later decisions new information can change the decision about whether to adopt (e.g. Conley and Udry, 2010; Beaman et al., 2020).

There are two particularly pertinent examples related to the high yielding variety (HYV) seed adoption relevant to this context. First, Foster and Rosenzweig (1995) develop a model with uncertainty about the optimal allocation of inputs when adopting a new technology, and then use household panel data from India on the adoption of high-yielding seed varieties in India to test the model. They find that the uncertainty of production outcomes lengthens the time period it takes for HYVs to diffuse throughout their sample. Suri (2011) studies HYV adoption among maize farmers in Kenya, asking why some farmers always adopt, some never adopt, and some do some years and not others. She explicitly models heterogeneity in outcomes by farmer and explores the correlation between the heterogeneity in farmers' own returns and their adoption decisions. She finds that farmers with the highest returns to adoption also face the highest fixed costs, for instance in terms of acquiring the seeds and complementary inputs.

A second important concept studied in the technology adoption literature is that the returns may depend upon the way that farmers use the technology. For example, Duflo, Kremer and Robinson (2011) find that the average returns to fertilizer in western Kenya are highly sensitive to the quantity used: using half a teaspoon of fertilizer per application is associated with a 69.5% return versus a return of 4.8% and -10.8% when using a quarter or full teaspoon, respectively. Similarly, a well-established literature in developed countries, in fact, indicates that there are potentially high returns to more precisely using farm inputs, both in terms of profits and in reducing externalities that occur from overuse or incorrect use (Finger, et al. 2019).

³ A recent summary is provided by Foster and Rosenzweig (2010).

Based on this literature, and assuming that availability and affordability are not the primary constraints to BM6 adoption (since the intervention focused on upgrading an existing distribution channel for BM6, and given that the costs of seeds are low relative to total production costs),⁴ we identify two potential pathways through which risk and uncertainty may potentially lead to either low adoption rates or slow adoption of BM6 seeds. First, uncertainty in the returns to adoption may lead farmers to fail to adopt due to risk aversion, or partial adoption as farmers learn about the technology by experimenting on a portion of their plots. Second, incomplete information about best practices for applying BM6 and complementary inputs may slow diffusion of the technology. For instance, the distance between individual mung bean seeds and the number of mung bean seeds used per unit area will affect plant density and potentially yields. Incomplete information about optimal sowing practices can reduce yields and slow diffusion.

3. Methods

To test these hypotheses, we first compare production outcomes for BM6 adopters with those for farmers using local seed varieties, then explore how variation in these outcomes may be associated with variation in input information. This section describes the data on which we rely in these analyses.

The primary data source for the analysis is a survey of mung bean producing households conducted as part of an impact evaluation of the Bangladesh AVC project. The original research design was to implement a panel survey of farmer households for three years from 2016 to 2018. A baseline survey was carried out in 2016, prior to implementation of any program activities. However, due to changes in program implementation, the original survey area was not an appropriate sample to evaluate the intervention. As a result, no survey activities were conducted in 2017, and the research team developed a new sampling strategy for which household surveys were implemented in 2018, which specifically targeted farmers who already purchased seeds (and hence were considered more likely to take up a new seed variety). We refer to this sample as the “main sample,” and it used for analysis throughout the paper.

⁴ For example, the USAID Scaling Seeds and Technologies Partnership (SSTP) studied smallholder adoption of improved seeds in a group of African countries and found costs were not one of the primary drivers of dis-adoption (USAID 2019).

Since the main sample was targeted specifically at those most likely to adopt the technology, and included only those who had purchased mung bean seeds for the agricultural season of interest, it is not representative of all smallholder mung bean farmers in the survey area. Since the original dataset collected in 2016 is representative of the broader population of mung bean producing households (at that time) regardless of seed purchasing behavior (i.e., technology adoption), and partially overlaps geographically with the 2018 sample, we use it for comparison purposes to examine to what extent the main sample (of likely adopters) differs in observable ways from the general population of mung bean farmers in the region (including the likely non-adopters).

For the main 2018 sample, farmers were selected through a two-stage process. The main intervention of interest around BM6 promotions was implemented through a network of preferred retailers for Partex. Partex had identified these retailers as relatively high-quality, and whose reputation aligned with the image that Partex would like to be associated with. The aim of our study was to compare adoption by farmers who were linked to a retailer who was part of the network of Partex preferred retailers (which by definition is a selected sample) to otherwise similar retailers who were not part of the network. The first stage of our sampling strategy was therefore to identify these retailers and create a relevant comparison group. To do so, we first selected 20 retailers from administrative data on the project who had been part of the intervention. We then matched each of these preferred retailers with a “non-preferred” retailer based on data from a retailer census including all retailers in the study region who had been accredited by the Agricultural Inputs Retailer Network (AIRN). The AIRN network had been trained through an earlier USAID funded project and therefore were thought to be a reasonable comparison group.

After establishing our sample of preferred and non-preferred retailers, in the next phase of sampling, we identified farmers who had purchased seed from one of these types of retailers. To build that sample, each seller was asked to provide the locations of villages where most of their seed customers were located, and then a listing exercise was carried out in those villages (since very few sellers maintained written records of clients—an interesting finding on its own) to identify farmers who purchased seeds for the coming season. For each of the forty retailers (20 preferred, 20 non-preferred), a sample of twenty farmers was drawn from seed purchasers in the identified villages, to create a total sample to be interviewed of 800 farmers.⁵ The full sampling

⁵ Of these, 2 were not available for interview, hence the final sample of sellers was 38.

procedure and analysis of adoption between the two retailer groups for the 2018 survey is described in de Brauw et al. (2019).

For the purposes of this analysis, we focus on a comparison between those who report having adopted BM6 and farmers using local seed varieties. While the decision to adopt is not exogenous, we are able to use detailed data on input decisions and production outcomes to descriptively explore observable differences between the two groups, controlling for a set of observed farmer characteristics. To do so, we use data on outcomes taken from the 2018 household-level survey, which was administered to the primary mung bean farmer in each sampled household (as identified by the members of the household). The survey contained detailed modules including a full listing of the household's plots, a production section specifically focused on mung bean production, a detailed inputs module focusing on purchases of improved seed, and a knowledge module in which the farmer was asked questions on best practices for mung bean production.

4. Results

4.1 Descriptive Statistics

First, we set out to compare adoption in the 2016 and 2018 samples and describe BM6 adoption from a number of perspectives. Among farmers in the 2016 sample, 32% of respondents report having ever used improved seed for mung bean cultivation, with 30% reporting having done so in the previous year (Figure 1). Among these farmers, approximately one quarter (26%) used BM6 seeds, hence the overall adoption rate of BM6 is 7.8%. In the 2018 sample, the overall use rate is higher, with 59% of farmers reporting having used improved seed in the previous season. Among users of improved seeds, 78% used BM6, yielding an overall BM6 adoption rate of 46% in the 2018 sample. Note, however, that the 2018 sample specifically targeted farmers who purchased seed for the previous growing season, meaning that we should by design expect to observe higher adoption rates of improved varieties and thus of BM6.

Between the two samples, there are important differences in terms of both the personal characteristics of the farmers themselves, and how they allocate production inputs (Table 2). A much lower share of the 2018 sample is female (in part because the 2016 sample aimed to over-sample female farmers). Farmers interviewed in 2018 have completed higher levels of formal education, with higher literacy rates. In terms of inputs, members of the 2016 sample were more likely to apply chemical fertilizer but less likely to use insecticides. They used less household

labor, but similar amounts of hired labor.⁶ In terms of production, the two samples look however very similar. There are no statistically significant differences between the two samples in how much land was used to grow mung beans, in the overall quantity harvested, and thus, in observed yield estimates.

These production estimates, although in line with other data sources for the area (Ahmed et al. 2015), are considerably lower than the level of productivity found in the agronomic studies cited above. In these agronomic studies, mung beans were grown under controlled conditions, and the improved varieties were used alongside appropriate levels of complementary inputs and farming practices. This finding is a first indication that farmers are not reaping the full benefits from improved mung bean varieties such as BM6. If gains are lower among these initial adopters, they may be less likely to recommend the seeds to peers, or otherwise discourage peers from adopting these seeds. Beyond simply lowering the rate of initial diffusion, the lowering of the initial spread of a novel technology can have negative spillovers on long-run adoption (Catalini & Tucker 2017). Data from input sellers suggests that availability is not a significant constraint within our sample-most report having BM6 seeds available (Table 3).

To compare the performance of BM6 versus local varieties, we use the main sample surveyed in 2018. While the 2016 survey collected limited information on the variety and quantity of seeds used, the 2018 survey instrument included a detailed inputs module that allowed farmers to report which mung bean variety they had planted. In addition, farmers could report multiple varieties if they had planted more than one mung bean variety, even if on the same plot. This feature of the data collection instrument appeared to be important, as 18.8% of farmers reported purchasing multiple varieties of mung bean seed for the current season (Figure 2). The proportion of farmers purchasing multiple varieties of mung beans is one unanticipated finding of the fieldwork⁷

We therefore develop potential hypotheses for why farmers may have used multiple varieties, based on our understanding of the context. Price does not appear to be a primary constraint, while the mean price for BM6 is higher than for local varieties, the difference is not statistically

⁶ Farmers in the 2018 sample report much lower average wages paid to hired workers, though it is difficult to distinguish spatial, temporal and other sources of variation in day-labor rates.

⁷ Since we observe data on inputs and production at the household level, we cannot disentangle production cost and productivity by variety for these farmers. We therefore treat farmers planting multiple varieties as a distinct category in our analysis, and focus comparisons on the differences between exclusive local seed users and users of BM6. While farmers do report other varieties of certified seed, the prevalence of any given variety (other than BM6) is very low.

significant and comparable to other improved varieties (Figure 3). Farmers recycling seed may not have enough seed for the full area they wish to plant, and hence supplement by purchasing from retailers, who might offer other varieties than the local varieties retained by farmers. Farmers who would prefer to grow a single variety may have been unable to do so because of supply constraints on their preferred variety, or potentially lacked access to credit during the planting season to purchase those seeds. Alternatively, some farmers who are interested in trying a new variety may engage in experimentation by applying it only to a portion of their land in order to see test it, thus mitigating the risk of a harvest failure should the variety perform poorly.

Table 4 presents summary statistics on land use, input allocation, and production outcomes as reported in the main 2018 sample, comparing farmers who only used local mung bean seeds to farmers who used only BM6. Both groups are comparable in terms of the total area on which they cultivated mung bean in the season preceding the 2018 survey, with local variety users cultivating on average 0.33 hectares, relative to 0.38 hectares among exclusive BM6 users. They also use similar quantities of seed per hectare, labor and fertilizer and insecticide (the two principal chemical inputs used for mung bean production). In total, BM6 users, however, spend on average more on seeds (\$12.76) than users of local seeds (\$9.61), reflecting the fact that the price of BM6 seeds is higher than the price of local seeds, and BM6 users report spending more on hired laborers (\$19.60) than users of local seeds (\$11.76). We will control for these differences in input cost and labor allocation in subsequent regression analyses.

In terms of productivity, revenues and profitability, we observe small and statistically insignificant differences between the two groups of farmers. BM6 users reported harvesting on average 0.74 T/Ha, compared to the 0.72 T/Ha harvested by users of local seeds. Similarly, BM6 users report earning on average \$162.34 from sales with profits of \$115.73, whilst local seed users earned on average \$134.26, with profits equal to \$99.75.⁸ Although local seed users earned less than BM6 users, none of these differences are statistically significant, contrary to our expectation. Holding the use of complementary inputs (such as fertilizers and insecticides) and improved practices constant, we find that adopters of BM6 in our sample are not significantly more productive than

⁸ Here, profits are being defined as returns to land and family labor.

non-adopters. This raises the question of why we do not observe greater yields for BM6 users, given yield gains identified in the agronomic literature.

4.2 Yield Comparison

To provide a more structured comparison in which we control for any observed differences between BM6 and local seed users, we regress measures of production and revenue on a vector of indicator variables that categorize farmers based on their reported mung bean varieties (exclusively BM6 seeds; exclusively one other improved variety; multiple or unspecified varieties), and the total area cultivated with mung bean (Table 5).⁹ In even numbered specifications, we also control for farmers' demographic and educational characteristics. Note that the comparison here is descriptive, since adoption of a given seed type is not plausibly exogenous. Therefore, we are testing for a statistically significant association between seed type and outcomes, rather than a causal relationship, holding reported cultivated area constant.

We do not observe a statistically significant association between the outcomes for output, revenue or profit for exclusive use of BM6 seed, relative to the exclusive use of local varieties. While the coefficients on the BM6 indicator have an expected positive sign for output and revenue, the standard errors are large, hence the estimated magnitude of the relationship is not statistically significantly different from zero. For production costs, there is a positive and weakly significant association between exclusive BM6 use and costs. Similarly, for other improved varieties, or mixed seed users, there is no statistically significant relationship observed between seed type and output, revenues or profit, though again there is a positive association between these two categories and overall production costs.

To explore the relationship between production costs and seed type, we estimate the same regression model as above, but now with production costs as dependent variable (Table 6). In doing so, we disaggregate the overall production cost variable into its constituent parts: expenditures on seeds; expenditures on other inputs (fertilizers, insecticide, herbicide and pesticide); payments to hired laborers; and expenditures on hired machinery.¹⁰ We find a positive

⁹ Farmers exclusively using local varieties are used as the omitted category.

¹⁰ Hired labor is used for land preparation, pre-harvest crop management (particularly weeding) and harvesting. Machinery is used almost exclusively for land preparation. Beyond the use of machinery, the data do not provide further details on how households prepared their land (e.g. whether they were using hoes or animal traction), but relatively few households report using both hired labor and machinery for land preparation, meaning that we can rule out the use of machinery by hired laborers for land preparation.

association between the use of BM6 seeds and seed expenditures, with BM6 users spending on average between 88 and 97% more on seeds than users of local varieties, reflecting the higher price of BM6 seeds. There are also positive and statistically significant correlations between the use of other improved seeds (and multiple varieties) and expenditures on seeds, likely due to a market premium for other varieties relative to local seeds. Other input expenditures are not higher for BM6 seed users, confirming that the observed similarity in yields from BM6 and local seeds is not driven by a higher use of other productive inputs among local seed users.

Agronomic trials have shown that BM6 seeds should inherently be higher yielding than locally produced varieties, raising the question why we do not observe higher yields among farmers using them. As we have observed, there does not appear to be evidence of positive selection effect, with more advanced farmers who use more complementary inputs being more likely to adopt BM6. In fact, one possible explanation is a negative selection effect: farmers adopting BM6 seeds either have less productive land, or are lower-productivity farmers, compared to farmers who do not adopt. If this explanation was correct, the positive yield effects of using the improved variety could be offset by the lower productivity of adopting farmers, relative to those using local varieties. While the available data does not allow us to explicitly test for such a selection effect, in our view the farm and farmer characteristics which we do observe – particularly similarities in area planted and allocation of other inputs – suggest that this explanation is unlikely, though we cannot definitively rule it out.

An alternative explanation is that farmers growing BM6 or other improved varieties may have applied seeds in a way that did not optimize their productivity. As a next analysis, we therefore explore whether there is observable variation in farmers' practices relative to recommended practices. The 2018 survey data include two measures to capture such variation: farmers' knowledge of recommended practices, and farmers' self-reported seeding rate, or the quantity of seed applied to a given area of land. The input knowledge module asked farmers to list the recommended method of sowing mung bean (broadcast or line sowing) and the recommended amount of seed that should be applied for a given area of land.¹¹

¹¹ The question was asked in terms of kilograms per 'bigha' which is a local land unit equivalent to one third of an acre, which was also the unit used in extension materials for BM6 seed. For comparability with standard yield measures, we use hectares throughout and therefore convert the recommended amount to Kg/Ha.

In terms of the quantity applied, most farmers do not report using the recommended amount. Only 26% of BM6 users report a quantity within the recommended range (20% of local seed users apply within this range).¹² This finding is partly explained by farmer knowledge: while a majority of farmers correctly reported that line sowing should be used for mung bean seed, fewer than half (42% of local seed users, 44% of BM6 users) identified the appropriate seeding rate of 9-11 Kg/bigha (Figure 4). While knowing the recommended seed rate is a statistically significant predictor of applying the recommended rate ($p=0.001$), it only partially explains the variation. A possible complementary explanation is that since seed is sold in fixed quantities, farmers may simply apply an approximate quantity to their land, particularly if they do not perceive there to be negative production impacts from over-seeding.

The left plot of Figure 5 shows the individual seeding rate values generated from farmers' reports against the area they cultivate, while the right fits a curve to demonstrate the trend. The red dotted lines show the range of the recommended seeding rate. Consistent with the descriptive statistics, most farmers fall outside of the recommended values. Moreover, the reported seeding rate appears to be related to the cultivated area differently depending on seed type. Whereas farmers with smaller landholdings over-apply seed compared to those cultivating larger areas when using local varieties, over-seeding is less pronounced among BM6 users with smaller landholdings. Splitting the sample by cultivated area, farmers in the 1st and 2nd quartiles apply too much seed, particularly when using local seeds, while those in the 4th quartile are applying too little seed, particularly when using BM6 (Figure 6). Only farmers in the 3rd quartile tend to apply quantities of seeds that fall within the recommended range for optimal production.¹³

A follow-up question, then, is whether following the recommended seeding rate is associated with an improved productivity of improved seeds, and if so, whether the low proportion of farmers following the recommended seeding rate could explain why BM6 users do not obtain significantly higher yields than farmers who planted local varieties. In Table 7, we therefore interact an indicator variable for having applied seed at the recommended rate with the independent variables in our regression framework. For BM6 users, the coefficients on the interaction term are positive for

¹² Note that the true optimal rate for local seeds may vary. In particular, high rates could in fact be beneficial if germination rates are poor.

¹³ The average area cultivated is small (the median farmer in our sample cultivates 0.6 acres of mung bean) so the quantity of seed required is correspondingly sensitive to imprecision.

output, revenue, and profits, but not for the cost of production. In other words, among farmers that applied the recommended amount of seed, the adoption of BM6 was associated with higher yields, revenues and profits. This is only the case for BM6 users, not for users of local seeds; the coefficient on the variable indicating farmers who apply the recommended amount is not significant. As with previous specifications, it should be stressed that these results should not be interpreted causally, but they do suggest that if gains from adopting BM6 exist, they are dependent on applying seed at the recommended rate.¹⁴

4.3 Seeding Rate

Given the large number of farmers over- and under-applying seed, we hypothesize that a relatively small degree of imprecision in the application of this agricultural technology may have meaningfully affected production, and hence adoption. To illustrate this point, we construct a simple model of production using parameters from our data and introduce an uncertainty term to represent this imprecision.

Specifically, we simulate a sample of farmers and assign each a land area drawn from a random normal distribution, to represent the land area cultivated with mung bean. This original value will determine production outcomes in the model. We then generate a random value (which can be positive or negative, with mean zero) and add this value to the original value generated for each "farmer," which is the value based on which the "farmers" in our model will determine how much seed to use. For example, if the value of the noise term is -0.15, a farmer with an "actual" area of 1ha will apply the recommended quantity of seed for 0.85ha and hence will apply insufficient seed. Conversely, if the value is +0.15, they will apply for an "actual" area of 1.15ha and hence will over-seed. Note that we do not intend to suggest that farmers simply misperceive their land area; we could equally have introduced noise into the seeding rate in our model (and held land area fixed). Rather than suggesting a single cause for why farmers over- or under-seed, we aim to illustrate how variation in seeding rates could affect returns to a given seed type.

The rest of the model is fully deterministic. For each observation, we determine the rate at which the farmer would seed using a local variety and BM6, each with an optimal seeding rate (with local seed assumed to require a higher rate due to poorer germination). The output value is assumed to

¹⁴ This result could also be an indication that the recommended seeding rate is indeed the correct seeding rate at which BM6 yields are indeed optimized.

be a multiple of the amount of seed planted, up to the optimal seeding rate for each variety. Once a farmer is planting more seeds at the upper boundary of the recommended range, we assume that there are zero marginal returns to sowing additional mung bean seeds. Output is determined for each observation only by the variety, the cultivated land area, and the applied seeding rate. We hold all other input costs fixed, so profits for a given farmer are likewise driven purely by seed choice. Consequently, maximizing yield in the model is very closely correlated with maximizing profit. Given these simplifying assumptions, it is important to note that the aim of the model is not to capture full complexity of agricultural production. Rather the goal is to demonstrate in a stylized way, how, holding other factors constant, introducing a moderate degree of uncertainty around a production input can be sufficient to reduce adoption for a meaningful share of farmers.

Figure 7 plots the result of this simulation, using fixed price parameters from the dataset. Under a fully deterministic scenario (i.e. where the noise term is equal to 0 for all farmers), a profit-maximizing farmer will always prefer the higher-yielding BM6 seeds over the local variety since the amount to be gained from increased production always outweighs the modest increase in production costs associated with using this improved variety. However, as the error increases, the share of farmers for whom BM6 maximizes profits declines. If we assume a 10% yield gain associated with BM6 use, at an error rate of 20%, using BM6 seeds is only optimal for 81% of farmers, which declines to 70% for an error rate of 30%. Note that by assuming farmers to maximize their expected profit, we imply risk neutrality. If we would have assumed that farmers are risk averse instead of risk neutral, then the share of farmers preferring local varieties would be higher for a given error rate.

4.4 Cost Effectiveness

We build on this model to develop an analysis of the potential relative gains associated with BM6 adoption. In doing so, we consider both the benefits that the private firm might reap, as well as the benefits to farmers from adoption, to consider what maximum benefits could be attained from more widespread BM6 adoption.

To consider relative gains, we used observed average seed prices and yields among those seeding within the recommended range from our data. We apply these figures to estimate gains to farmers under the observed adoption rate for our sample, and under the optimal adoption rate from the model. We estimate these results for differing market conditions, using three different output price

levels for mung beans (45, 55 and 65 Taka/Kg). We also consider three alternative scenarios on part of retailers. First, we use the 38 input sellers from our sample, for which we estimate a total current client base for mung bean seeds of 3154 farmers (based on the average sales volume of BM6 seeds reported by sellers). Second, we expand the number of sellers to all of those in our sampling frame for the area (86 sellers) and assume the same average number of clients per seller. Lastly, we estimate outcomes for a scenario in which the sellers can significantly expand their market share, doubling the number of farmers purchasing BM6 seeds.¹⁵

Table 8 presents the results of these analyses. For our survey sample, we estimate that the average gain in farmer profits from adoption is \$11.46 per individual at current prices (equivalent to a 10% increase in profits from the average in the main sample).¹⁶ Note that these simulation results hold other input costs constant, so the difference here is driven solely by the productivity of the seed type, and its cost. The gain is equivalent to a gain of \$14,435 in total value added for farmers per year. Under our model's optimal adoption rate, the total number of farmers adopting would nearly double (from 1,457 to 2,791) for a total annualized gain to farmers of \$31,982 at current prices. Under our second scenario, where we consider the full number of input sellers whom we were able to identify in the surveyed area, we estimate the total gain to farmers at \$32,621 for observed adoption rates, rising to \$72,335 under optimal adoption. Finally, under the scenario in which sellers expand their client base purchasing BM6 seeds, the expected value gained by farmers also approximately doubles. At current adoption rates, this expansion would create an estimated additional value of \$64,293 to farmers per year, or \$144,439 under the model's estimated optimal level of adoption.

Therefore, the maximum amount of potential aggregate farmer profits, under the model's estimated optimal adoption, is just under \$145,000 per year. There are obviously costs in creating that additional value under the market systems approach that we are not modeling. For example, to expand adoption among a significantly larger number of farmers, the firm would have to work with retailers on promoting the BM6 seeds above and beyond other seeds, and expand the number of retailers engaged by the firm. As a result, the maximum net economic gains to the intervention

¹⁵ In the 2016 data, approximately 85% of farmers were not purchasing seeds, so there is large potential for retailers to expand their market share. Thus, although an optimistic scenario, this expansion does not appear impossible.

¹⁶ \$11.46 is obtained by dividing the total gain by the number of farmers adopting. Relevant parameters in the model are based on median values in the data, hence the median plot area is 66 decimals (0.27ha) and price per kg of BM6 seed is 120 taka (\$1.45).

will be lower than \$144,439 per year. This point is true regardless of whether the maximum gain is attained or not; costs of maintaining the marketing component would always have to be outweighed by the benefits of selling additional seeds, in this case, for the seed company to maintain interventions.

Note that this figure accounts for the total potential gains to farmers; input sellers would also want to see their profits increase. The median retailer in the data sold 235 kg of mung bean seed per agricultural season, and charges about \$0.24 more per kg of BM6 than per kg of a local variety. Converting all sales of seed for the median retailer from other types to BM6 would yield the median retailer an extra revenue of \$56.40, relative to his or her total revenue from seed sales of \$693.72 in a given season. This \$56.40, or 8.1% of a retailer's total revenue, can be thought of as an absolute maximum; bounding the costs of participation and obtaining that seed. Similarly, Partex (and any middlemen between Partex and the input sellers) would also need to receive positive profits to make the intervention sustainable. The additional revenue estimate is low and at least partially over-estimated (since BM6 seeds already account for a portion of some retailers' sales) so retailers might be hesitant to participate if there are any costs involved.

As a result, while the overall benefits could be fairly large, they are aggregated across a large number of farmers. Yet, the sustainability of an investment like this one would appear to hinge on the benefits to either Partex or to retailers relative to costs. For individual retailers, the benefits are quite small even under optimistic assumptions; they may not be even noticeable given that relatively few retailers engaged in written bookkeeping. Costs to continued participation would likely be negative, and retailers would be unlikely to engage in marketing activities to expand sales absent a clear profit motive. That is not to say they would not continue to sell BM6; rather, that they would revert to selling it as they sell other seeds, without additional promotion generated through the market systems approach.

5. Conclusion

In this paper we consider a market systems intervention with lower than anticipated take up, at least initially, of an improved seed technology. In contrast to results obtained under controlled field trials in the agronomic literature, we do not observe statistically significantly higher yields among adopters relative to non-adopters using local seed varieties. We find evidence of a significant positive association between use of the improved variety and production outcomes for

farmers applying seed within the recommended guidelines, but not for those using less or more than the recommended amount. Using a simple model, we illustrate how modest variation in information on how much seed to apply can lead to adoption being sub-optimal for a meaningful share of farmers. Our cost-benefit analysis demonstrates that there is a substantial gap between the potential benefits to low-income producer households under a high take-up scenario and the estimated benefits observed from our data with low levels of adoption.

A notable feature of our analysis is that while some complementary information about BM6 has reached farmers, it has not reached a majority. Among the farmers it has reached, there remains a substantial gap between the share of farmers who correctly report the recommended application rate from BM6 and the share of farmers who report applying the correct amount given their reported land area. This point suggests that a lack of information about the product is not the only barrier to following the recommended seeding practice. If a technology requires experimentation or locally specific recommendations, it is unclear how these can be identified, and how appropriate information is conveyed by other actors in the value chain.

This illustrates a broader challenge with applying market systems interventions within agriculture. Where technologies have broadly similar general properties, it may be the case that facilitating interactions between market participants can be an effective way to disseminate information. For agricultural technologies, however, returns are generally heterogeneous, and strongly linked to local and even individual farm conditions. In such a context, it is unclear how a market systems intervention can address these local constraints, without additional or complementary programs.

References

Ahmed, Akhter, Ricardo Hernandez, Arifeen Akter, Nusrat Hossain, Wahid Quabili, Zeeshan Abedin, and Fiona, Rokon, Redwan Shaba. 2015. *Agricultural Value Chains in the Feed the Future Zone of Influence in Bangladesh: Baseline Study*. Washington: USAID.

Beaman, Lori, BenYishay. Ariel, Jeremy Magruder, and Ahmed Mushfiq Mobarak. 2020. "Can Network Theory-based Targeting Increase Technology Adoption?" *Working Paper*.

Biswas, Jatish C., Naveen Kalra, Md. Maniruzzaman, and Apurba Kanti Choudhury. 2018. "Development of mungbean model (MungGro) and its application for climate change impact analysis in Bangladesh." *Ecological Modelling*.

Campbell, Ruth. 2014. *A framework for inclusive market system development*. LEO Brief, Washington DC: USAID.

Catalini, Christian, and Catherine Tucker. 2017. "When early adopters don't adopt." *Science* 357 (6347): 135-136.

Conley, Timothy G., and Christopher R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 35-69.

Conroy, Kevin, and Adam Kessler. 2019. *The results achieved by programmes that use: A narrative synthesis of current evidence*. BEAM Exchange.

DAI. 2015. *Agricultural Value Chains (AVC) Project Bangladesh: Year 3 Workplan*. Washington: USAID.

de Brauw, Alan, Berber Kramer, Elena Martinez, and Mike Murphy. 2019. *Endline Report on Impacts Associated with the Bangladesh Agricultural Value Chains Project*. Washington DC: USAID.

Duflo, Esther, Michael Kremer, and Jonathan Robinson. 2008. "How High Are Rates of Return to Fertilizer: Evidence from Field Experiments in Kenya." *American Economic Review: Papers & Proceedings* 98 (2): 482-488.

Feder, Gershon, Richard E. Just, and David Zilberman. 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural Change* 33 (2): 255-298.

Finger, Robert, Scott M. Swinton, Nadja El Benni, and Achim Wlatter. 2019. "Precision Farming at the Nexus of Agricultural Production and the Environment." *Annual Review of Resource Economics* 11:313-335.

Foster, Andrew D., and Mark R. Rosenzweig. 1995. "Learning by Doing and learning from Others: Human Capital and Technical Change in Agriculture." *Journal of Political Economy* 1176-1209.

Foster, Andrew D., and Mark R. Rosenzweig. 2010. "Microeconomics of Technology Adoption." *Annual Review of Economics* 2: 395-424.

Hossain, M.A., M.A. Hasan, S. Sikder, and A.K.M.M.B. Chowdhury. 2017. "Leaf Characteristics and Yield Performance of Mungbean (*Vigna radiata* L.) Varieties under Different Levels of Shading." *The Agriculturists* 15 (2): 40-51.

IFPRI. 2015. *Bangladesh Integrated Household Dataset*. <http://dx.doi.org/10.7910/DVN/BXSYEL>.

Iowa State. 2013. *Extension and Outreach: Alternative Agriculture*. Accessed 3 17, 2020. <https://www.extension.iastate.edu/alternativeag/cropproduction/mungbeans.html>.

Islam, Kh. Shafiqul, Apurba, Rashid, Md. Harunor Roy, DB Pandit, Md. Abdul Matin, Shahidul Haque Khan, Sumona Shahrin, and Timothy J Krupnik. 2016. *Easy to use methods to improve mungbean production in Bangladesh*. Dhaka: CIMMYT-Bangladesh.

Islam, Md. Amirul, Md. Atikuzzamman, and Maria Akter Sathi. 2018. "Performance of BARI Mung 6 at recommended fertilizer rates, biofertilizer and farmer practice." *International Journal of Natural and Social Sciences* 5 (4): 16-19.

Islam, Q. M. Shafiqul, M.A. Monayem Miah, and M.S. Hossain, M.S. Rahman. 2013. "Adoption of BARI Mung Varieties and its Constraints to Higher Production in Souther Region of Bangladesh." *Bangladesh Journal of Agricultural Research* 38 (1): 85-96.

Islam, Q.M. Shafiqul, M.S. Rahman, M.A. Hossain, and M.S. Hossain. 2011. "Economic Analysis of Mungbean (*Vigna radiata*) Cultivation in Some Coastal Areas of Bangladesh." *Bangladesh Journal of Agricultural Research* 36 (1): 29-40.

Jack, B. Kelsey. 2011. "Market inefficiencies and the adoption of agricultural technologies in developing countries." *White paper prepared for the Agricultural Technology Adoption Initiative*. Berkeley: JPAL(MIT)/CEGA.

Kasy, Maximilian, Sautmann, Anja. 2020 "Adaptive treatment assignment in experiments for policy choice". *Econometrica* Forthcoming

Mahbub, Md Mostofa, and Bir Jahangir Shirazy. 2016. "Growth and Yield Performance of Mungbean Varieties in Summer Cultivation." *Scientia Agriculturae* 16 (3): 79-82.

Mainul, M.I., W.S. Rupa, A. Nasir, H. Mehraj, and AFM Jamal Uddin. 2014. "Performance of Mungbean (BARI Mung 6) to Different Nitrogen Levels ." *International Journal of Business, Social and Scientific Research* 1 (3): 172-175.

Osorio-Cortes, Luis E, and Mark Lundy. 2018. *Behaviour Change Scale-Up in Market Systems Development: A literature review*. Washington DC: International Food Policy Research Institute.

Pasanen, Tina, and Inka Barnett. 2019. *Supporting adaptive management: Monitoring and evaluation tools and approaches*. Working Paper, ODI.

Rashid, M. Harunor, M. Sazzadul Aktar, Ismail Hossian, M. Mahbubur Rahman, M. Rashed Hasnat, and RM Nair. 2013. "Effect of dates of sowing on incidence and severity of Mungbean Yellow Mosaic Virus and Cercospora Leaf spot of mungbean." *International Journal of Advancements in Research & Technology* 2 (9).

Suri, Tavneet. 2011. "Selection and Comparative Advantage in Technology Adoption." *Econometrica* 79 (1): 159-209.

United States Agency for International Development. 2019. *Mid-Term Performance Evaluation of the Scaling Seeds and Technologies (SSTP) Partnership in Africa: Wave Two Survey Report, Smallholder Farmers' Adoption of Improved Seeds in Program Areas*. Washington DC: USAID.

Figures and Tables

Figure 1- Type of seed reported, baseline sample

Figure 2- Type of seed reported, endline sample

Figure 3- Reported seed price by type, endline sample

Figure 4– Knowledge and application of recommended seed practices

Figure 5 – Quadratic plot of seed rate and area planted, by seed type

Notes: For visualization, we omit 8 observations where the reported seeding rate exceeds 100 Kg/ha.

Figure 6 – Seeding rate, by area cultivated (quartile) and seed type

Figure 7 – Simulated optimal BARI-Mung 6 adoption rate with uncertainty under different yield gains

Table 1 – Summary of agronomic studies on BARI-Mung 6

Authors	Journal	Yield estimate (T/Ha.)	Location	Study Type
Biswas et al	Ecological Modelling	0.8-1.6	N/A	Yield model
Hossain et. al	The Agriculturalists	0.79-0.82	Dinajpur	Experimental plots (University)
Q.M. Islam et al	Bangladesh Journal of Agricultural Research	0.8	Noakhali, Patuakhali	Observational
Q. M. Islam et al	Bangladesh Journal of Agricultural Research	0.78	Barisal, Noakhali, Patuakhali	Observational
M.A. Islam et. al	International Journal of Natural and Social Sciences	0.49-0.66	Patuakhali	Experimental plots (Village)
Mahbub et al	Scientia Agriculturae	0.77	Dhaka	Experimental plots (University)
Mainul et al	International Journal of Business, Social and Scientific Research	0.5-1.1	Dhaka	Experimental plots (University)

Table 2 – Summary statistics: mean values of selected indicators for 2016 and 2018 samples

Variable	2016 Sample	Main Sample
Demographic Characteristics		
Household size	4.56	4.78
Farmer is female	0.19	0.08
Farmer is Muslim	0.94	0.92
Age of farmer	47.00	49.69
Farmer can read & write	0.48	0.65
Farmer completed primary education	0.36	0.50
Farmer completed secondary education	0.07	0.12
Agricultural Input Use		
Purchased seeds	0.16	1.00
Expenditure on seeds (USD)	0.66	11.47
Used any improved/certified seed	0.30	0.59
Used BARI-Mung 6 seed	0.08	0.46
Used chemical fertilizer	0.43	0.35
Expenditure on chemical fertilizer (USD)	6.86	4.38
Used insecticide	0.75	0.86
Expenditure on insecticide (USD)	7.14	13.25
Labor for Agriculture		
Household labor (worker-days)	43.46	27.40
Used hired labor	0.63	0.65
Hired labor (worker-days)	16.19	17.41
Expenditure on hired labor (USD)*	34.32	18.92
Mung bean Production		
Area cultivated (hectares)	0.38	0.37
Mung bean harvest (kg)*	260.73	244.87
Yield (tons/hectare)*	0.73	0.75
Sales revenue (USD)*	187.95	160.03
Profit (USD)*	135.82	114.79

* indicates variable has been winsorized (2%) *Source:* Household survey data, 2016 and 2018 samples.

Table 3 – Mean input seller sales data, by seed type

	Local varieties	BARI-Mung 6	Other improved
Share who sold seed type	0.63	0.82	0.24
Sale price per kg (USD)	1.30	1.58	1.51
Volume sold (Kg)	331.84	312.66	144.21
Share of mung bean sales	0.37	0.50	0.13
Sales revenue (USD)	19.07	22.67	10.08
Share of mung bean revenue	0.34	0.53	0.13

Source: 2018 household survey data

Table 4 – Input allocation and production outcomes, by seed type category

	Mean value, by seed type		p-value
	Local varieties	BARI-Mung 6	Difference
Area cultivated (hectares)	0.33	0.38	0.240
Seeding rate (Kg/Hectare)	29.86	27.78	0.186
Expenditure on seeds	9.61	12.76	0.139
Household labor (worker-days)	26.56	24.69	0.553
Used hired labor	0.60	0.63	0.507
Hired labor (worker-days)	14.77	11.66	0.665
Expenditure on hired labor (USD)*	11.76	19.60	0.055
Used chemical fertilizer	0.30	0.38	0.155
Expenditure on chemical fertilizer	3.74	3.70	0.979
Used insecticide	0.85	0.86	0.831
Expenditure on insecticide	13.17	11.93	0.684
Mung bean harvest (kg)*	205.22	251.96	0.234
Yield (tons/hectare)*	0.72	0.74	0.790
Sales revenue (USD)*	134.26	162.34	0.203
Profit (USD)*	99.75	115.73	0.361

Source: 2018 household survey data. * indicates variables have been winsorized at the 1% level.

Table 5 – Relationship between seed use category and production outcomes, endline sample

	Value (Winsorized 2%)							
	Output (Kg)		Revenue (USD)		Production cost (USD)		Profit (USD)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BARI-Mung 6	12.32 (22.17)	13.32 (23.18)	1.97 (11.49)	2.34 (11.68)	5.26 (3.21)	5.63* (3.32)	-3.29 (10.96)	-3.28 (10.98)
Other improved variety	13.60 (21.67)	15.25 (21.10)	5.61 (14.72)	6.06 (14.49)	13.01** (5.39)	13.76** (5.69)	-7.41 (15.70)	-7.69 (15.53)
Multiple varieties	22.87 (27.69)	24.77 (26.65)	21.59 (15.42)	22.14 (15.28)	12.60** (4.83)	13.08** (4.84)	8.99 (14.21)	9.06 (14.08)
Area cultivated: Hectares	515.94*** (79.65)	511.01*** (77.66)	282.45*** (33.47)	280.46*** (32.74)	73.36*** (8.88)	73.02*** (9.13)	209.09*** (30.61)	207.44*** (29.97)
Number of current household members		7.45 (4.57)		2.38 (1.97)		-0.60 (0.95)		2.97 (2.22)
Farmer is female		6.66 (24.37)		6.07 (17.06)		2.72 (6.26)		3.35 (18.06)
Farmer age		-0.48 (0.62)		-0.38 (0.33)		0.09 (0.11)		-0.46 (0.33)
Farmer is muslim		15.40 (17.06)		-2.46 (13.75)		0.36 (4.80)		-2.82 (11.26)
Farmer is married		35.23* (17.98)		23.66** (10.08)		2.06 (8.41)		21.60** (9.49)
Farmer can read and write		-33.44 (25.50)		-18.57* (10.26)		-8.52** (3.42)		-10.06 (9.58)
Farmer completed primary school		18.98 (16.20)		11.58 (9.41)		10.62** (4.04)		0.95 (10.32)
Farmer completed secondary school		-0.37 (23.90)		1.62 (15.27)		-1.04 (7.58)		2.66 (13.38)
Mean (Local seeds users)	205.2	205.2	134.3	134.3	34.5	34.5	99.7	99.7
Test: BARI-Mung 6 == Other improved	0.966	0.948	0.836	0.830	0.170	0.162	0.825	0.813
Adjusted r-squared	0.393	0.392	0.421	0.420	0.231	0.229	0.282	0.280
Observations	782	782	782	782	782	782	782	782

Notes: Ordinary least-squares regression with village-pair level fixed effects. Standard errors are clustered at the village-pair level. *, ** and *** indicate significance at the 10%, 5% and 1% level respectively. Source: 2018 household survey data

Table 6 – Relationship between seed use category and input expenditure, endline sample

	Expenditure in USD on [Category] (Winsorized 2%)							
	Seeds		Other inputs		Hired labor		Machinery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BARI-Mung 6	1.88**	1.97**	3.39	3.66	2.87	2.86	3.71	5.55
	(0.76)	(0.81)	(3.10)	(3.16)	(2.65)	(2.68)	(4.80)	(4.46)
Other improved variety	1.01	1.02	12.00**	12.74**	9.16*	9.60*	7.91	8.79
	(0.80)	(0.82)	(5.14)	(5.46)	(4.57)	(4.90)	(5.74)	(5.98)
Multiple varieties	1.75**	1.84**	10.85**	11.24**	7.63*	7.79*	13.60*	15.04*
	(0.85)	(0.85)	(4.44)	(4.42)	(4.08)	(4.16)	(7.87)	(8.06)
Area cultivated: Hectares	19.13***	19.18***	54.23***	53.85***	30.69***	30.49***	67.79***	68.44***
	(1.50)	(1.50)	(8.27)	(8.58)	(7.21)	(7.52)	(11.64)	(11.20)
Number of current household members		0.16		-0.75		-0.81		0.18
		(0.18)		(0.89)		(0.80)		(1.57)
Farmer is female		1.57		1.15		6.36		-1.31
		(1.46)		(6.11)		(5.04)		(5.11)
Farmer age		-0.02		0.10		0.10		0.04
		(0.02)		(0.10)		(0.08)		(0.11)
Farmer is muslim		-0.59		0.95		0.82		-0.84
		(0.90)		(4.70)		(3.55)		(5.28)
Farmer is married		1.32		0.74		3.67		2.34
		(1.14)		(7.66)		(5.50)		(3.71)
Farmer can read and write		-0.11		-8.41**		-3.61		-10.48*
		(0.80)		(3.15)		(3.06)		(6.16)
Farmer completed primary school		-0.19		10.81***		8.52***		1.56
		(0.74)		(3.59)		(3.00)		(5.02)
Farmer completed secondary school		-0.87		-0.16		1.58		-10.28*
		(0.90)		(6.91)		(6.55)		(5.83)
Mean (Local seeds users)	9.6	9.6	24.9	24.9	11.8	11.8	33.8	33.8
Test: BARI-Mung 6 = Other improved	0.350	0.334	0.102	0.096	0.179	0.160	0.440	0.540
Adjusted r-squared	0.409	0.408	0.159	0.158	0.074	0.076	0.133	0.135
Observations	782	782	782	782	782	782	782	782

Notes: Ordinary least-squares regression with village-pair level fixed effects. Standard errors are clustered at the village-pair level. *, ** and *** indicate significance at the 10%, 5% and 1% level respectively. Source: 2018 household survey data

Table 7 – Relationship between seed category & production outcomes, interacting with following seeding rate recommendations, endline sample

	Value (Winsorized 2%)							
	Output (Kg)		Revenue (USD)		Cost of production (USD)		Profit (USD)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BARI-Mung 6	-13.94 (21.03)	-13.96 (20.94)	-11.19 (12.94)	-10.90 (12.92)	4.06 (3.98)	4.39 (3.97)	-15.25 (12.81)	-15.29 (12.64)
Other improved variety	-3.80 (27.97)	-3.48 (26.87)	-3.46 (17.97)	-4.38 (17.49)	12.86* (6.37)	13.00* (6.67)	-16.32 (19.69)	-17.38 (19.41)
Multiple varieties/Don't know	23.57 (26.57)	25.18 (25.90)	18.48 (14.88)	18.71 (14.79)	12.63** (5.41)	12.87** (5.42)	5.85 (12.96)	5.84 (12.91)
Used recommended seed rate	-7.37 (22.19)	-9.49 (21.85)	-12.08 (11.24)	-12.97 (11.31)	-1.03 (4.51)	-1.39 (4.51)	-11.05 (10.75)	-11.58 (10.53)
Recommended x BARI-Mung 6	92.75* (47.99)	96.85* (47.90)	49.37*** (17.40)	49.95*** (17.46)	4.43 (8.00)	4.67 (8.07)	44.94*** (16.42)	45.28*** (16.05)
Recommended x Other improved	57.49 (40.26)	62.79 (40.30)	33.04 (21.61)	37.78* (21.10)	0.79 (12.09)	2.85 (11.82)	32.25 (22.36)	34.93 (22.01)
Recommended x Multiple/DK	-20.47 (46.78)	-18.50 (45.72)	10.62 (30.87)	12.82 (30.15)	-1.00 (12.46)	0.49 (12.40)	11.61 (33.29)	12.33 (32.48)
Area cultivated: Hectares	516.55*** (79.12)	511.31*** (76.98)	282.19*** (33.55)	280.00*** (32.79)	73.36*** (8.92)	72.99*** (9.17)	208.83*** (30.47)	207.01*** (29.77)
Controls for HH characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Mean (Local seeds users)	205.2	205.2	134.3	134.3	34.5	34.5	99.7	99.7
Test: BARI-Mung 6 == Other improved	0.756	0.736	0.708	0.742	0.225	0.260	0.963	0.927
Adjusted r-squared	0.397	0.397	0.423	0.422	0.227	0.225	0.284	0.282
Observations	782	782	782	782	782	782	782	782

Notes: Ordinary least-squares regression with village-pair level fixed effects. Standard errors are clustered at the village-pair level. *,** and *** indicate significance at the 10%, 5% and 1% level respectively. Source: 2018 household survey data

Table 8 – Simulated estimates of total value added for survey sample and market expansion scenario

		Interviewed Sellers				All Sellers		All Sellers, Expanded Market		
Parameters	Farmers per seller	83	83	83	83	83	83	166	166	166
	Sellers	38	38	38	86	86	86	86	86	86
	Farmers	3,154	3,154	3,154	7,138	7,138	7,138	14,276	14,276	14,276
	Output price (Taka)	45	55	65	45	55	65	45	55	65
	Error rate (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%
Current	Adoption rate	46%	46%	46%	46%	46%	46%	46%	46%	46%
	Farmers adopting	1,458	1,457	1,450	3,272	3,284	3,296	6,563	6,549	6,558
	Farmer gain (USD)	12,175	14,435	16,425	27,215	32,621	37,198	54,544	64,293	74,305
Optimal	Adoption rate	91%	89%	87%	90%	89%	87%	90%	88%	87%
	Farmers adopting	2,855	2,791	2,758	6,453	6,335	6,226	12,894	12,619	12,451
	Farmer gain (USD)	26,876	31,982	37,132	60,560	72,335	83,456	121,306	144,439	167,457

Source: Simulation results using parameters from 2018 household survey data

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