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ORIGINAL ARTICLE

An experimental approach to farmer valuation of African rice genetic resources

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Abstract

Genebanks serve as both providers of valuable traits for breeding programs and repositories of diverse crop genetic material representing society's agricultural heritage. In this study, we use a Becker-DeGroot-Marschak mechanism to elicit the willingness-to-pay of rice farmers in Côte d'Ivoire for small amounts of African rice (*Oryza glaberrima*) landraces held by the genebank of the Rice Biodiversity Center for Africa, and for seed of newly developed ARICA rice varieties bred using genebank materials. Using a field experiment, we additionally investigate how randomized exposure to and experimentation with small amounts of African rice landrace seed or seed of advanced rice varieties developed by AfricaRice affect how smallholder rice farmers value these novel genetic resources. Surprisingly, we find that farmers generally value having access to African rice landraces at approximately the same level as for advanced rice varieties (and far above market rates for improved seed), and that those farmers who grew landrace seed in the offseason were willing to pay more than those who did not. Our results demonstrate the additional value provided by the conservation of African rice landrace varieties (apart from their use in breeding) and highlight the importance of experimentation in the adoption process.

KEYWORDS
African rice, farmer experimentation, genebanks, genetic resources, landraces, open selective trials

JEL CLASSIFICATION
033, 034, Q12

1 INTRODUCTION

Genebanks are collections of genetic resources represented by the great diversity of extant crop varieties (and their wild relatives), and consist of conserved sets of accessions, which are samples of genetic material collected from farmers' fields in the past (or from wild ecosystems). They can be seen as collections of old cultivars at risk of being lost, which are maintained for future use as inputs into the research and development processes that drive the creation of new more productive and resilient varieties. In addition, these old varieties may have value in and of themselves to farmers apart from their use in the breeding process (Meng et al., 1998; Ocampo-Giraldo et al., 2020; Poudel & Johnsen, 2009; Rocchi et al., 2016). Genebanks thus serve as both providers of valuable traits for breeding programs and repositories of diverse crop genetic material representing society's agricultural heritage.

A primary value of the genetic resources of crop varieties derives from their use to breed new crop varieties that are more productive and resilient. The Green Revolution provides a prime example of diverse genetic materials being used to breed more productive crop varieties (Hedden, 2003), leading to substantial increases in crop yield and production, a reduction in child malnourishment, and reduced crop prices in developing countries (Evenson & Gollin, 2003). Many past studies have thus focused on demonstrating the "impacts" of genetic diversity on a large scale. Others have attempted to demonstrate the value of genetic resources for research and development by using models in which individual firms engage in optimal search in pursuit of profits (Craft & Simpson, 2001; Rausser & Small, 2000; Simpson et al., 1996), with some extensions, such as in Zohrabian et al. (2003), who utilize a maximum entropy approach to value the expansion of the United States soybean collection based on the search for a single pest resistance trait, and other studies focusing on modeling the value of a marginal genebank accession (Evenson and Gollin, 1997; Gollin et al., 1998, 2000).

However, it is likely that these approaches underestimate the social value of genetic resources. For example, Drucker and Caracciolo (2013) argues that the commercial value of plant genetic resources is likely to represent only a small proportion of their total economic value to society. Goeschl and Swanson (2002) highlight the recurrence of biological problems over time driven by pest and disease evolution and suggest that the social value of genetic resources exceeds the private value placed on genetic diversity by private firms. Kassar and Lasserre (2004) highlight the uncertainty surrounding future use values of genetic resources and the irreversibility of biodiversity loss and suggest that biodiversity conservation can provide insurance against unknown future risks and shocks, as shown empirically by di Falco and Chavas (2009) in the context of Ethiopian agriculture and as modeled by Xepapadeas et al. (2014) using the Greek genebank as a case study.

Our experiment contributes to this literature by investigating a less explored research question: how smallholder farmers themselves value having direct access to landraces[1] for cultivation—more specifically landraces of African rice (*Oryza glaberrima*)[2], in our case. We concurrently assess how the same farmers value having access to new, advanced rice varieties containing genebank materials to allow for a direct comparison and relative valuation of these two types of genetic resources. These rice varieties are either maintained by or are products of breeding efforts utilizing genetic resources maintained by the Africa Rice Center (AfricaRice) genebank (in M'be, Côte d'Ivoire), the Rice Biodiversity Center for Africa (RBCA). Our research builds upon an existing body of literature investigating how farmers value and decide to cultivate landraces and varying levels of agrobiodiversity on farm, including Birol et al. (2006); Birol et al. (2009); Dusen et al. (2007); Meng et al. (1998); Smale et al. (2001); and Bellon et al. (2015), as well as more recent literature on the rematriation and repatriation of farmer varieties from genebanks such as Ocampo-Giraldo et al. (2020) and the experimental work of Bairagi et al. (2020) to assess consumer demand for Cordillera heirloom rice in the Philippines.

Farmers may value having access to genebank materials for direct use—that is, they may value being able to access and cultivate rice varieties that were grown by previous generations but that have since disappeared from farmers' fields. Investigating the extent to which they do is an important area of inquiry because if farmers are found to value having access to ancestral landrace varieties, this would indicate an additional (and potentially important) source of value provided by genebanks that is typically not taken into account, alongside the more commonly addressed value in the literature corresponding to the use of collections of conserved genetic diversity in crop breeding efforts. In addition, the experiment more broadly explores whether facilitating farmer experimentation with diverse crop genetic materials can help to promote the

[1] Local varieties (or "farmer varieties") improved through farmer selection.

[2] *Oryza glaberrima* landraces, though cultivated in some limited areas in West Africa (such as in Togo and Senegal), were not present in our dataset and are almost certainly not available for purchase in local seed markets. Thus, a primary reason they are not cultivated may simply be that they are not available or known, even though the varieties may be of interest to producers for their climatic resilience and/or culinary and cultural values. Our experiment aimed to test whether rice producers in Côte d'Ivoire would be interested in cultivating these varieties (and willing to pay to do so) if they were given the opportunity.

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diffusion of both newly developed and heritage[3] landrace rice varieties, contributing to farm-level yield growth as well as on-farm conservation of African rice landraces.

Methodologically, we use the revealed preference Becker et al. (1964) technique (BDM) to elicit farmer willingness-to-pay (WTP) for the seed of both African rice landraces and advanced rice varieties developed by AfricaRice. In addition, using a field experiment, we implement a simplified version of the open selective trials methodology proposed by Chassang et al. (2012) to investigate how randomized exposure to and experimentation with small amounts of both seed types affects how smallholder rice farmers value having access to these novel genetic resources. Surprisingly, while we originally assumed that most farmers would need to be paid to cultivate landraces (as suggested by the payment for agrobiodiversity conservation services literature, e.g., Narloch et al., 2011 and Krishna et al., 2013), we find that farmers generally value having access to African rice landraces at roughly the same level as for advanced rice varieties (and far above market rates for improved seed). Furthermore, we find that those farmers who grew landrace seed in the offseason were willing to pay more than those who did not. Our findings demonstrate the additional value provided by the conservation of African rice landrace varieties (apart from their use in breeding), and also highlight the importance of experimentation in the adoption process.

The significance of this experiment is its combined investigation of how farmers value both African rice landrace varieties conserved by the AfricaRice genebank, the RBCA, and newer advanced rice varieties bred through AfricaRice's programs. This study's focus on rice producers themselves contributes to the literature on the economic value provided by genebanks by shifting the scale of analysis from larger-scale impact evaluations of the benefits provided through crop breeding using genebank materials to a more participatory, farmer-based valuation of African rice varieties whose conservation or development relied on the activities of the RBCA, a genebank that conserves a diverse collection of landraces representing the results of millennia of rice farming in Africa.

2 | CONTEXT

In this section, we describe the context in which the experiment was conducted, including both relevant background information and the institutional setting.

2.1 | Background

AfricaRice[4] manages one of the largest collections of African rice (*Oryza glaberrima*) in the world. Domesticated in West Africa approximately 3000 years ago and indigenous to the continent, the cultivation of African rice has declined, replaced in farmers' fields in many cases by the higher-yielding Asian rice (*Oryza sativa*). However, African rice genetic resources are of interest due to their numerous valuable traits in the genepool such as tolerance to iron and aluminum toxicity, drought, and soil acidity, and other qualitative traits related to consumption preferences, such as taste, aroma, and cooking qualities (Wang et al., 2014). Much applied economics research has focused on the impact of the interspecific New Rice for Africa (NERICA)[5] varieties bred by AfricaRice (Agboh-Noameshie et al., 2007; Arouna et al., 2017; Diagne, 2006; Kijima et al., 2008, 2011; Yokouchi & Saito, 2016). However, very little work has investigated the value of the newer generation of Advanced Rice Varieties for Africa (ARICA)[6] varieties or has attempted to analyze how farmers value African rice (*Oryza glaberrima*) landraces.

2.2 | Institutional setting of the experiment

The experiment was carried out in the Vallée du Bandama region of Côte d'Ivoire in collaboration with AfricaRice. AfricaRice is involved in both conserving and distributing tens of thousands of rice accessions and contributing to the development of new rice varieties in collaboration with the Africa-wide Rice Breeding Task Force, which includes both AfricaRice breeders and national rice breeders. Varieties developed by AfricaRice (such as ARICA) are meant to first be nominated by one of the thirty African countries participating in the Africa-wide Rice Breeding Task Force, although Economic Community of West Africa States (ECOWAS) regulations allow varieties released in one country to be used in others as well in West Africa. AfricaRice and their National Agricultural Research System (NARS) partners (such as

[3] We use the terms "heritage" and "heirloom" interchangeably to denote landraces or farmer varieties of African rice that have been developed and passed down through centuries of African agriculture.

[4] AfricaRice is a CGIAR Research Center founded in 1971 as the West African Rice Development Association (WARDA), and as a pan-African intergovernmental association with 28 African member countries.

[5] NERICA refers to multiple high-yielding interspecific rice varieties developed by AfricaRice and first released in 2000.

[6] The newest generation of improved rice varieties developed by AfricaRice are called "ARICA" varieties, short for "Advanced Rice Varieties for Africa," and are designed to outperform other varieties in local environments, have superior grain quality, and are bred to be more resilient in the face of biotic and abiotic stresses (such as drought or pests and diseases).

Centre National de Recherche Agromonique (CNRA) in Côte d'Ivoire) produce breeder seed, the NARS organization produces foundation seed, and the private sector (including seed producer farmers and private NGOs) produces certified seed. Seed of improved varieties is also meant to be distributed and diffused through different projects and field demonstrations with farmers.

AfricaRice's genebank maintains the largest collection of African rice landraces in the world and is the largest collection of rice varieties in Africa with nearly 22,000 accessions. This collection represents a strategic resource for breeding new, advanced rice varieties that are well-adapted to growing conditions across Africa. The genebank also distributes samples widely, with a total of 113,083 samples having been distributed to a total of 164 institutions across 57 countries over the past 25 years. The majority of these samples were distributed to NARS institutions (44%), other institutions within the Consultative Group on International Agricultural Research (CGIAR) (43%), and to a lesser extent universities (10%). Notably, only a single sample was provided directly to a farmer organization during this period. Thus, the distribution of African rice landrace seed that occurred as part of this study represents by far the largest dissemination effort to date of *O. glaberrima* seed directly to farmers from the AfricaRice genebank.[7]

3 | EXPERIMENTAL DESIGN

3.1 | Research question and hypothesis

This study approaches the valuation of genebank activities by focusing on two mechanisms by which genebanks provide value: first, by providing useful genetic variation to breeding programs, and second, by maintaining farmer varieties of crops for future direct use in cultivation, that may possess various forms of cultural, culinary, agronomic and nutritional value. The literature on the value of genetic resources has tended to emphasize the first mechanism, in many cases to the near complete exclusion of the second.

To provide more evidence for the second mechanism by which genebanks can provide economic value, we ask the following research question:

Do farmers value having access to African rice landraces conserved by genebanks for direct use (apart from the value these varieties have as inputs into the plant breeding process), and if so, how does this value compare to their WTP for advanced rice varieties bred using genebank materials?

In addition, we investigate how information gained by farmers through their own experimentation impacts their valuation of both types of seed. Farmers may have an initial demand for seed of both landraces and advanced rice varieties, but it is also of interest to understand how their valuation of these genetic resources changes after they have had experience with them.

Our first hypothesis can be expressed as follows:

Hypothesis 1. Farmers will value having access to conserved African rice landraces for direct use in cultivation.

Second, we hypothesize the following:

Hypothesis 2. Farmers will value having access to advanced rice varieties developed using genebank materials through the efforts of AfricaRice and its partners.

The first hypothesis addresses the research question of how farmers value landrace conservation for direct use as varieties in and of themselves (and apart from their value as inputs into the breeding process), while the second hypothesis addresses how farmers value having access to advanced rice varieties developed using genebank materials. Our concurrent analysis of how individual farmers value the ability to access both new varieties bred using genebank materials and African rice landraces allows us to compare their relative valuations of the two different types of germplasm.

Third, we investigate how information about genetic resources can be provided through experimentation, and how this information affects farmer valuation of different varieties. The corresponding hypothesis can be expressed as follows:

Hypothesis 3. The provision of experiential information regarding the characteristics of both landraces and advanced rice varieties through facilitated experimentation will positively affect the value farmers ascribe to these genetic resources.

This last hypothesis is investigated through the implementation of a randomized controlled trial (RCT) in which treatment farmers were assigned to experiment with either landrace seed or ARICA seed in the off season.

3.2 | Sample selection and data collection

A recently published "e-registration" of approximately 8000 rice farmers in Côte d'Ivoire was used to develop the sampling strategy (Arouna & Aboudou, 2020). We aimed to generate a sample with more connected villages located closer to Bouaké and roads, as well as more isolated villages. Villages with a higher ratio of female to male farmers were also targeted to allow for more robust gender analysis

[7] *Pers. communication*, Marie-Noelle Ndjiondjop.

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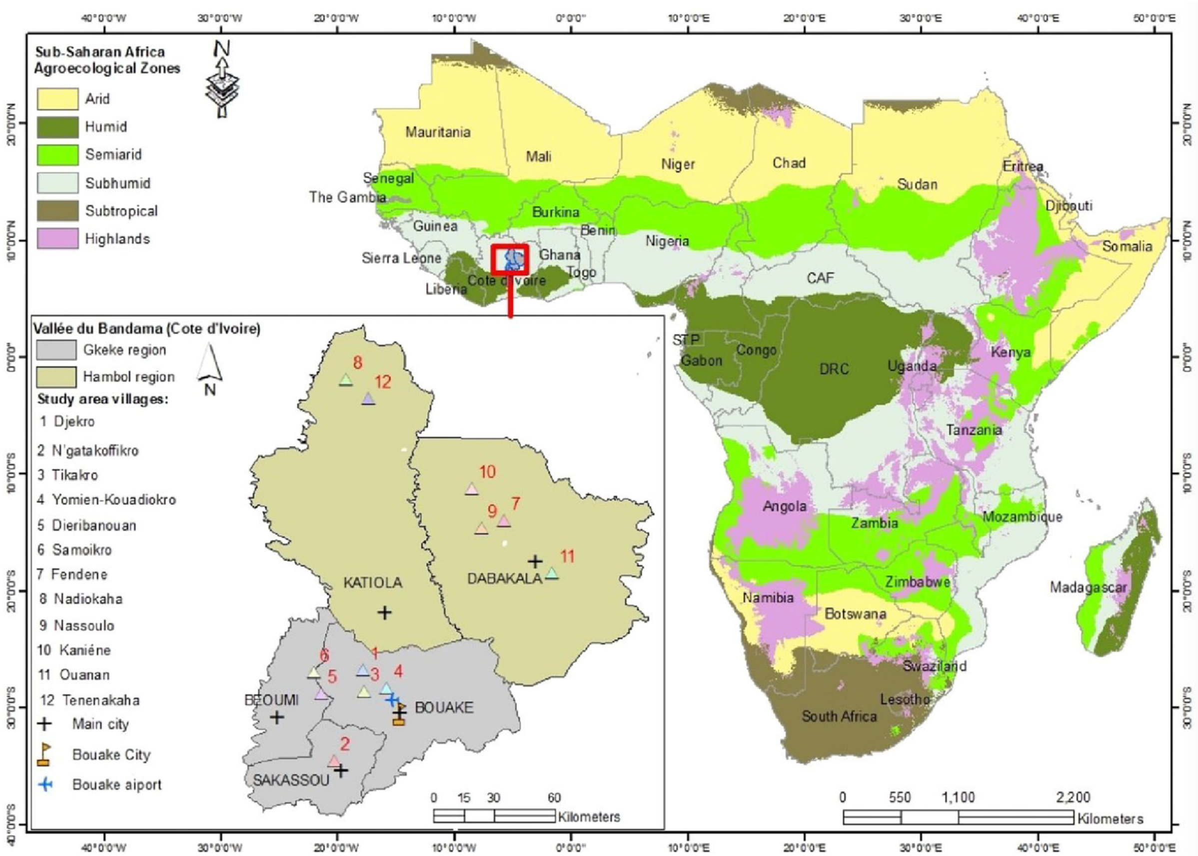

FIGURE 1 Map of the study area.

of our results, as well as villages reflecting different types of growing ecology (upland, irrigated lowland, and rainfed lowland). In total, 12 villages were selected for inclusion in the study, and we attempted to survey all the rice producers in each village. Table A1 presents summary information for each village, while Figure 1 illustrates the villages' locations on a map. Table A2 provides summary statistics for the overall sample of farmers.

The dataset includes a total of 569[8] farmers across the 12 villages (six in Hambol, and six in Gbeke), with the number of rice farmers per village ranging from 13 in Ouanan to 90 in Nassoulo. We aimed to survey as many farmers as possible given budgetary constraints, and to include a diverse group of farmers through our sample selection. Farmers were interviewed in whichever language they were most comfortable with (Baoulé, Senoufo, French, etc.) and the enumerators hired to carry out the data collection recorded the language of the interview as well as the language that the farmer stated was most used in their household.

Ethics approval was obtained from the Graduate Institute of International and Development Studies following internal regulations, and respecting the measures taken by AfricaRice. Travel occurred strictly within the Vallée du Bandama area around Bouaké with experienced local staff and enumerators in small groups. Farmers were asked for their consent before being surveyed, and no farmer was forced to participate against their will.[9] Before collecting data, a preregistration (AEARCTR-0006448) of the experiment was published in the AEA RCT Registry.[10]

Figure 2 provides a timeline of the experiment. The first survey round occurred in October–November 2020, during which we constructed our sample and implemented

[8] Power calculations were not carried out, given that the distribution of preferences regarding WTP for either landrace or advanced rice seed was unknown (and likely non-normal), and also given the limited and fixed amount of funds available for the study. Instead, efforts were made to carry out the experiment with as large a sample as possible given the limited budget.

[9] Safety precautions including social distancing measures were taken during surveying activities, which were conducted using electronic tablets in outdoor locations. Masks and disinfectant were purchased for enumerators. During the two periods of data collection, the epidemiological situation was stable and at a low-risk level (approximately 0.1 cases per 100,000 per day) with active cases clustered in the greater Abidjan area (about 300 km from the survey area).

[10] The preregistration is accessible at http://www.socialscienceregistry.org/trials/6448.

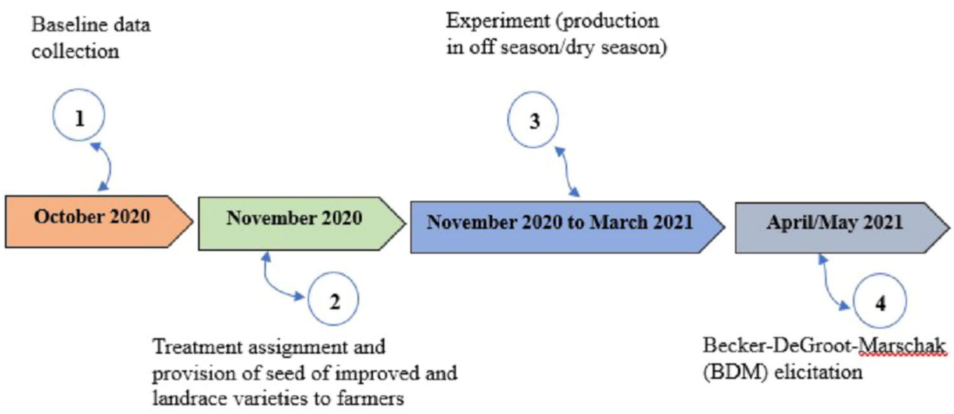

FIGURE 2 Timeline of the experiment.

our experimentation treatments during the off-season winter months, while the BDM elicitation occurred as part of the second survey round during the following spring (April–May 2021).

3.3 | RCT and selective trials

To empirically assess Hypothesis 3, we designed an experiment to understand how farmer experimentation with either of the types of rice varieties would affect how farmers value having access to these technologies. The objective of this experimentation treatment was to investigate whether gaining greater knowledge of African rice landraces (or seed of advanced varieties developed by AfricaRice) by cultivating them during the off-season would increase farmers' interest in obtaining access to more seed of such varieties, as measured through a BDM elicitation after the growing season.

To address these questions, the experiment involved the assignment of farmers into two treatment groups during the baseline data collection period in October 2020: first, an advanced rice variety "ARICA" treatment group, and second, a landrace variety treatment group. Farmers were assigned to these two treatment groups (and a control group) during the baseline survey in the fall of 2020, to cultivate the provided rice seed of two different varieties (either African rice landrace or advanced rice varieties) during the off-season, winter months.[11]

We chose to elicit WTP/willingness-to-accept (WTA) for the cultivation of two varieties of either African rice landrace or advanced rice varieties because of our focus on experimentation and desire to have the producers compare the performance of two separate varieties. The two types of germplasm are quite different. The African rice landrace is an indigenous variety (*Oryza glaberrima*) traditionally domesticated and cultivated in West Africa with tolerance to local conditions (climate and diseases) while ARICA varieties (*Oryza sativa*) are modern, advanced varieties bred to combine high yield and climate resilience. We thus expected different WTP values for the two types of rice varieties.

In contrast to a simple RCT, we use a simplified version of the open selective trials methodology proposed by Chassang et al. (2012) to assign some farmers to experiment with cultivating either African rice landrace seed or seed of an advanced rice variety in the off season based upon their elicited WTP for advanced rice seed and willingness-to-accept (WTA)[12] to cultivate small quantities of African rice landraces. The selective trials approach is designed for situations where outcomes are influenced substantially by unobserved individual beliefs and efforts (as is the case for technology adoption in agriculture, particularly in the smallholder context), and our elicitation of WTP and WTA for the two treatments enables us to obtain a measure of the beliefs of farmers in our sample regarding the perceived value of the genetic resources provided in the experiment (landrace seed or the seed of advanced rice varieties provided).

In our adaptation of the selective trials methodology, treatment was assigned as follows (illustrated in Figure 3).[13]

[11] The primary rice cultivation season in Côte d'Ivoire takes place during the summer months into the fall, while the "off-season" occurs in the drier, winter months.

[12] Following the payment for agrobiodiversity conservation services (PACS) literature (Krishna et al., 2013; Narloch et al., 2011), we assumed that most farmers would require some payment in order to cultivate the landrace seed during the off-season and assess its characteristics, as we requested. On the other hand, since improved rice seed has a market value and is generally more available, we asked farmers for their WTP for the (larger) quantity of improved seed that we provided. In contrast, at the end of the experiment, farmers were asked their WTP for identical quantities (35 g) of both seed types to allow for direct comparability between the two types of genetic resources.

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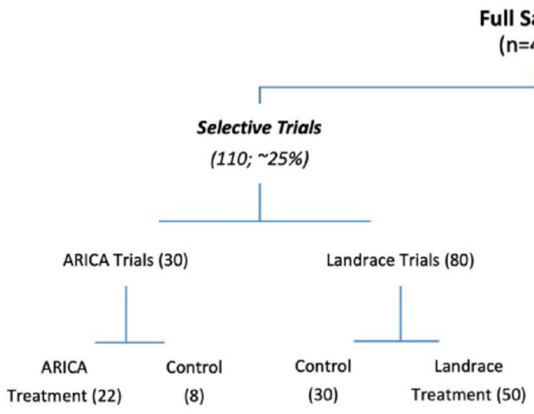

FIGURE 3 Diagram of the experimental design.

We elicited the WTP of farmers for one kilogram each of two advanced rice varieties developed by AfricaRice by asking the following:

> "How much would you be willing to pay to receive seed of two high quality rice varieties from AfricaRice (1 kg per variety, 2 kgs in total)? The sum that you state you would be willing to pay will play a role in the selection of those who will participate in the trial. We thus ask you to estimate how much you would be willing to pay with great attention and precision."

Thus, farmers were aware that their WTP would affect whether or not they would be selected to receive the advanced rice seed, and enumerators were instructed to collect the money that the farmer had stated when providing the seed. Figure A1 in the Appendix provides a histogram of farmer WTP for the advanced rice seed from this question.

We elicited the WTA of farmers to cultivate two landrace varieties during the off-season with the following question:

> "How much would you have to be paid to cultivate 70 g of traditional rice seed (covering a space of approximately 14m^2)? We would also ask you for your evaluation of the seed afterwards: how it grows, what are the positive and negative aspects, the taste, the aroma, etc. The sum that you request will play a role in the process of selecting the farmers who will participate in the testing of the traditional rice seed. We ask you to thus respond attentively and precisely."

Figure A2 in the appendix provides a histogram of the WTA of farmers in our sample for the cultivation of two landrace varieties during the off-season, while Figure A3 plots farmers' WTP (for advanced rice seed) and WTA (to cultivate landrace seed) by gender.

After we elicited the farmers' WTP and WTA, around 75% of farmers in each village were randomly assigned to a nested RCT. More specifically, these farmers were randomly assigned to either the landrace or ARICA treatment or control groups, as in a normal RCT (and allowing for typical RCT analysis and randomization inference). The remaining 25% of farmers in each village were randomly selected to participate in either ARICA selective trials (in which the farmers willing to pay the most for ARICA seed were assigned to the ARICA treatment) or to the landrace selective trials (in which farmers willing to accept the least to grow the landrace seed were assigned to the landrace treatment). Thus, crucially, farmers had the ability to influence their probability of being assigned to treatment, thus roughly following the concept of "open selective trials" proposed by Chassang et al. (2012). A balance test for the nested RCT is provided in Table A3 in the Appendix.[14]

[13] The sample size for the experiment is less than 569 because we decided to exclude farmers with upland plots in the experiment during the off-season given the typically dry conditions of those plots relative to irrigated and rainfed lowland plots.

[14] We find that all variables considered are balanced across the control and two treatment groups, with the exception of three cases. First, the mean age of farmers in the ARICA treatment group is slightly (but significantly) higher than that of farmers in the control group. Additionally, the rate of sharecropping is significantly higher in the landrace treatment group than in the control group. Finally, the rate of inherited plots is found to be significantly higher in the ARICA treatment group than in the control group.

3.4 | Becker-DeGroot-Marschak (BDM) elicitation of use value

To empirically assess Hypotheses 1 and 2, we elicited farmer WTP for both ARICA and landrace seed using an incentivized, revealed preference BDM methodology. The experimental BDM elicitation of use value took place after several introductory sections of the survey questionnaire during the second round of data collection in the spring of 2021. Farmers were randomly assigned to start with either a bag of African rice landrace seed or a bag of ARICA seed (which was not identical to that provided in the baseline for those farmers who participated in the experimental treatments during the winter months). The landrace seed was described as:

> "A traditional variety (landrace) of African rice (glaberrima) adapted to the ecology of your parcel. The traditional variety is a variety of African rice, not Asian, that was domesticated originally in Africa during the course of the past centuries and that could be better adapted to local conditions."

The ARICA seed was described as follows:

> "A new variety of improved rice, 'ARICA,' developed by AfricaRice and adapted to the ecology of your plot."

After a brief exercise[15] to prompt farmers to consider how much they would be willing to pay for 35 g[16] of seed, the BDM elicitation dice game was explained to the farmer. Each farmer was asked to pick a value they would be willing to pay for the bag of landrace or ARICA seed, associated with a roll of two dice (2–12, a potential value resulting from the sum of the two dice rolled). The enumerator explained that if the dice roll was greater than the roll associated with the value they had selected, they would not receive the seed, but rather the full sum of 550 West African CFA francs (FCFA), equivalent to approximately $1.[17] If the dice roll was equal to or less than the value they selected, they would receive the seed and the 550 FCFA minus the value associated with the roll of the dice (and not their WTP value). Figure A5 provides an image of the experimental materials.

The exact values used and the associated dice rolls are shown in Figure A4 in the Appendix, while the experimental materials are shown in Figure A5. To further help the farmers understand the game, a hypothetical first round was played for a 1-kilogram bag of fertilizer (although no money or fertilizer changed hands as a result of this practice round). After this practice round, the dice game was played, and each farmer received a combination of money and/or seed based on the outcome before moving to the next seed type (ARICA or landrace).

4 | EMPIRICAL STRATEGY

This section describes the estimation strategy of the analysis. We ran three sets of regressions. First, we run one set of regressions that takes the BDM-elicited WTP for either landrace or ARICA seed as the dependent variable (corresponding to Hypotheses 1 and 2, respectively). Second, we analyze regressions including only farmers randomly assigned to the landrace or ARICA treatments or control group, to empirically test our third hypothesis. Third, and last, we run a set of exploratory regressions that take the farmer's preference for ARICA seed—that is, their WTP for ARICA seed minus their WTP for African rice landrace seed—as the dependent variable.

The first set of regressions we run are shown in Equation (1). On the left-hand side, the dependent variable is defined as the farmer's BDM-elicited WTP for either landrace or ARICA seed (in CFA francs), α is a constant, x is a vector of variables that may theoretically have a significant impact on WTP, μ_v is a set of village controls, λ_e is a set of enumerator controls (to control for any effect the individual enumerators may have had on WTP), and ε is the error

[15] Before we began the BDM elicitation, farmers were prompted to think about how much they would be willing to pay for the 35 g bag of seed through a ladder elicitation method. At the end of this exercise, the enumerators asked the farmers how much they would be willing to pay for the seed. A random value was pulled and the farmer was asked, "Would you rather have X FCFA or the seed?" If they answered that they would rather have the seed, then the enumerators were instructed to ask the same question but add 25 FCFA to the amount of money offered. If the farmer now chose the money, the enumerator was instructed to ask the same question but to instead subtract 25 FCFA from the amount of money offered. This exercise ended once the farmer switched their answer (from seed to money if they originally favored the seed and from money to seed if they originally preferred the money).

[16] We elicited producer WTP for 35 g of seed to provide enough seed to experiment with but not so much that cultivating it would require a substantial amount of time or effort or take up a large portion of the average rice plot. That is, we wanted to elicit WTP for a rice variety as a technology (just enough for experimentation and multiplication) and not WTP for rice seed as an input.

[17] While a relatively small sum, the amount was deemed economically significant given that 550 FCFA is sufficient to purchase one to two kilograms of milled rice in the setting of the villages where the experiment took place, and in relation to the small amount of seed provided. We provided the funds to ensure the results were not impacted by the temporary liquidity constraints faced by farmers, and also because the genebank is restricted in terms of its ability to sell the landraces it conserves.

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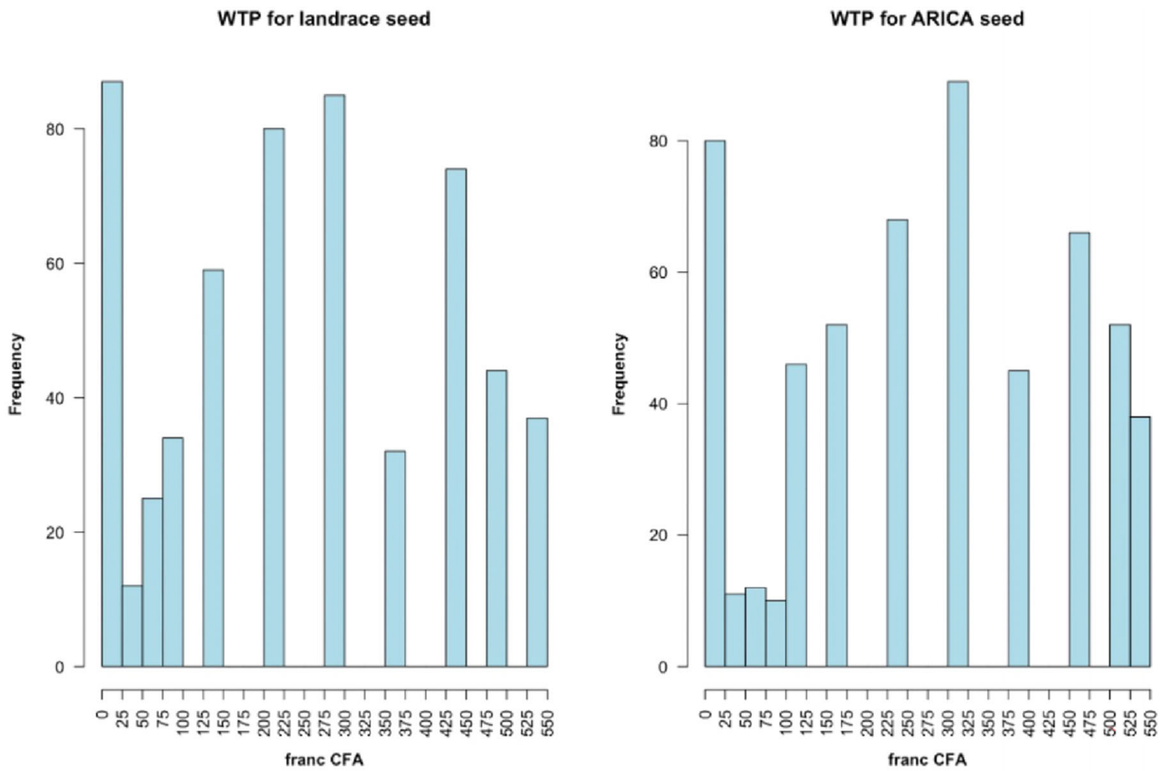

FIGURE 4 Histograms of farmer WTP for landrace and ARICA seed (BDM elicitation). BDM, Becker-DeGroot-Marschak; WTP, willingness-to-pay.

term.

$$WTP_{ive} = \alpha + \beta_i x + \mu_v + \lambda_e + \varepsilon \tag{1}$$

In Equation (2) we run another set of regressions designed to test our third hypothesis. Here, we similarly run a set of enumerator and village controls and other variables x, and additionally include δT_i, our estimation of the treatment effects (experimenting with either advanced rice or landrace seed). In addition to OLS, we also use Fisherian randomization inference as a robustness check for the analysis of the RCT data.

$$WTP_{ive} = \alpha + \delta T_i + \beta_i x + \mu_v + \lambda_e + \varepsilon \tag{2}$$

Finally, we run a similar set of regressions but instead take the farmer's preference for ARICA seed (over landrace) as the dependent variable—defined as the BDM-elicited WTP for ARICA seed minus the BDM-elicited WTP for landrace seed. This set of regressions is designed to analyze the factors contributing to a greater farmer preference for advanced rice seed (in relation to landrace seed).

$$(WTP_{ARICA} - WTP_{Landrace}) = \alpha + \beta_i x + \mu_v + \lambda_e + \varepsilon \tag{3}$$

5 | RESULTS

5.1 | BDM elicitation of use values

In this section we summarize the results of the BDM elicitation of use values for 35 grams of either landrace or ARICA seed (corresponding to Hypotheses 1 and 2). We begin by first providing histograms of the elicited farmer WTP values for both landrace and ARICA seed, and then present a set of regression results analyzing the different factors contributing to the farmers' demand for the two types of seed.

As an outcome of the experiment, approximately three-quarters of all farmers obtained at least one bag of landrace or ARICA seed, with 138 obtaining no seed bag. Seventy-five farmers (13% of the sample) received only the landrace variety and not the advanced rice seed, while 91 farmers (16% of the sample) received only the advanced rice (ARICA) variety and not the landrace variety. The remaining 264 farmers (46%) received both seed types.

Figure 4 provides histograms for farmer WTP for both landrace and ARICA seed. On average, farmers in the sample were willing to pay about 257 FCFA for the bag of landrace seed (about ~\$.47), supporting Hypothesis 1, and 263 FCFA for the bag of ARICA seed (about ~\$.50), supporting Hypothesis 2. These mean values are not statistically

TABLE 1 Determinants of WTP for African rice landrace seed.

Dependent variable: WTP for African rice landrace seed	(1)	(2)	(3)	(4)
Original WTA, landrace cultivation, 1000 s of FCFA	**−1.327*** **	**−1.380*** **	**−1.372*** **	**−1.372*** **
	(.358)	(.350)	(.351)	(.351)
Landrace seed first (in game)	−.301	2.224	1.786	1.783
	(14.87)	(14.44)	(14.43)	(14.44)
ARICA received first (in game)	16.34	14.98	14.95	14.95
	(16.49)	(16.18)	(16.19)	(16.20)
ARICA treatment	−12.98	−18.08	−18.06	−18.05
	(23.12)	(24.12)	(24.16)	(24.21)
ARICA treatment, grew variety	44.82	37.43	36.86	36.87
	(28.88)	(29.74)	(29.74)	(29.78)
Landrace treatment	−25.92	−32.69	−32.13	−32.12
	(31.11)	(32.70)	(32.82)	(32.91)
Landrace treatment, grew variety	**83.04** **	**73.24** *	**73.21** *	**73.19** *
	(39.07)	(39.81)	(39.86)	(39.92)
Female		24.22	16.84	17.24
		(25.90)	(28.09)	(43.50)
Female household head			37.54	37.60
			(63.76)	(63.82)
Household head		28.77	23.85	23.85
		(22.84)	(24.05)	(24.07)
Speaks Baoulé		−26.47	−27.56	−27.51
		(52.86)	(52.51)	(52.20)
Female = speaks Baoulé				−.553
				(45.40)
Farmer's age		**−2.396** **	**−2.360** **	**−2.359** **
		(.910)	(.910)	(.914)
Cultivates landrace		−15.07	−16.90	−16.90
		(27.07)	(27.13)	(27.15)
Believes variety better than average		**67.43*** **	**66.91*** **	**66.90*** **
		(17.05)	(17.07)	(17.11)
Years growing rice		.884	.906	.907
		(.897)	(.903)	(.902)
Household size		−1.647	−1.668	−1.668
		(1.348)	(1.354)	(1.355)
Has phone number		8.612	8.581	8.561
		(20.67)	(20.75)	(20.85)
Member of farmer association		15.04	15.07	15.06
		(26.77)	(26.82)	(26.76)
Cultivates other crops		**57.08** **	**56.78** **	**56.80** **
		(28.65)	(28.64)	(28.95)
Personal income (last month), 10,000 s of FCFA		.045	.042	.042
		(.277)	(.276)	(.276)
Favorability of climatic conditions, last season		**37.30*** **	**37.20*** **	**37.20*** **
		(13.34)	(13.33)	(13.33)
Discount rate, 2-year period		11.52	11.37	11.36
		(16.38)	(16.43)	(16.46)
Cultivates irrigated lowland plot		**−52.84** **	**−52.48** **	**−52.48** **
		(24.86)	(25.00)	(25.03)

(Continues)

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TABLE 1 (Continued)

Dependent variable: WTP for African rice landrace seed	(1)	(2)	(3)	(4)
Upland farmer		**−79.09*** **	**−77.99*** **	**−77.96*** **
		(28.42)	(28.50)	(28.78)
Enumerator and village controls	Yes	Yes	Yes	Yes
Observations	569	569	569	569
R-squared	.117	.193	.193	.193

Note: Robust standard errors in parentheses.
Abbreviation: WTP, willingness-to-pay. ***$p < .01$. **$p < .05$. *$p < .1$.

different from each other. Fifty-two farmers (around 9% of the sample) were not willing to pay anything for either seed type; approximately 5% of the sample was willing to either pay for landrace seed but not advanced rice (ARICA) seed or for ARICA seed but not landrace seed. Sixteen farmers were willing to pay the maximum amount (550 FCFA) for both seed types. These striking results show through an incentivized, revealed preference experiment that farmers value having access to conserved African rice landraces roughly as much as having access to advanced rice varieties. As shown by the histograms, the distributions of WTP values for both seed types are quite dispersed.

To better understand the factors driving farmer demand for both seed types, we run two sets of regressions: the first takes the BDM-elicited WTP for landrace seed as the dependent variable, and the second takes the BDM-elicited WTP for ARICA seed as the dependent variable. The results for the first set of regressions are shown in Table 1. In the first regression (shown in Column 1 of Table 1), we run a simple model incorporating only experimental variables: whether the farmers were assigned to either the landrace or ARICA treatment groups, whether the farmers actually grew the variety they were assigned in the off season, and the farmers' original WTA for landrace cultivation in the baseline survey (which took place in the fall of 2020). We include two additional variables associated with the dice game that may also influence WTP: whether the game was first played for the landrace seed, and whether the farmer had previously won the ARICA seed in the first round of the game.[18]

Most of these experimental variables are not found to be significant, except the original farmer WTA (which is significant and negative, indicating that farmers who had to be paid more originally to cultivate landraces were willing to pay less for landrace seed in the BDM experiment, as expected), and the variable for farmers assigned to the landrace group who had planted the African rice landrace seed they had been given, which is positive and significant (indicating that those farmers assigned to receive landrace seed who planted in the off-season had a higher WTP for seed of an additional landrace variety). This result could be driven by an effect where after having had experience cultivating the landrace seed, farmers became interested in other seed offered by the same provider (AfricaRice).

We run a similar set of regressions for the BDM-elicited farmer WTP for ARICA seed. The results of these regressions are shown in Table 2. Here, we again find that those farmers who were assigned to the landrace treatment and who grew the landrace varieties they were provided in the off-season are willing to pay significantly more for ARICA seed (with the coefficient being almost half the mean farmer WTP for ARICA seed), perhaps because the experience of experimenting with landrace seed from AfricaRice may have increased the interest of the producers in other varieties they could obtain from the institution.

Counterintuitively, we do not find that the interaction between ARICA treatment and the "grew variety" variable (those farmers in the ARICA treatment who grew the provided varieties during the off-season) to be significant. In addition, farmers who speak the Baoulé language, who have a phone number, and who believe that the primary rice variety that they currently cultivate is better than average were willing to pay more for the bag of ARICA seed. Farmers with a larger household size were willing to pay less.

Finally, female farmers were willing to pay less for the ARICA seed. However, when an interaction term between "female farmer" and "household head" is included, we find that female farmers who are household heads were in fact willing to pay *more* than the average male farmer for ARICA seed. These results suggest that for ARICA seed, the position of female farmers in the household may be an important factor enabling or restricting their experimentation with new crop varieties. In a fourth and final regression including an interaction between "Female

[18] These factors are potentially important because, for example, if the farmer had already won the ARICA seed in the first round of the game, this outcome might bias their WTP for the landrace seed downward. In addition, whether the farmer first played the game for the landrace seed, this may have the opposite effect—biasing the WTP for the landrace seed upward.

TABLE 2 Determinants of WTP for ARICA seed.

Dependent variable: WTP for ARICA seed	(1)	(2)	(3)	(4)
Original WTP (ARICA seed), 1000 s of FCFA	1.289	.615	1.941	2.108
	(11.321)	(11.630)	(11.403)	(11.397)
ARICA seed first (in game)	17.71	18.17	19.83	19.92
	(14.66)	(14.73)	(14.77)	(14.78)
Landrace received first (in game)	−6.003	−8.446	−10.18	−10.30
	(16.35)	(16.08)	(16.03)	(16.07)
ARICA treatment	3.180	10.08	10.19	10.47
	(23.91)	(25.33)	(25.43)	(25.42)
ARICA treatment, grew variety	37.31	37.19	35.00	35.24
	(31.24)	(32.23)	(32.21)	(32.23)
Landrace treatment	−46.57	−37.00	−34.82	−34.38
	(30.03)	(29.14)	(29.17)	(29.10)
Landrace treatment, grew variety	**115.7*****	**123.4*****	**122.7*****	**122.22*****
	(36.58)	(36.49)	(36.40)	(36.40)
Female		**−45.50***	**−72.65****	−59.47
		(26.25)	(28.70)	(46.18)
Female household head			**128.3*****	**140.2*****
			(51.95)	(53.61)
Household head		−7.970	−26.12	−26.05
		(22.44)	(24.00)	(24.00)
Speaks Baoulé		**124.8****	**120.3****	**122.0****
		(58.05)	(56.59)	(56.81)
Female × speaks Baoulé				−18.14
				(48.97)
Farmer's age		.470	.597	.623
		(.904)	(.895)	(.898)
Cultivates improved variety		2.690	9.184	9.222
		(28.67)	(28.18)	(28.20)
Believes variety better than average		**40.63****	**38.84****	**38.47****
		(17.43)	(17.55)	(17.61)
Years growing rice		−.750	−.669	−.654
		(.888)	(.875)	(.878)
Household size		**−3.280*****	**−3.353*****	**−3.361*****
		(1.190)	(1.190)	(1.188)
Has phone number		**54.50****	**54.30****	**53.65****
		(21.19)	(21.17)	(21.16)
Member of farmer association		22.64	22.52	21.98
		(25.99)	(25.99)	(26.09)
Cultivates other crops		4.171	2.986	3.646
		(27.19)	(27.35)	(27.56)
Personal income (last month), 10,000 s of FCFA		−1.154	−.167	−.168
		(.215)	(.211)	(.211)
Favorability of climatic conditions, last season		21.84	21.68	21.79
		(14.12)	(14.13)	(14.13)
Discount rate, 2-year period		3.341	2.879	2.787
		(16.41)	(16.34)	(16.35)

(Continues)

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TABLE 2 (Continued)

Dependent variable: WTP for ARICA seed	(1)	(2)	(3)	(4)
Cultivates irrigated lowland plot		−25.14	−24.20	−24.22
		(24.91)	(24.73)	(24.70)
Upland farmer		−6.682	−2.698	−1.843
		(27.79)	(27.61)	(27.71)
Enumerator and village controls	Yes	Yes	Yes	Yes
Observations	569	569	569	569
R-squared	.126	.177	.185	.185

Note: Robust standard errors in parentheses.
Abbreviation: WTP, willingness-to-pay. ***$p < .01$. **$p < .05$. *$p < .1$.

farmer" and "speaks Baoulé," we do not find this variable to be significant.

5.2 | RCT analysis

In the previous subsection, we found that farmers who were assigned to grow landrace seed—and chose to plant it during the off-season—were willing to pay more for seed of both additional landrace and ARICA varieties of rice. However, these estimates should not be considered to be causal since they include farmers who were assigned to either the landrace or ARICA treatment groups through selective trials and those who were randomly assigned to the treatment groups. Thus, farmers were able to influence the probability that they were assigned to either of the two treatment groups. In this subsection, we present the results of the analysis of our RCT data (corresponding to Hypothesis 3), restricting the sample to only farmers who were randomly assigned to either the control group, the ARICA treatment group, or the landrace treatment group (total random sample $n = 304$).

We present the first set of regressions (taking the BDM-elicited WTP for landrace seed as the dependent variable) in Table 3. We first run a simple model (1), then include an interaction with the farmers' original WTA for landrace cultivation (2), and finally include models with interaction terms between treatment and those farmers who decided to plant in the off-season (3–4).

The analysis of the random sample shows that the landrace treatment itself did not lead to a higher WTP for landrace seed in the BDM game, but in Column (3), we find that the farmers assigned randomly to the landrace treatment who planted during the off-season (and who tended at first to be *less* interested in African rice landrace cultivation) were willing to pay approximately 90 FCFA more than farmers who were randomly assigned to the control group. We also find that if farmers received a bag of ARICA seed first in the BDM game, they were willing to pay approximately 40 FCFA more for landrace seed in the BDM elicitation.

However, the decision to plant the provided landrace seed in the off-season as requested (instead of the main season) is not a random choice; thus, it is of interest to understand which factors contributed to this decision. To this end, we run a probit regression where the dependent variable is whether or not the farmer grew either ARICA or landrace seed during the off-season (among farmers randomly assigned to treatment). The results are shown in Table A4 in the Appendix.

We find that farmers who initially had a high WTA for landrace cultivation and were assigned to be included in the landrace treatment group were more likely to decide to plant during the off-season—that is, farmers who at first were least interested in cultivating African rice landraces. We hypothesize that this is because these farmers are those who stood to gain the most financially by doing so (through our payment-for-agrobiodiversity-conservation payment program). This result suggests that the act of experimentation convinced farmers who were originally not interested in landrace cultivation of the value of these genetic resources, leading to these farmers to be willing to pay more for additional landrace seed than their peers. In addition, we find that producers who already cultivate improved varieties were less likely to plant in the off-season (perhaps because they wanted to plant both the provided advanced rice seed and their current improved variety simultaneously at the same time during the normal growing season).

Next, we run a similar set of regressions including the BDM-elicited WTP for ARICA seed. We present the results in Table 4.

We find in the second column—where we include an interaction between random ARICA treatment and the farmer's original WTP but do not include an interaction term capturing whether the producer grew the variety in the off-season or not—that ARICA treatment led to a statistically significant increase of 68 FCFA in the farmer's

WTP for ARICA seed in the BDM elicitation with respect to the randomly assigned control group (regardless of original WTP for the seed, given that the coefficient for the interaction between "ARICA treatment" and "original WTP" is found to be insignificant).

5.3 | Farmer preference for ARICA versus landrace seed

In this section, we present a histogram and regression results illustrating the preference of individual farmers for ARICA seed (that is, the difference between a farmer's WTP for ARICA and that for landrace seed). This exploratory analysis was not present in the preregistration. Figure 5 presents the distribution of farmer preferences for a given seed type, with a positive value indicating a preference for advanced rice seed (ARICA), a negative value indicating a preference for landrace seed (*O. glaberrima*), and a value of 0 indicating no preference for either seed type.

Approximately 36% (205 out of 569) of the farmers had the same WTP for both seed types (with about 10%–52% farmers—of this 36% having a WTP of zero for both the bags of ARICA and landrace seed bags). Approximately 5% of the sample was willing to pay for ARICA seed but not for landrace seed, and a similar proportion of farmers were willing to pay for African rice landrace seed but not for ARICA seed. The histogram shows that great heterogeneity existed among farmers in terms of their preference for either landrace seed or advanced rice seed.

Table A5 in the Appendix presents our regression results. We find that upland farmers, farmers with a phone, farmers who speak Baoulé, and farmers who were either originally willing to pay more for ARICA seed or who asked for a higher amount of money (WTA) in order to experiment with landrace seed all preferred ARICA seed (when compared with their WTP for landrace seed).

6 | ROBUSTNESS CHECK: RANDOMIZATION INFERENCE

In this section, we present the randomization inference estimates obtained as part of a robustness check for the random sample analysis presented earlier. Fisherian randomization statistical inference is a method of analysis that can be used with data generated from RCTs. This

TABLE 3 Determinants of WTP for African rice landrace seed—Random sample.

Dependent variable: WTP for landrace seed	(1)	(2)	(3)	(4)
Original WTA, landrace cultivation, 1000 s of FCFA	−1.238	−1.214	−1.234	−1.031
	(.996)	(1.027)	(.998)	(1.038)
Landrace received first (in game)	−17.96	−17.70	−18.56	−16.05
	(20.09)	(20.30)	(20.10)	(20.40)
ARICA received first (in game)	**40.15*** **	**40.14*** **	**38.95*** **	**40.16*** **
	(22.42)	(22.46)	(22.64)	(22.91)
ARICA treatment	−8.912	−8.848	−14.42	−14.32
	(21.25)	(21.27)	(26.41)	(26.52)
ARICA treatment, grew variety			13.77	15.59
			(31.19)	(31.16)
Landrace treatment	−11.50	−7.580	−62.92	−74.76
	(29.87)	(54.84)	(40.54)	(66.45)
Landrace treatment × Original WTA		−.210		.809
		(2.626)		(3.301)
Landrace treatment, grew variety			**90.86*** **	154.6
			(52.85)	(98.77)
Landrace treatment, grew variety × Original WTA				−3.248
				(4.810)
Enumerator and village controls	Yes	Yes	Yes	Yes
Observations	304	304	304	304
R-squared	.143	.143	.1952	.155

Note: Robust standard errors in parentheses.
Abbreviation: WTP, willingness-to-pay. ***$p < .01$. **$p < .05$. *$p < .1$.

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TABLE 4 Determinants of WTP for ARICA seed—Random sample.

Dependent variable: WTP for ARICA seed	(1)	(2)	(3)	(4)
Original WTP (ARICA), 1000s of FCFA	−2.982	7.538	−3.171	6.945
	(19.398)	(19.599)	(19.408)	(19.489)
ARICA first (in game)	−4.410	−4.042	−4.694	−4.553
	(21.43)	(21.41)	(21.42)	(21.73)
Landrace received first (in game)	−18.39	−18.40	−18.25	−17.34
	(23.15)	(23.14)	(23.23)	(23.52)
ARICA treatment	25.94	**67.91*****	21.17	46.18
	(22.59)	(39.28)	(28.76)	(70.14)
ARICA treatment × Original WTP (1000 s)		−42.549		−27.478
		(32.933)		(68.113)
ARICA treatment, grew variety			10.98	38.75
			(35.70)	(75.24)
ARICA treatment, grew variety × Original WTP				−.021
				(.070)
Landrace treatment	10.94	11.24	10.84	−16.50
	(28.21)	(28.18)	(28.34)	(44.15)
Landrace treatment, grew variety				48.70
				(51.90)
Enumerator and village controls	Yes	Yes	Yes	Yes
Observations	304	304	304	304
R-squared	.119	.123	.119	.126

Note: Robust standard errors in parentheses.
Abbreviation: WTP, willingness-to-pay. ***$p < .01$. **$p < .05$. *$p < .1$.

method allows for the construction of exact tests of sharp hypotheses, that are less dependent on assumptions (such as large-sample theory). Here, we include the *p*-values calculated using randomization inference as a robustness check to our random sample analysis (in Table 5), and present them alongside the unadjusted, OLS *p*-values.

In the first column (for the first set of values), we present the results for a simple model, while in the second column, the interaction between the farmer's original WTP for advanced rice seed and random assignment to the ARICA treatment is included. In column three, we test whether farmers randomly assigned to the landrace treatment were willing to pay more for ARICA seed in the BDM elicitation. For the second set of values, under "Landrace WTP, BDM," we present *p*-values for similar regressions that instead take WTP for landrace seed as the dependent variable. The first two columns test whether farmers randomly assigned to the landrace treatment were willing to pay more for landrace seed in the BDM elicitation than were the control farmers (with the second column including an interaction between the landrace treatment and the farmer's original WTA for cultivating landrace seed), while column three tests whether randomly assigned ARICA farmers were willing to pay more for landrace seed. While we find some differences in the magnitude of the *p*-values, the randomization inference *p*-values do not differ in terms of significance from the unadjusted OLS *p*-values.

7 | DISCUSSION

7.1 | Strengths

The strongest aspect of this analysis is its use of a realized preference approach to valuation using the BDM elicitation technique to investigate how farmers value having access to two novel technologies with which they have no previous experience—namely, either new, advanced rice seed or heritage landrace varieties of African rice. Farmers are incentivized to be honest about their preferences because their stated WTP will directly affect their probability of obtaining the bags of either landrace or ARICA seed as well as set a lower bound on their minimum potential financial reward from the experiment.

We follow other recent papers utilizing this approach such as Berry et al. (2020), where the authors used a BDM mechanism to estimate willingness-to-pay for clean water technology in a field experiment in Ghana, as well as other recent experiments investigating farmer WTP for different types of seed, such as Mastenbroek et al. (2021) and Gharib et al. (2021). In addition, we experimentally

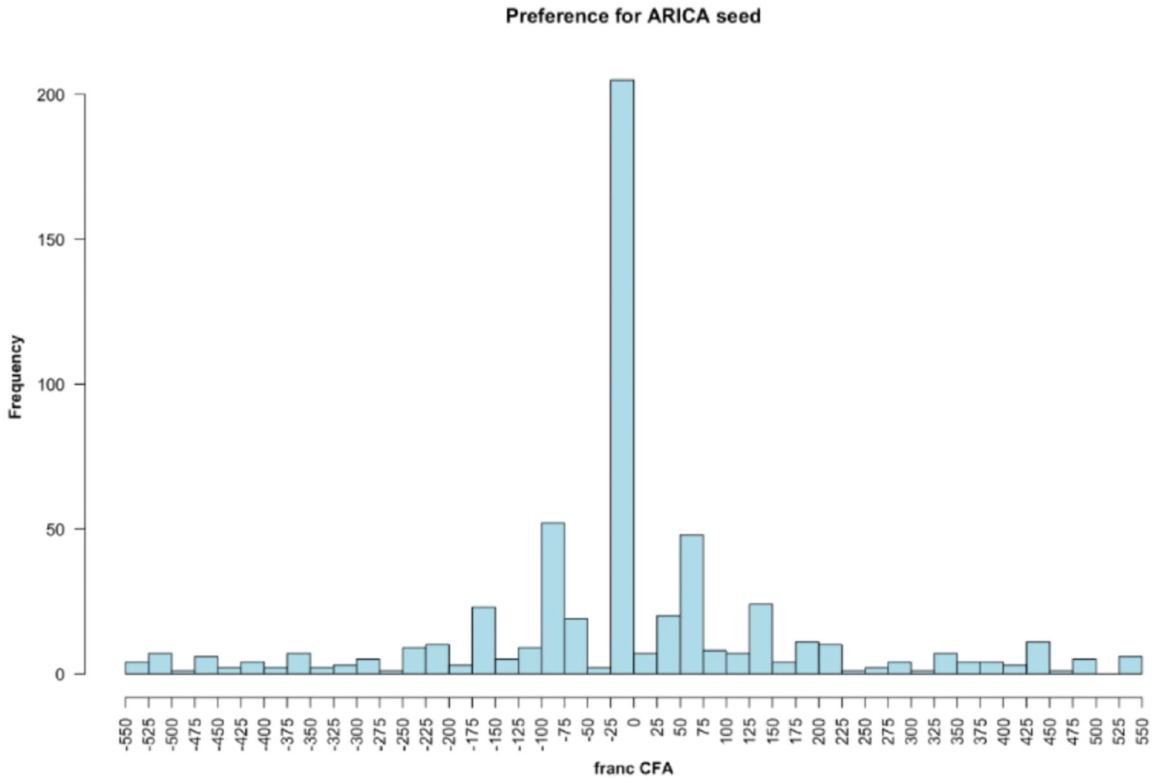

FIGURE 5 Preference for ARICA seed (with respect to landrace seed).

control for other factors that may affect the relative valuation of ARICA seed versus landrace seed, including by randomly alternating which seed type appeared first in the experiment, and by including numerous variables in the regressions, such as which seed type came first and whether the farmer had previously won a bag of seed.

The inclusion of a RCT in which some farmers were randomly assigned to experiment with seed of either a landrace or advanced rice variety provides additional evidence that those farmers who cultivated the landrace seed they were provided were then willing to pay more in the BDM elicitation in the end-line survey. Interestingly, we find that farmers in the landrace treatment who cultivated the landrace seed in the off-season were the least interested in doing so in our initial WTA elicitation (i.e., they had higher WTA values)—but had a significantly higher WTP for additional landrace seed after doing so. This evidence suggests that experimentation with landrace varieties of African rice increased farmer demand for additional access to landrace seed, particularly among those who initially required a greater financial reward for cultivating African rice landraces.

7.2 | Limitations

It is important to note that the small sample size, lack of power calculations and several treatment arms pose some internal validity concerns and make our results for Hypothesis 3 less robust than those for the first two hypotheses (tested with the BDM elicitation). Future research could address this issue by including a larger sample of farmers. We consider the results of our BDM elicitation to be stronger, on the other hand, through their demonstration that rice producers in Côte d'Ivoire were willing to forego financial gain in order to obtain small quantities of African rice landrace seed. In addition, while our findings may not be generalizable to all settings, it is likely that farmers in areas where African rice landraces are cultivated, such as in the Togo Hills and Casamance area of West Africa (Agnoun et al., 2012), or individuals in developed countries, may ascribe even greater value to landrace and heirloom varieties.

8 | CONCLUSION

In this article, we present the results of an incentivized, revealed preference experiment that demonstrates that smallholder rice farmers are willing to pay not only for seed of advanced rice varieties developed by AfricaRice and the Africa-wide Rice Breeding Task Force using diverse genetic resources maintained in genebanks but also for heritage landrace varieties of African rice (*Oryza glaberrima*). In other words, while the payment for agro-biodiversity conservation services literature suggests that

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TABLE 5 Randomization inference *p*-values, BDM.

	(1)	(2)	(3)
ARICA WTP, BDM			
Unadjusted *p*-value (OLS)	.252	.085	.252
RI-adjusted *p*-value	.267	.005	.721
Landrace WTP, BDM			
Unadjusted *p*-value (OLS)	.701	.913	.675
RI-adjusted *p*-value	.685	.833	.675

Note: Run with 2000 repetitions and a starting seed of 47.
Abbreviations: BDM, Becker-DeGroot-Marschak; WTP, willingness-to-pay.

most farmers would need to be paid to grow landraces, most rice farmers in our sample were willing to sacrifice financial gain to have access to the heritage rice varieties provided through the study—at approximately the same level as they were for advanced rice variety seed.

This finding is the most striking result of our experiment, and suggests that the efforts of the RBCA to conserve the agricultural heritage of African rice diversity may provide potential economic value not only through the provision of inputs to the breeding process leading to the release of new, advanced rice varieties such as NERICA and ARICA varieties, but also by maintaining the option to directly provide heirloom African rice varieties to farmers. Although most genebanks focus on the provision of genetic material for research and crop breeding programs, our results underscore the importance of genebank activities to repatriate or rematriate landraces to farmer communities, such as the International Maize and Wheat Improvement Center's Jala Rematriation Project[19] in Mexico and the International Potato Center's efforts to repatriate potato landraces via clean seed potatoes provided to Andean communities in Peru (Lüttringhaus et al., 2021). Both of these experiences highlight the value of landraces and emphasize that farming communities continue to value these heirloom varieties in and of themselves for their cultural and culinary value (Lüttringhaus et al., 2021; Ocampo-Giraldo et al., 2020), a finding that our experimental results confirm this finding in the context of Côte d'Ivoire.

Interestingly, we also find that farmers who were assigned to grow landraces during the off-season and followed through by planting were consistently willing to pay more for additional African rice landrace seed than other farmers in the sample, suggesting that greater experience with these novel varieties increased farmers' interest in them. Future work could further investigate whether farmers who received landrace seed continued to cultivate the African rice varieties provided, and how their WTP for seed of other African rice varieties may have changed from our baseline BDM elicitation.

Finally, and more broadly, the experiment shows that while most farmers in the sample had not tried or experimented with new varieties for at least several years, nearly all (approximately 90%) of the farmers exhibited some interest and willingness to experiment with the two novel types of rice seed provided in the experiment. This result suggests that the low adoption of recently developed improved rice varieties is likely not a result of farmers being unwilling or uninterested in experimentation with new technologies, but rather of other potential factors (such as the high cost of improved seed or an underdeveloped formal seed system).

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[19] Ocampo-Giraldo et al. (2020) envision rematriation as a "co-creative process of engaging with a community of farmers, including indigenous and local people, to transfer germplasm conserved in an *ex situ* collection back to its place of origin, where it can continue to evolve in situ in a nurturing environment as part of a cultural heritage and livelihood improvement."

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APPENDIX

TABLE A1 List of study villages.

Village name	Region	Driving distance to Bouake (in mins)	Number of farmers	Female farmers	% Female	% upland farmers	Latitude	Longitude
GBÊKÊ region ($n = 302$)								
Dieribanouan	GBÊKÊ	58	44	15	14.42	11.36	7.801118	−5.39288
Djekro	GBÊKÊ	51	47	8	7.69	0	7.883299	−5.14877
N'gatakoffikro	GBÊKÊ	51	52	21	20.19	9.62	7.884134	−5.14699
Samoikro	GBÊKÊ	62	25	5	4.81	0	7.816984	−5.40232
Tikakro	GBÊKÊ	42	59	13	12.50	32.20	7.840565	−5.17001
Youmien-Kouadiokro	GBÊKÊ	95	75	13	12.50	28	7.830607	−5.14736
Hambol region ($n = 267$)								
Fendene	Hambol	139	84	19	18.27	52.38	8.516518	−4.672
Kaniéne	Hambol	109	31	3	2.88	25.81	8.516458	−4.67203
Nadiokaha	Hambol	166	32	0	0	100	9.216402	−5.23447
Nassoulo	Hambol	108	90	7	6.73	16.67	8.516502	−4.67202
Ouanan	Hambol	120	13	0	0	38.46	8.388819	−4.37754
Tenenakaha	Hambol	165	17	0	0	47.06	9.182076	−5.23745

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TABLE A2 Summary statistics.

Variables	Mean	Std. dev	Min	Max
Farmer characteristics				
Age	42.47	11.47	19	78
=1 if male farmers	.83	.38	0	1
=1 if female farmers	.17	.38	0	1
=1 if None	.71	.45	0	1
=1 if primary education only	.23	.42	0	1
= 1 if higher than primary education	.06	.24	0	1
=1 if Muslim	.60	.49	0	1
=1 if Christian	.19	.39	0	1
=1 if Animist	.21	.41	0	1
=1 if language is Baoulé	.52	.50	0	1
=1 if living in Gbêkê region	.53	.50	0	1
=1 if living in Hambol region	.47	.50	0	1
=1 if have a phone (%)	.81	.39	0	1
Household characteristics				
Household size	12.59	6.17	3	65
Children	5.05	3.32	0	39
Adults	6.82	3.24	1	27
Older than 65 years	.71	1.00	0	8
=1 if skipped meal sometimes/often	.11	.31	0	1
=1 if reduce food during the day sometimes/often	.12	.32	0	1
Institutional characteristics				
=1 if belong to farmer association (%)	.15	.35	0	1
=1 if in contact with extension agents in the last 6 months (%)	.52	.50	0	1
=1 if access to credit (%)	.08	.27	0	1
Plot characteristics				
Total area cultivated (ha)	5.82	6.25	0	40
Rice area (ha)	.83	.59	.2	6
=1 if lowland, irrigated	.28	.45	0	1
=1 if lowland, rainfed	.41	.49	0	1
=1 if upland, irrigated	.11	.31	0	1
=1 if upland	.17	.38	0	1
=1 if inherited	.73	.44	0	1
=1 if marriage	.04	.19	0	1
=1 if donation	.16	.37	0	1
=1 if purchased	.01	.09	0	1
=1 if rented	.01	.11	0	1
=1 if sharecropped	.05	.21	0	1

TABLE A3 Summary statistics and balance test across treatments, random sample (nested RCT).

Variables	Treatment [T1] (*n* = 136)	Treatment [T2] (*n* = 46)	Control (*n* = 122)	Differences in treatment status within groups [T1-C]	[T2-C]	[T1-T2]
Farmer characteristics						
Age	43.816	41.283	41.074	**2.742*** **	.209	2.534
=1 if male farmers	.787	.783	.779	.008	.004	.004
=1 if female farmers	.213	.217	.221	−.008	−.004	−.004
=1 if no education	.684	.565	.623	−.013	−.058	.119
=1 if primary education only	.257	.370	.270	−.048	.099	−.112
= 1 if higher than primary education	.059	.065	.107	−.056	−.041	−.006
=1 if Muslim	.199	.196	.189	.01	−.015	−.042
=1 if Christian	.632	.674	.689	.046	.007	.003
=1 if Animist	.169	.130	.123	−.003	.007	.039
=1 if language is Baoulé	.596	.543	.598	−.004	−.055	.052
=1 if living in Gbêkê	.603	.587	.607	.004	−.02	.016
=1 if living in Hambol	.397	.413	.393	.012	.02	−.016
=1 if have a phone (%)	.824	.848	.811	2.152	.036	−.024
Household characteristics						
Household size	12.566	13.957	13.107	−.23	.85	−1.39
Children	5.147	6.022	5.377	−.317	.645	−.875
Adults	6.691	7.065	7.008	.007	.057	−.374
Older than 65 years	.728	.87	.721	−.005	.148	−.142
=1 if Skipped meal sometimes/often	.118	.13	.123	.012	.007	−.013
=1 if Reduce food during the day sometimes/often	.11	.13	.098	−.101	.032	−.02
Institutional characteristics						
=1 if belong to farmer association (%)	0096	.13	.197	−.033	−.066	−.035
=1 if in contact with extension agents in the last 6 months (%)	.537	.522	.451	.656	.071	.015
=1 if access to credit (%)	.074	.13	.107	−.004	.024	−.057
Plot characteristics						
Total area cultivated (ha)	5.779	8.652	5.123	.656	3.529	−2.873
Rice area (ha)	.704	.712	.708	−.004	.004	−.008
Cultivates other crops	.75	.652	.689	.061	−.036	.098
=1 if Inherited	.706	.696	.803	**−.097****	−.108	.01
=1 if Marriage	.059	.065	.057	.001	.008	−.006
=1 if Donation	.14	.087	.09	.05	−.003	.053
=1 if Purchased	.015	0	.016	−.002	−.016	.015
=1 if Rented	.007	.022	.016	−.009	.005	−.014
=1 if Sharecropped	.074	.13	.016	.057	**.114****	−.057
=1 if Lowland, irrigated	.34	.41	.38	−.04	.04	−.07

Note: The first three columns report the means of the data for the random sample. The final three columns report the differences between the three experimental groups (two treatments and one control) and whether the differences are significant. $^{*}p < .05$. $^{**}p < .10$. $^{***}p < .01$.

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TABLE A4 Probit model results: Factors influencing whether farmer cultivated the variety provided.

Dependent variable: Grew variety	**(1)**
Landrace treatment (randomized)	−.465
	(1.311)
Original WTA (1000 s of FCFA)	−.029
	(.188)
Original WTA (1000 s of FCFA) × Landrace treatment	**.097*****
	(.039)
Landrace treatment × Cultivates landrace	.157
	(.845)
Original WTP (1000 s of FCFA)	−.986
	(.780)
Original WTP (1000 s of FCFA) × ARICA treatment	1.104
	(.942)
ARICA treatment × cultivates improved variety	**−1.054****
	(.636)
Cultivates irrigated lowland plot	1.251
	(.850)
Constant	−3.159
	(309.572)
Enumerator and village controls	Yes
Observations	144
Pseudo R^2	.483

Note: Robust standard errors in parentheses.
*$p < .05$. **$p < .1$. ***$p < .01$.

TABLE A5 Determinants of preference for ARICA seed (in relation to landrace seed).

Dep. Var.: WTP_{ARICA}—$WTP_{Landrace}$	(1)	(2)
ARICA seed first (in game)	16.49	18.84
	(16.38)	(16.32)
Landrace seed won first (in game)	−11.89	−10.60
	(18.87)	(18.96)
Original WTA (landrace), 1000s FCFA	1.004*	1.010**
	(0535)	(38.610)
Original WTP (ARICA), 1000s FCFA	21.826*	21.606*
	(11.552)	(11.240)
Female	−30.19	−40.52
	(25.38)	(48.12)
Household Head	−8.308	−15.40
	(20.84)	(21.90)
Female Household Head		88.22
		(68.27)
Female, speaks Baoulé		−6.874
		(48.84)
Speaks Baoulé		150.0**
		(58.45)
Cultivates other crops	−51.94	−49.04
	(36.77)	(36.48)
Manages rice income	10.23	11.47
	(23.55)	(23.39)
Household income (past 6 months), 10,000 s FCFA	−.069	−.074
	(.172)	(.176)
Remembers lost varieties	−7.880	−7.178
	(18.91)	(19.02)
Contact with extension agent	7.354	9.833
	(22.81)	(22.78)
Has phone	45.88*	46.76*
	(26.81)	(26.85)
Cultivates improved variety	−20.00	−13.38
	(29.77)	(28.71)
Inherited plot	9.630	6.153
	(25.53)	(25.68)
Rice-growing area (ha)	−15.67	−16.24
	(10.17)	(10.17)
Upland farmer	67.77**	70.73**
	(33.22)	(33.50)
Cultivates irrigated lowland plot	21.46	21.02
	(27.79)	(27.29)
Enumerator and village controls	Yes	Yes
Observations	569	569
R-squared	.101	.116

Note: Robust standard errors in parentheses. We include experimental control variables (ARICA and landrace treatments and interaction with whether the variety provided was grown) but do not display them here in the interest of space (all were insignificant). $^{*}p < .1$. $^{**}p < .05$. $^{***}p < .01$.

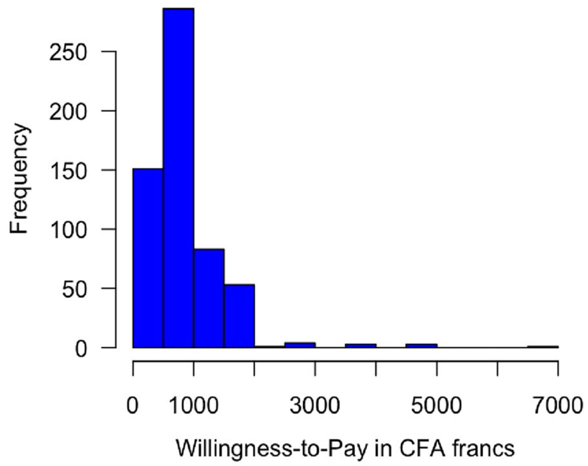

FIGURE A1 Histogram of willingness-to-pay values (for advanced rice seed) in CFA francs, from the first survey round.

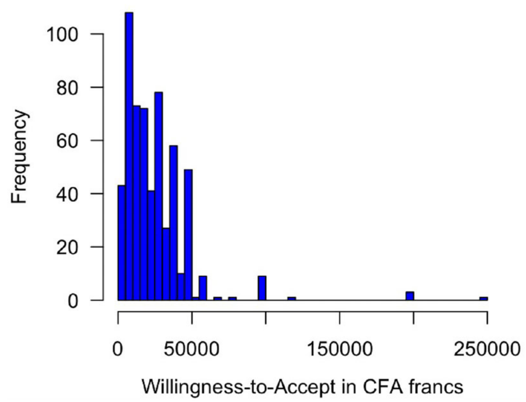

FIGURE A2 Histogram of willingness-to-accept values (for the cultivation of landrace seed) in CFA francs, from the first survey round.

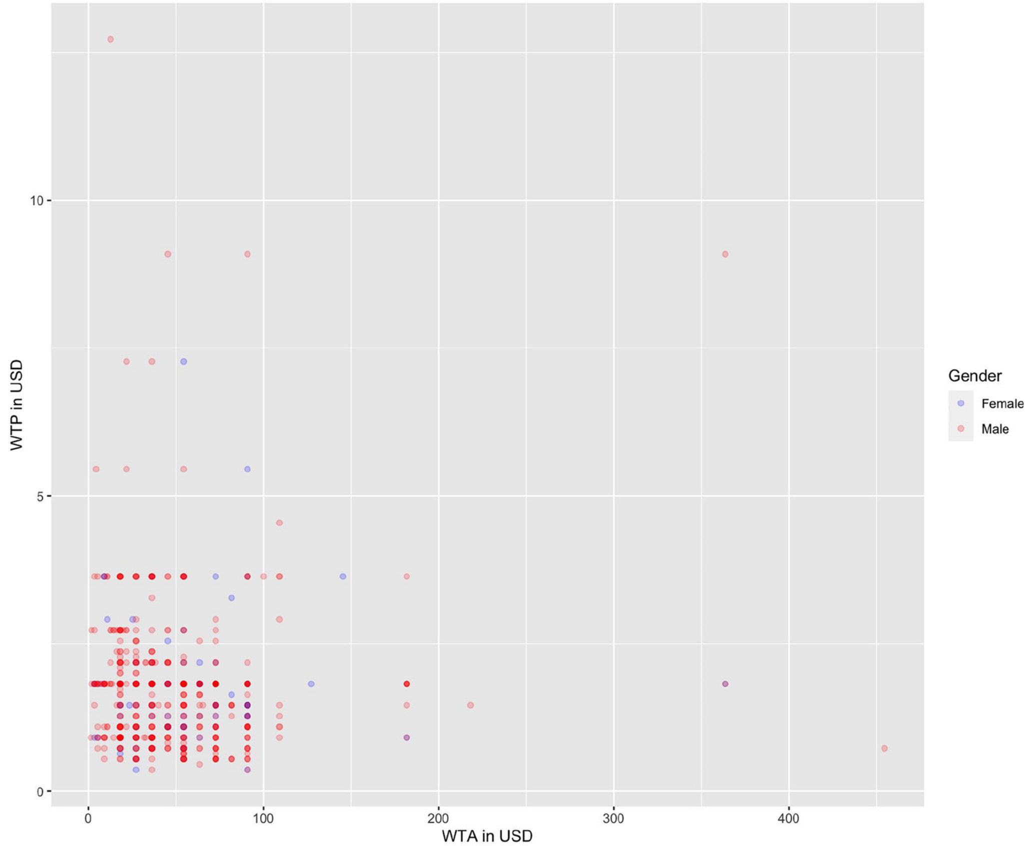

FIGURE A3 Plot of WTP (for improved rice seed) and WTA (for landrace seed) values by gender. WTA, willingness-to-accept; WTP, willingness-to-pay.

- The producer wants the full amount (550 FCFA)
- Dice roll= 2: 25 FCFA
- Dice roll= 3: 50 FCFA
- Dice roll= 4: 75 FCFA
- Dice roll= 5: 100 FCFA
- Dice roll= 6: 150 FCFA
- Dice roll= 7: 225 FCFA
- Dice roll= 8: 300 FCFA
- Dice roll= 9: 375 FCFA
- Dice roll= 10: 450 FCFA
- Dice roll= 11: 500 FCFA
- Dice roll= 12: 550 FCFA

FIGURE A4 Values used in BDM elicitation (with associated dice rolls). BDM, Becker-DeGroot-Marschak.

FIGURE A5 Image of the experimental materials.