Farmer Preferences for Abiotic Stress Tolerance in Hybrid versus Inbred Rice: Evidence from Bihar, India

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Abstract

Recent efforts to develop rice cultivars with drought-tolerance (DT) traits have resulted in the release of several varieties that demonstrate significant resiliency to drought stresses. In this paper, we use discrete choice experiments to examine farmers' preferences for DT traits and explore heterogeneity in these preferences using primary data collected in rural Bihar, India. We evaluate farmers' preference for yield performance under different weather scenarios, duration, seed reusability and seeding rate. Our results show that farmers value the reduction in yield variability offered by DT cultivars, but are willing to pay even more for cultivars that offer yield advantages even under normal conditions. Rice farmers were found to prefer short duration cultivars, which provide an alternative pathway by which farmers can manage drought risk. Finally, we find that farmers highly value seed-reusability, and would, other things equal, demand a discount on hybrid seeds that do not have this characteristic.

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Keywords: choice experiments, drought tolerance, rice, India

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1 Introduction

Rice is the most important staple food commodity in South Asia, with roughly 60 million hectares of rice cultivated each year. India is the world's second largest rice producer, producing roughly 20 percent of the world's rice. In India alone, there are approximately 43 million hectares under rice cultivation, providing a source of livelihood for millions of people.[1] In addition to being an important source of employment and income, rice contributes nearly 30 percent of total caloric energy and over 20 percent of total protein per capita in India.

Droughts represent a significant constraint to rice production in much of India. Roughly 20 percent of India's total land area is drought-prone. When droughts occur, there are significant negative impacts on rice production, both in terms of a decrease in cultivated area as well as a decrease in yield. In addition to the immediate, farm-level consequences of drought such as lower output and income, there are often significant secondary household impacts such as indebtedness, asset depletion and health consequences that perpetuate already high levels of poverty and deprivation in India (World Bank, 2008). Even broader and economy-wide impacts include rapid increases in rice prices that can increase vulnerability among food-insecure households, and strains of fiscal expenditures required to offset price increases and operate social protection schemes. This situation is disconcerting, since evidence suggests that droughts have been occurring with greater frequency in India since the beginning of the 20th century (World Bank, 2008).

Recent efforts to develop rice cultivars with drought-tolerance (DT) traits have resulted in the release of several varieties that demonstrate significant resiliency to drought stresses with no yield penalty under normal conditions.[2] Simulation exercises aimed at

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[1] FAO estimates that over 100 million households in Asia and Africa are directly dependent upon rice cultivation.

[2] Recent research has involved improvements in terms of both drought tolerance as well as drought resistance. While the terms are often used interchangeably, they in fact describe different physiological phenomenon. Drought tolerance involves enduring periods with scanty or deficient water supplies. Drought resistance, on the other hand, generally involves mechanisms by which plants protect themselves from the harsh drying sun in during drought conditions. Throughout the remainder of this paper, we will use the term "drought tolerant" as a generic term describing crops that are both drought tolerant as well as drought resistant.

assessing the impacts of DT rice suggest that the successful development and delivery of these varieties will produce significant benefits across South Asia, well in excess of the investments necessary to develop the technology (Mottaleb et al., 2012). While this holds potential promise for both public or private sector research efforts, Lybbert and Bell (2010) argue that development of DT cultivars does not necessarily imply that DT varieties will be widely adopted with the same speed as other recent improvements (e.g., crops genetically engineered to contain the *Bacillus thuringiensis* toxin, thereby making crops virtually impervious to insect) due primarily to the non-monotonic nature of the benefits associated with drought tolerance and their effect on social learning and technology diffusion.

In this paper, we use discrete choice experiments to examine farmers' preferences for DT traits embodied in different rice backgrounds, and explore heterogeneity in these preferences. Our empirical approach allows for the elicitation of a money-metric valuation for specific attributes in hypothetical rice seeds. In this study, we included drought tolerance and alternative backgrounds (self-pollinating varieties vs. hybrid) within a series of other varying attributes that characterize hypothetical rice seed options to assess farmers' choices among alternatives and determine their valuation for the DT attribute. These choices aim to simulate future market scenarios and situations that farmers will potentially face in India.[3]

The remainder of this paper is organized as follows. In Section 2, we provide a background on rice production in India, paying specific attention to the challenges wrought by frequent droughts in key rice-growing regions. In Section 3, we describe the empirical methodology used in analyzing farmer preferences and demand heterogeneity. In Section 4, we describe the data used in this study, including a discussion of the geographic and socioeconomic context of our sample area as well. In Section 5, we present the results of our empirical analysis. Finally, we offer some concluding remarks in Section 6.

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[3] For example, farmers in India may face the question of whether to purchase low-cost seed of a DT rice variety developed by public breeders versus higher-cost seed of a DT rice hybrid developed by private breeders. Similar choices (albeit for different traits) are already faced by small-scale, resource-poor farmers who cultivate cotton and maize in India, and similar choices have already been modeled for eggplant in India (Kolady and Lesser, 2006).

2 Background on rice production in India and the challenges associated with droughts

During the Green Revolution, the introduction of modern agricultural inputs such as improved seeds, fertilizers, and pesticides—along with supportive policies and investments in credit, pricing, research, and infrastructure—greatly increased agricultural production in India (see, e.g., Hazell, 2010). However, the Green Revolution's impacts in India were largely confined to the country's main irrigated areas and favorable agro-ecologies, most notably the western Indo-Gangetic plains (Punjab, Haryana, and western Uttar Pradesh) where irrigation infrastructure was most developed and where the provision of credit and fertilizers was particularly concentrated (Evenson and Gollin, 2003; Kumar et al., 2008).

In other parts of India, including the eastern reaches of the Indo-Gangetic plains where irrigation was slow to develop, the innovations associated with the Green Revolution are still being introduced today. And even despite such investments, the rate of yield growth for rice across India has decelerated in recent decades alongside a similar deceleration in wheat. While some estimates of food supply do suggest an impending Malthusian crisis, there is still a need for increased investment in new and innovative technologies that improve yield, allow for the sustainable use of scarce natural resources used in production, and resistance to biotic and abiotic stresses.

Droughts represent one of the most pressing constraints to rice yields in unfavorable and rainfed ecosystems (Pandey et al., 2007; Serraj et al., 2009). Since the early 1960s, there have been 15 instances in which total rice production in India failed to exceed the production level from the previous year. Not coincidentally, the majority of these have coincided with significant droughts in key-rice growing regions. The dynamics of drought impacts involve a complex interaction between climate, weather, infrastructure, and human behavior. The ultimate agricultural and societal impacts of droughts are dependent upon factors such as the timing and severity of the drought. For example, the 2002 drought was particularly destructive to rice production, affecting some 300 million people across India, including in some of the most important rice producing states in India such as Uttar Pradesh, Andhra Pradesh, Punjab, Orissa (now

Odisha) and Tamil Nadu. For the country as a whole the monsoon season rainfall was roughly 20 percent below the historical average mainly due to a significantly dry spell in July, during which rainfall was 49 percent below the long run average, the largest monthly rainfall deficiency in recorded history (IMD, 2002).

While decreases in production and productivity may be the most immediate consequence of droughts, these are often accompanied by lower farm incomes, increased indebtedness, asset depletion and negative health consequences that perpetuate already high levels of poverty and malnutrition in India (World Bank, 2008). Even broader and economy-wide impacts include rapid increases in rice prices that can increase vulnerability among food-insecure households, and strains of fiscal expenditures required to offset price increases and operate social protection schemes. This is disconcerting since evidence suggests that droughts have been occurring with greater frequency in India since the beginning of the 20th century (World Bank, 2008; see also EM-DAT[4]).

Questions remain as to whether existing technologies combined with improved crop management practices can meet the demands of growing populations under these increased stresses. The development of DT traits for a variety of crops has been seen as a potential avenue through which human livelihoods can be at least partially insulated from the effects of droughts. However, drought resistance has, until recently, received relatively little attention from plant breeders. For an early example of the failure to marshal resources around research on drought resistance, see Doering (2005).

Despite significant challenges and early setbacks, research on drought tolerance is proceeding in both the public and private sectors, and at both the global and national levels. Many agricultural scientists and development practitioners agree that DT varieties present a means of avoiding the increasing threat of droughts. An ex ante assessment by Mottaleb et al. (2012) suggests that the development of such rice varieties would provide significant benefits, both in terms of economic benefits to farmers as well as nutritional benefits to consumers, concluding that the monetized

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[4] EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.net – Université catholique de Louvain – Brussels – Belgium.

benefits of these advances exceed the costs of research and development necessary to bring these varieties to the market.

This is not to say that the dissemination and adoption of DT rice varieties, once developed, will be a rapid or straight-forward process. Lybbert and Bell (2010) argue that the nature of drought—and crop responses to drought—make adoption pathways for DT varieties more complicated than those for varieties tolerant to other stresses, particularly insect-resistant crops.[5] Among other important differences, they argue that drought tolerance introduces non-monotonic benefits relative to non-tolerant varieties, which, as a productivity-*enhancing* (yield variability reducing) benefit rather than purely a productivity-*increasing* (yield increasing) benefit, introduces stochastic-relative benefit streams that may complicate the decision-making calculus of risk-averse farmers.[6] But the benefits of DT rice may be nearly monotonic, as currently available DT rice varieties provide farmers with significant yield advantages over conventional varieties even under severe drought conditions. Thus, their results should perhaps be interpreted as providing a caveat that there may be a need for interventions in order to expedite the widespread adoption of DT crops.

While current efforts in developing DT cultivars have resulted in self-pollinating (inbred) DT varieties, the present study also considers the possibility that drought-tolerance traits could be embedded in a hybrid background as an alternative solution to embedding the trait in an inbred (modern or high-yielding) varietal background. The relative yield advantage of hybrid rice under irrigated systems is well documented, with some studies estimating hybrids yielding 10-30 percent higher than inbred varieties in India, China, and Bangladesh (see, e.g., Li et al., 2009; Lin, 1991; Virmani et al., 1982, 2003; Janaiah and Hossain, 2003). Creating hybrid rice with both high yield potential

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[5] The genetically modified insect-resistant crops referred to here share a similar insect-resistance trait that is conferred by the introduction of genes from the soil bacterium Bacillus thuringiensis (Bt) into their DNA. While Bt cotton and Bt maize are the largest commercial applications of this technology, Bt has also been introduced into potato, soybeans, and brinjal (eggplant), among other crops.

[6] We define a productivity-*enhancing* benefit as one that either increases yield or reduces yield variability or yield susceptibility to stress, while a productivity-*increasing* benefit more narrowly only increases yield. In this regard, productivity-enhancing technologies involve higher-order moments of the yield distribution, while productivity-increasing technologies involve only the first-order moment.

and drought resistance could both improve and stabilize yields in drought-prone environments (Villa et al., 2012).

In addition to the yield potential of hybrid rice is its economic potential for private innovators. The economic value of hybrids stems from the fact that yield gains conferred by heterosis decline dramatically after the F1 generation, thus compelling farmers to purchase new F1 seed each season if they want to continually realize these gains. These purchases of F1 seed provide innovators—breeders and seed companies—with a means of recouping their investments in research, while maintaining secrecy over the hybrid’s pedigree or the high fixed costs of producing hybrids provides the innovators with a form of protection over their intellectual property.

While hybrid rice in India is still characterized by low rates of adoption (on the order of 6 percent nationally), and while hybrid rice is still fraught with issues such as poor cooking qualities and variable yield performance, there is a sense that hybrid rice will play an important role in the future of rice production in India. The Government of India has set its sights on introducing hybrid rice on 25 percent of all cultivated rice area by 2015: although this may not be feasible, there are indications of high adoption levels in poorer northeastern states such as Bihar where 24 percent of farmers had cultivated hybrid rice at least once as of 2009 (Spielman et al., 2012).

3 Empirical Methodology

Our empirical methodology is based on using experimental choice modeling methods to analyze farmers’ preferences for seeds among a series of alternatives. Choice modeling has become an increasingly important mode of studying economic behavior and demand patterns, since this methodology allows the researcher to estimate marginal values for various attributes embodied in different goods or services, including non-market goods and services for which such marginal valuations are difficult or impossible to measure by examining revealed preferences. In addition, choice modeling allows for relatively straightforward estimation of welfare effects arising from incremental changes in the levels of the attributes included in the analysis (Colombo et al., 2008). Within the agricultural and environmental economics literature, choice experiments have been used extensively for analyzing consumer preferences for environmental amenities (e.g., Adamowicz et al., 1994; Boxall et al., 1996; Bennet and Blamey, 2001), food certification and food safety attributes (e.g., Lusk et al., 2003; Nilsson et al., 2006; Loureiro and Umberger, 2007; Ubilava and Foster, 2009; Ortega et al., 2009), adoption of voluntary traceability systems in cow-calf operations (Schulz and Tonsor, 2009), and quantify welfare effects of various agricultural and food policies (Ortega et al., 2012; Lusk et al., 2009; Tonsor et al., 2009).

In the context of this study, the use of choice experiments allows us to elicit farmers' willingness to pay (WTP) for drought tolerance as a characteristic embodied in rice. Choice experiments represent an empirical application and extension of the theoretical and conceptual work of Lancaster (1966). It may at first seem inappropriate to use an empirical approach designed within the context of consumer theory to understand producer behavior. In fact, such an approach has rarely been attempted with technology adoption, even though agricultural technologies (especially biotechnologies) are often differentiated largely on a trait-by-trait basis (Useche et al., 2009). In situations where there are missing markets or when the traits of a particular technology exhibit non-monetary effects or otherwise give rise to non-separability, the production and consumption decisions of the household must be taken simultaneously. Under these conditions, it is appropriate to view technology adoption decisions as components of a utility maximization problem, where utility of farm profits is maximized by choosing a combination of technology attributes amongst a set of feasible alternatives (e.g., Useche et al., 2012). By incorporating technology choices, farm production and farm profits in a utilitarian framework, we are able to analyze the demand for and welfare implications of traits that affect the variability of expected profits.

Choice experiments closely simulate real world purchasing decisions. In these experimental settings, consumers are asked to choose among a series of alternative bundles of attributes. Suppose that individual i faces m alternatives contained in choice set $\mathcal{C}$ during occasion t. We can define an underlying latent variable V_{ijt}^{*} that denotes the value function associated with individual i choosing option $j \in \mathcal{C}$ during occasion t. For a fixed budget constraint, individual i will choose alternative j so long as $V_{ijt}^{*} >$

$V_{ikt}^{*}\ \forall k \neq j$. The researcher does not directly observe V_{ijt}^{*}, but instead directly observes V_{ijt}, where

$$V_{ijt} = \begin{cases} 1 & \text{if } V_{ijt}^{*} = \max(V_{i1t}^{*}, V_{i2t}^{*}, \dots, V_{imt}^{*}) \\ 0 & \text{Otherwise} \end{cases} \tag{1}$$

Following standard practice, we assume that indirect utility is linear, which ensures that marginal utility is strictly monotonic in traits and yields corner solutions in which only one good is purchased (Useche et al., 2012). We can write individual i's indirect utility function as

$$V_{ijt}^{*} = X_{ijt}'\beta + \varepsilon_{ijt} \tag{2}$$

where X_{ijt}' is a vector of attributes for the jth alternative, β is a vector of taste parameters (i.e., a vector of weights mapping attribute levels into utility), and ε_{ijt} is a stochastic component of utility that is independently and identically distributed across individuals and alternative choices, and takes a known distribution. This stochastic component of utility captures unobserved (to the econometrician) variations in tastes and errors in consumer's perceptions and optimization.

The probability of observing $V_{ijt} = 1$ (i.e., the consumer chooses option j given all other alternatives in $\mathcal{C}$) can be written

$$\text{Prob}(V_{ijt} = 1) = \text{Prob}\left(X_{ijt}'\beta + \varepsilon_{ijt} > X_{ikt}'\beta + \varepsilon_{ikt}\right)\ \forall k \in \mathcal{C}, \forall k \neq j \tag{3}$$

We assume that the random component of utility ε_{ijt} follows a Gumbel (extreme value type I) distribution with cumulative distribution function $F(\varepsilon_{ijt}) = \exp[-\exp(-\varepsilon_{ijt})]$ and corresponding probability density function $f(\varepsilon_{ijt}) = \exp[-\varepsilon_{ijt} - \exp(-\varepsilon_{ijt})]$. Re-arranging terms in equation (3), we can easily observe that

$$\text{Prob}(V_{ijt} = 1) = \text{Prob}\left(\varepsilon_{ikt} < X_{ijt}'\beta + \varepsilon_{ijt} - X_{ikt}'\beta\right)\ \forall k \in \mathcal{C}, \forall k \neq j \tag{4}$$

Then, under the assumption that $\varepsilon_{i1t}, \varepsilon_{i2t}, \dots, \varepsilon_{imt}$ are identically and independently distributed, we can write our expression for the probability of observing alternative j

chosen over all other alternatives conditional upon the observed levels of the attribute vector for all alternatives in the choice set C as

$$\text{Prob}(V_{ijt} = 1 | X'_{i1t}, X'_{i2t}, \dots, X'_{imt}) = \frac{exp\left[X'_{ijt}\beta\right]}{\sum_{k=1}^{m} exp\left[X'_{ikt}\beta\right]} \tag{5}$$

which can be estimated using maximum likelihood.

Given the utilitarian interpretation of our econometric specification, the $n-$vector of parameters $\beta = (\beta_1, \beta_2, \dots, \beta_n)$ defining tastes and preferences over the n attributes can be interpreted as marginal utilities. If one of the included attributes (say, the n^{th} attribute) is the cost of the alternative, then β_n can be interpreted as the marginal utility of cost. With an estimate for the marginal utility of money, WTP for each of the corresponding attributes can be estimated as

$$\text{WTP}_s = -\frac{\beta_s}{\beta_n}, s \in [1, n-1] \tag{6}$$

where β_s is the estimated parameter for the s^{th} attribute. The negative sign appears because the marginal utility of cost is assumed to be negative, while the marginal utility for favorable attributes will be positive; thus, we must take the negative of this ratio to ensure that the WTP for a favorable attribute is represented as a positive sum.

Because farmers are heterogeneous, their preferences for drought tolerance will also be heterogeneous. Within the discrete choice literature, there are several ways for accounting for preference heterogeneity. A common method of evaluating preference heterogeneity is estimation of random parameters logit (RPL) models, also called mixed logit. The RPL is regarded as a highly flexible model that can approximate any random utility model and relaxes the limitations of the traditional logit by allowing random taste variation within a sample according to a specified distribution (McFadden and Train, 2000). Under RPL the deterministic component of utility (V_{ijt}) takes the form of

$$V_{ijt} = X'_{ijt}\,\beta \tag{7}$$

where we now treat β as a vector of random parameters with mean $\bar{\gamma}$ and variance-covariance η_i representing individual preferences. Following Train (2003), the probability that individual i chooses alternative j from the choice set C in situation t is given by

$$P_{ijt} = \int \frac{exp(V_{ijt})}{\sum_k exp(V_{ikt})} f(\beta) d\beta \qquad \textbf{(8)}$$

where the researcher can specify the distribution of the random parameter $f(\cdot)$. If the parameters are fixed at β_c (non-random), the distribution collapses, i.e. $f(\beta_c) \rightarrow \infty$ and $f(\beta) = 0$ otherwise (Ortega et al., 2012).

4 Data

The data used in this study is derived from household surveys conducted in the state of Bihar, India (Figure 1). Although roughly 90 percent of the state's population live in rural areas (compared with only 72 percent at the national level), Bihar has the highest population density of any state in India, with an estimated 1,104 persons per square kilometer as of 2011.[7] Bihar also has the lowest state-wise per capita income in India, at only 35 percent of the national average in 2009-10 (Government of Bihar, 2012).

Because of topographical and climatic conditions, Bihar is vulnerable to meteorological and hydrological hazards on a recurring basis, particularly flood and droughts. Nearly 50 percent of the total cultivated area in Bihar is prone to these hazards. Bihar's vulnerability to droughts has become much more apparent and urgent in recent years. Though roughly 57 percent of gross rice cropped area is irrigated (in some fashion or another), a large share of this irrigation infrastructure relies on diesel-powered tubewells, which significantly increase farmers' production costs, especially during years when rainfall is scarce. It seems plausible that the development and delivery of rice varieties and hybrids that demonstrate resiliency to drought conditions could significantly reduce output variability and reduce farmers' vulnerability to these hazards.

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[7] This ranking excludes Union Territories such as Chandigarh and Delhi, which each have over 9,000 persons per square kilometer.

Our sample consists of 576 rice-producing households in rural Bihar. We used a multi-stage sampling approach to form our survey sample. In the first stage, we selected three districts heavily dependent upon rice production in which to sample households: Bhojpur, Madhubani, and Nawada (Figure 1). These three districts provide a great deal of heterogeneity, not least in terms of geography and agro-ecology. Madhubani and Nawada are both participants in the Government of India's Drought-Prone Area Programme (DPAP) as of 2010, while Bhojpur and Nawada were participants in DPAP from 2002-2010. All three districts were affected by rainfall deficiencies during *kharif* 2012: Nawada and Madhubani had rainfall deficiencies of 49 percent and 48 percent, respectively, while Bhojpur had a rainfall deficiency of 32 percent (India Meteorological Department, 2012).[8] In the second stage, we selected 16 high rice producing blocks across the three districts. The number of blocks drawn from each district is proportional to the share of rice production attributable to each district.[9] Seven blocks were selected from Bhojpur, three from Nawada, and six from Madhubani. Within each of these blocks, we randomly selected two villages from which to draw households. From these villages, we randomly selected 18 rice growing households from village rosters prepared by enumerators through door-to-door listing. We therefore have data on 252 households from Bhojpur, 216 households from Madhubani, and 108 households from Nawada.

For the choice experiment, the alternatives that the individuals were presented are comprised of varying levels of key attributes that are thought to be the most important attributes that condition rice seed purchasing decisions. In our particular context, since we are concerned with farmers' preferences with regard to rice seed, we are interested in incorporating the traits that are most important to farmers when deciding on which seeds to purchase and to cultivate. The attributes included in our choice experiment and the levels over which they vary were determined through consultation with scientific

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[8] The *kharif* season is the monsoon season in India, which lasts from roughly mid-June through the end of September.

[9] These figures are based on average total rice production during 2007-08, 2008-09 and 2009-10. On average, total rice production was 227,733 (42 percent) tonne in Bhojpur, 118,163 tonne (22 percent) in Nawada, and 196,621 tonne (36 percent) in Madhubani.

experts, focus group discussions with farmers, pre-testing choice experiments in the field, and through careful review of related literature.

Paddy yield was widely identified as the most important attribute that farmers consider when deciding on which rice variety to cultivate. Since yields are ultimately the result of both deterministic and stochastic processes, it is possible that farmers consider yields under both “normal” and drought stress conditions to be important. A study by Dalton et al. (2011) that explores farmers’ demand for DT maize in Kenya demonstrated drought tolerance by quantifying yields under different rainfall scenarios, corresponding to maize varieties with different forms of stochastic dominance relative to a popular local variety: one in which the improved variety first-order stochastically dominated (FSD) the reference variety; one in which the improved variety second-order stochastically dominated (SSD) the reference variety; and a final distribution in which the improved variety third-order stochastically dominated (TSD) the reference variety.[10] Such an approach involves an attribute (drought tolerance) with three distinctly varying levels (FSD, SSD, TSD), though the attribute levels are presented as yields under different rainfall conditions, which simplifies the choice task for the respondent. This offers a novel method for characterizing drought tolerance (i.e., dehydration tolerance, which is in contrast to drought escape through a shorter duration to maturity) without necessarily specifying the pathway by which such tolerance was achieved.

For our study, we have used a similar approach to quantifying drought tolerance. Our yields under different stress conditions are derived based both on published figures for a newly-released inbred variety as well as hypothetical yields that may be obtained through hybridization. Researchers from the International Rice Research Institute (IRRI) have been actively engaged in research on DT rice, and have released a DT rice variety (Sahbhagi dhan) for use in Jharkhand and Odisha, which will soon be tested in Bihar. This variety has been shown to give better yields over check varieties in trials

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[10] Specifically, the FSD variety had higher yields than the local variety under normal conditions (thereby providing a higher expected yield) as well as under both moderate and severe drought stress conditions (thereby providing lower yield variability). The SSD variety yielded the same as the popular local variety under normal conditions (thus preserving mean or expected yields), but yielded higher under both moderate and severe drought stress. The TSD variety yielded the same as the popular local variety under both normal and moderate stress conditions, but yielded higher under extreme drought stress conditions (thereby providing protection against downside risk).

conducted during the 2005-2007 *kharif* seasons, including under both stressed and non-stressed conditions. Under severe drought conditions, Sahbhagi dhan provided a 1 t/ha yield advantage over IR 64 and IR 36, two prominent mega-varieties grown throughout eastern India. The yield distribution of Sahbhagi dhan under various water stress conditions has provided important guidance in specifying the yield distributions for potential inbred varieties presented in our choice experiment.

For hypothetical hybrid DT varieties, we had to consider the yield advantages presented by heterosis, and consider how such yield advantages might decay with increased drought stress. Based on personal communication with rice breeders from IRRI, it was determined that the most optimistic scenario for a hybrid DT rice variety is that it would yield 15% higher than Sabhagi dhan under normal conditions, but that this yield advantage would diminish to 10% under moderate drought stress conditions and 5% under severe drought stress conditions (A. Kumar, pers. comm.). We are therefore able to specify yield distributions that roughly correspond with inbred and hybrid rice with differing degrees of stochastic dominance relative to local check varieties. In the actual choice sets, we do not identify the seeds as either inbred or hybrid, but merely allow for the attribute to have six different levels. A summary of these different yield attribute levels is seen in Table 1. We label these as “hybrids” and “inbreds” to reflect the difference in yield levels, though we note there is nothing inherently hybrid or inbred about them.

Focus group discussions and consultations with scientists working on DT rice have indicated the importance of short durations to maturity for farmers in drought-prone areas, since short durations provide a means of escaping drought. Focus group discussions with farmers in several districts of Bihar have suggested that short duration remain important attributes. In our choice experiment, we have incorporated time-to-harvest, or duration, as an attribute with three distinct levels, corresponding to short (less than 120 days), medium (120-135 days) and long (greater than 135 days) duration

Specifying drought tolerance through both dehydration tolerance and drought escape mechanisms allows the researcher to determine which, if either, of these mechanisms are more valued by farmers, which additionally facilitates cost-benefit analysis that could inform public and private sector research and development programs in the discovery, development and delivery of DT rice.

Since we are interested in estimating whether demand is sufficient enough to justify private sector investment in the further development and delivery of DT rice, we also want to determine whether there are significant differences in the valuation between a DT hybrid and a DT variety. As previously discussed, heterosis is fully expressed in first generation seeds, but significantly declines in subsequent generations. Thus, farmers must typically purchase new hybrid seeds on a seasonal basis in order to obtain the maximum benefits conferred by heterosis. Inbreds, on the other hand, maintain their performance for several generations, so harvested grains can generally be stored and reused as seeds in subsequent years. Therefore to isolate the characteristic of non-reusability we characterize the choice as one between a seed that can be reused rather than a seed that cannot. This has been specified as a binary variable equal to 1 if grains can be stored and used as seeds and 0 otherwise.

We have also included an attribute to capture differences in the seeding rate between inbreds and hybrids. Hybrids typically have significantly lower seeding rates than do inbreds, sometimes on the order of 1:3. We specified two levels for the seeding rate, a low seeding rate (4-6 kg/ha) roughly corresponding to seeding rates for hybrids, and a high seeding rate (12-16 kg/ha) roughly corresponding to the seeding rates for conventional inbred varieties. As before, to avoid biasing responses, only the seeding rate ranges are presented to respondents in the choice sets.

Finally, an additional parameter capturing seed price was included to allow for the estimation of money metric measures for WTP and welfare comparisons. We have specified six price levels to be included in our choice sets. The price levels included have been specified based on cost and returns survey data collected in Bihar as part of the Cereal Systems Initiative for South Asia (CSISA). The prices roughly correspond to prices at the 5th, 25th, 40th, 50th, 75th, and 99th percentiles of rice prices in these data. The actual prices included in the choice sets are Rs.15, 25, 45, 140, 220, and 300.

To construct our choice sets, we specified a D-efficient design that takes into account all main effects as well as interactions between the yield and seeding rate attributes with the binary reusability variable. The D-efficient design was achieved using a modified Federov search algorithm, with a full-factorial design constituting the candidate set. Choice sets were constructed with three alternatives per set, with a fourth option available to respondents whereby they choose to use the variety of rice they cultivated in the previous *kharif* season. Information on these "own varieties" are collected to allow us to control for attribute levels in the choice analysis.[11] To reduce the response burden on survey respondents and reduce the probability of respondent fatigue, the choice sets were blocked into four groups of nine choice sets each. Respondents were subsequently randomly assigned to respond to the choice tasks presented in one of these four groups, with an even number of households allocated to each of the groups. Illustrations were included in the choice sets to increase respondents' comprehension of the attributes and levels presented in the choice sets. An example of one of the choice sets is presented in Figure 2.[12]

In addition to collecting data pursuant to the choice experiments, we also collect data from a series of experiments designed to ascertain farmers' risk aversion, loss aversion, and ambiguity aversion. These experiments proceed along the lines of those in Tanaka et al. (2010) and Liu (2013).[13] As an additional component of this study, a household survey was conducted to collect information on, among other things, household characteristics (including demographic and socioeconomic characteristics), agricultural production, experiences with both positive and negative economic shocks (including droughts), dietary diversity, food security, role of women in household decision making and women's empowerment, and global positioning system (GPS) coordinates. The

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[11] While such information was used in the following analysis, it was not known during the experimental design, so the design proceeded assuming only three choice alternatives per choice set. By allowing respondents to "opt out" into simply re-using the seed they used last season may introduce status quo bias, we note that only 11 percent of farmers in our sample chose this alternative. Thus, there does not appear to be a systematic over-valuation of the traits in their existing varieties.

[12] While Figure 2 is shown in English, the actual choice sets presented to respondents were translated into Hindi to increase respondent comprehension.

[13] Tanaka et al. (2010) and Liu (2013) forego the assumptions of expected utility theory (EUT) and allow for preferences adhering to Cumulative Prospect Theory (CPT). There are three parameters that characterize CPT preferences: value function curvature (risk aversion), loss aversion, and a probability weighting parameter. For more information on the experiments conducted, see Ward and Singh (2013).

additional information is relevant for further understanding the determinants of WTP, especially as it pertains to preference heterogeneity, both between and within households.

5 Results

The results of estimating the random parameters (mixed) logit model represented by equation (8) are reported in Table 2. Two sets of results are reported: the first set provides mean values for the marginal utility parameters, while the second set provides estimates of the standard deviation for the normally distributed parameters. The former provides us with valuable information on the relative value associated with each of the attribute levels, while the latter provides us with information regarding the shape of the parameter distributions, which in turn gives insight into the degree of preference heterogeneity.

As expected, the marginal utility of price is negative, indicating that farmers generally prefer cheaper seeds to more expensive seeds. This term can be used to generate money-metric WTP figures for each of the attribute levels using equation (6). The estimated WTPs associated with each of these attribute levels are given in Table 3. We use a parametric bootstrapping procedure (Krinsky and Robb, 1986) to generate 95 percent confidence intervals for these estimates.

There are positive mean marginal utilities and WTPs for each of the six yield distribution attribute levels. This is as expected, since these yield distributions stochastically dominate the distributions of mega-varieties commonly grown in eastern India. The marginal utility of a FSD distribution is higher than that of a SSD distribution, which in turn is higher than that of a TSD distribution. This result implies that farmers prefer higher expected yields over and above lower yield variability or protection against low probability downside risk (similar to Lybbert, 2006).

Additionally, the marginal utility and WTP for the “hybrid” seed distributions are always and everywhere higher than the marginal utility and WTP for the corresponding “inbred” distributions. For example, the marginal utility of a FSD “hybrid” yield distribution is higher than the marginal utility of a FSD “inbred” yield distribution. This not particularly surprising, since, while both exhibit the same degree of stochastic dominance over check varieties, the “hybrid” yields are higher than the “inbred” yields under all conditions, so the “hybrid” FSD yield distribution actually also dominates the “inbred” FSD yield distribution in the first order. But comparing the results of the SSD and TSD yield distributions provides interesting insights into how farmers value higher moments of the yield distribution. Consider, for example, the two yield distributions third-order stochastically dominating the check variety. The two seeds represented by these distributions have the same expected yield (50 maunds per acre, also the same expected yield as the check variety) and even the same yield under moderate drought stress (26 maunds per acre, again also the same as the check variety). Where these two seeds differ is in how they perform under extreme drought stress. Both yield significantly more than the check variety: the “hybrid” and “inbred” TSD cultivars yield 17 and 16 maunds/acre, respectively, under extreme drought stress conditions, compared with the check variety, which yields only 9.1 maunds/acre under extreme drought stress. But the difference in the yields under extreme stress is rather small (only 1 maund/acre). So, a priori, one might expect the WTPs for these two yield distributions to be roughly the same. But this is not the case; the WTPs are quite different: respondents are willing to pay Rs. 82 for the “hybrid” TSD yield distribution, but only Rs. 75 for the “inbred” TSD yield distribution.[14] So, other things equal, respondents on average place a 10 percent premium on the additional maund/acre provided by the “hybrid” TSD seed under extreme drought stress conditions.

The negative marginal utilities and WTPs of medium and long duration suggest that farmers prefer short duration cultivars. As the rice cultivar’s duration increases, farmers demand increasing discounts on seed. For medium duration varieties, farmers demand a Rs. 7 discount, while for long duration varieties farmers demand a Rs. 25 discount. Farmers’ preference for short duration has particularly important implications for the development of new varieties for rice cultivation in rainfed ecosystems. With shorter duration varieties, farmers can delay transplanting if the monsoon rains are delayed and still be able to sow the rabi crop (in the case of Bihar, primarily wheat) in time. This

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[14] We note, however, that this difference is not statistically significant (e.g., see the confidence intervals reported in Table 3).

provides farmers with an avenue for dealing with droughts by “escaping” the negative impacts.

We also find that farmers value being able to save harvested grain and reuse it as seed in the following kharif season. This attribute is actually quite valuable to farmers, with farmers willing to pay an additional Rs. 84 for this characteristic. We also find a negative marginal utility and WTP for the high seeding rate (12-16 kg/acre), indicating that farmers appreciate the lower seeding rates associated with hybrids, since—other things equal—a lower seeding rate implies lower input costs. Farmers demand a Rs. 60 discount for seed with these higher seeding rates.

The lower panel of Table 2 demonstrates the heterogeneity in farmers’ preferences for these various rice seed attributes. The estimated standard error of the distribution of marginal utility parameters for the “hybrid” FSD yield distribution is larger than any of the other estimated standard errors, suggesting the greatest degree of preference heterogeneity for this characteristic. There is also a great deal of heterogeneity in farmers’ preferences for being able to store grain and reuse as seed. While the mean valuation of this characteristic is large, there are 24 percent of farmers in the sample who have a negative WTP for this characteristic. Understanding the sources of preference heterogeneity can be helpful for market segmentation and potentially targeting subsidies in order to increase the speed or level of adoption of seeds like those considered here. For example, to what degree do credit constraints or land constraints affect preferences? To what degree do household demographics explain differences in how farmers value these various attributes? Do behavioral parameters such as risk aversion or loss aversion explain a significant portion of preference heterogeneity? At present we are unable to address such interesting questions, but these are avenues of ongoing and future research.

6 Conclusion

In this study, we use discrete choice experiments to examine farmers’ preferences for DT traits embodied in different rice backgrounds, and model heterogeneity in these preferences. This research provides a novel analysis of demand heterogeneity that can inform public and private sector strategies for targeting resources—subsidies, vouchers, coupons, and other such incentives—that can generate demand for a new technology among risk-averse farmers without necessarily crowding out additional private investment or otherwise distorting market signals.

Rice farmers were found to prefer short duration rice varieties as well as low seeding rates. Seed-reusability was a characteristic highly valued by farmers, a trait available only in self-pollinating inbred rice varieties. We modeled preferences for various yield distributions and found that farmers prefer higher expected yields over and above lower yield variability or simply protection against low probability downside risk. These results can be used to inform public and private sector investment in the discovery, development, and delivery of DT rice varieties. For example, future efforts to develop DT cultivars should consider this finding when conducting cost-benefit analysis for future investments into research and development of these technologies, weighing the additional costs of developing varieties that perform well in all conditions against the additional revenue that could be generated by such sales.

Additionally, while this study focuses on rice in Bihar province, we provide a methodological toolkit to motivate similar studies that address abiotic stresses characterized by similar patterns of occurrence and learning among farmers such as submergence, salinity, excessive heat, and excessive cold for rice and other crops in developing countries.

References

Adamowicz, W., J. Louviere, and M. Williams (1994). Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management* 26, 271–292.

Bennett, J. and R. Blamey (2001). The choice modeling approach to environmental valuation (Northampton, MA: Elgar Publishing).

Boxall, P.C., W.L. Adamowicz, J. Swait, M. Williams, J. Louviere (1996). A comparison of stated preference methods for environmental valuation. *Ecological Economics* 18(3), 243—253.

Colombo, S., Hanley, N., & Louviere, J. (2008). Modelling Preference Heterogenity in Stated Choice Data: An Analysis for Public Goods Generated by Agriculture. University of Stirling Economics Discussion Paper 28.

Doering, D.S. (2005). Public–private partnership to develop and deliver drought tolerant crops to food-insecure farmers. The Drought Tolerant Crop Initiative, Winrock International: Arlington, VA.

Evenson, R. and D. Gollin (2003). Assessing the impact of the Green Revolution, 1960-2000. *Science* (300), 758—762.

Government of Bihar (2012). Economic Survey 2010-11. Government of Bihar Finance Department.

Hazell, P.B.R. (2010). The Asian Green Revolution. In: D.J. Spielman, and R. Pandya-Lorch, eds., *Proven Successes in Agricultural Development: A Technical Compendium to Millions Fed.* Washington, DC: IFPRI.

Holt, C.A. and S.K. Laury (2002). Risk aversion and incentive effects. *American Economic Review* 92(5), 1644-1655.

IMD (2002). Southwest Monsoon 2002 end-of-season report. India Meteorological Department. Available online at http://www.imd.gov.in/section/nhac/dynamic/mid.htm.

Janaiah, A., and M. Hossain. 2003. Can hybrid rice technology help productivity growth in Asian tropics? Farmers' experiences. *Economic and Political Weekly* 38(25): 2492-2501.

Kolady, D. and W. Lesser (2006). Is it feasible to provide genetically modified crops to small farmers on preferential terms? An ex ante analysis of Bt eggplant in India. Selected paper for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, CA, 23-26 July 2006.

Krinsky, I. and A. Robb (1986). On approximating the statistical properties of elasticities. *The Review of Economics and Statistics* 68(4), 715—719.

Kumar, A., J. Bernier, S. Verulkar, H.R. Lafitte, and G.N. Atlin (2008). Breeding for drought tolerance: direct selection for yield, response to selection and use of drought-tolerant donors in upland and lowland-adapted populations. *Field Crops Research* 107(3), 221—231.

Lancaster, K. (1966). A new approach to consumer theory. *Journal of Political Economy* 74(2), 132—157.

Li, J., Y. Xin, and L. Yuan. 2009. Hybrid rice technology development: Ensuring China's food security. In: D.J. Spielman, and R. Pandya-Lorch, eds., *Proven Successes in Agricultural Development: A Technical Compendium to Millions Fed.* Washington, DC: IFPRI.

Loureiro, M.L. and W.J. Umberger (2007). A choice experiment model for beef: what US consumer responses tell us about relative preferences for food safety, country-of-origin labeling and traceability. *Food Policy* 32(4), 496—514.

Lusk, J.L., Norwood, F.B., and Pruitt, J.R. (2006). Consumer Demand for a Ban on Antibiotic Drug Use in Pork Production. American Journal of Agricultural Economics, 88 1015-1033.

Lybbert, T.J. (2006). Indian farmers' valuation of yield distributions: Will poor farmers value pro-poor seeds? *Food Policy* 31(5), 415—441.

Lybbert, T.J. and A. Bell (2010). Stochastic benefit streams, learning, and technology diffusion: Why drought tolerance is not the new Bt. *AgBioForum* 13(1), 13—24.

McFadden, D. and K. Train (2000). Mixed MNL models for discrete response. Journal of Applied Econometrics, 15(5), 447-470.

Mottaleb, K.A., R.M. Rejesus, S. Mohanty, M.V.R. Murty, T. Li, H.G. Valera and M.K. Gumma (2012). “Ex ante assessment of a drought tolerant rice variety in the presence of climate change.” Selected paper prepared for presentation at the 2012 annual meeting of the Agricultural and Applied Economics Association (AAEA) in Seattle, Washington, USA.

Olynk, N.J., C.A. Wolf and G.T. Tonsor (2012). Production technology option value: the case of rbST in Michigan. *Agricultural Economics*, forthcoming.

Ortega, D.L., H. H. Wang, L. Wu, N. Olynk, and J. Bai (2012). Chinese Consumers’ Demand for Food Safety Attributes: A Push for Government and Industry Regulations. *American Journal of Agricultural Economics*, 94(2), 489-435.

Pandey, S., H. Bhandari, and B. Hardy (Eds.) (2007). *Economic costs of drought and rice farmers’ coping mechanisms: a cross-country comparative analysis* (Los Banos, Philippines: International Rice Research Institute).

Schulz, L. and G.T. Tonsor (2010). Cow-Calf Producer Preferences for Voluntary Traceability Systems. *Journal of Agricultural Economics* 61, 138-162.

Serraj, R., A. Kumar, K.L, McNally, I. Slamet-Loedin, R. Bruskewich, R. Mauleon, J. Cairns, and R.J. Hijmans (2009). Improvement of drought resistance in rice. *Advances in Agronomy* 103, 41—99.

Spielman, D.J., D. Kolady, P. Ward, H. Ar-Rashid, and K. Gulati. 2012 (forthcoming). *Public Expenditures, Private Incentives, and Technology Adoption: The Economics of Hybrid Rice in South Asia.* IFPRI discussion paper, Washington, DC: IFPRI.

Tonsor, G.T., N. Olynk, C. Wolf (2009). Consumer Preferences for Animal Welfare Attributes: The Case of Gestation Crates. Journal of Agricultural and Applied Economics 41 (3), 713-730.

Train, K. E. (2003). Discrete Choice Methods with Simulation. Cambridge Books. Cambridge University Press.

Useche, P., B.L. Barham, and J.D. Foltz (2012). Trait-based adoption models using ex-ante and ex-post approaches. American Journal of Agricultural Economics [in press], doi:10.1093/ajae/aas044.

Ubilava, D. and K.A. Foster (2009). Quality certification vs. product traceability: Consumer preferences for informational attributes of pork in Georgia. *Food Policy* 34(3), 305-310.

Ward, P.S. and V. Singh (2013). Risk and ambiguity preferences and the adoption of new agricultural technologies: Evidence from field experiments in Rural India. Paper selected for presentation at the Agricultural and Applied Economics Association 2013 AAEA & CAES Joint Annual Meeting, Washington, D.C., August 4-6, 2013.

Villa, J.E., A. Henry, F. Xie, and R. Serraj (2012). Hybrid rice performance in environments of increasing drought severity. *Field Crops Research* 125, 14—24.

Virmani, S., R. Aquino, and G. Khush (1982). Heterosis breeding in rice (Oryza sativa L.). *Theoretical and Applied Genetics* 63(4), 373—380.

Table 1. Specification of yield attribute levels used in discrete choice experiment

	Hypothetical Seed Yield Distribution Relative to Local Mega Variety (maunds per acre)					
	"Inbred" First-Order Stochastic Dominant	"Inbred" Second-Order Stochastic Dominant	"Inbred" Third-Order Stochastic Dominant	"Hybrid" First-Order Stochastic Dominant	"Hybrid" Second-Order Stochastic Dominant	"Hybrid" Third-Order Stochastic Dominant
Normal	51	50	50	59	50	50
Moderate Drought Stress	32	32	26	36	36	26
Extreme Drought Stress	16	16	16	17	17	17

Note: A maund is a unit of mass commonly used in Bihar, equivalent to 40 kg.

Table 2. Random parameters logit results

Attribute level	Estimate		Std. Error
Yields 51, 32, 16[‡] maunds/acre ("Inbred" FSD)	1.1016	***	0.0829
Yields 50, 32, 16[‡] maunds/acre ("Inbred" SSD)	0.9331	***	0.0805
Yields 50, 26, 16[‡] maunds/acre ("Inbred" TSD)	0.8377	***	0.0857
Yields 59, 36, 17[‡] maunds/acre ("Hybrid" FSD)	1.6651	***	0.1066
Yields 50, 36, 17[‡] maunds/acre ("Hybrid" SSD)	1.0809	***	0.0939
Yields 50, 26, 17[‡] maunds/acre ("Hybrid" TSD)	0.9220	***	0.8910
Medium duration (120-135 days)	-0.1020	*	0.0590
Long duration (more than 135 days)	-0.2744	***	0.0532
Grain can be stored and reused as seed	0.9416	***	0.0754
High seeding rate (12-16 kg/acre)	-0.6730	***	0.0513
Price (Rs.)	-0.0112	***	0.0003

Distribution Parameters	Estimate		Std. Error
Std. Deviation ("Inbred" FSD)	0.4323	***	0.1444
Std. Deviation ("Inbred" SSD)	0.1541		0.2161
Std. Deviation ("Inbred" TSD)	0.4468	***	0.1517
Std. Deviation ("Hybrid" FSD)	1.4326	***	0.1204
Std. Deviation ("Hybrid" SSD)	0.8457	***	0.1338
Std. Deviation ("Hybrid" TSD)	0.3987	***	0.2310
Std. Deviation (Medium Duration)	0.8450	***	0.0632
Std. Deviation (Long Duration)	0.4219	***	0.0890
Std.Deviation (Grain can be stored and reused as seed)	1.3463	***	0.0804
Std. Deviation (High Seeding Rate))	0.6428	***	0.0650

Note: * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level.

[‡] These figures correspond to yields under normal conditions, moderate drought stress conditions, and extreme drought stress conditions, respectively.

Table 3. Estimated willingness to pay for rice seed attributes

	WTP		
	Lower 2.5%	Mean	Upper 2.5%
Yields 51, 32, 16 maunds/acre ("Inbred" FSD)	83.85	98.10	112.32
Yields 50, 32, 16 maunds/acre ("Inbred" SSD)	68.57	83.24	97.91
Yields 50, 26, 16 maunds/acre ("Inbred" TSD)	59.06	74.55	89.19
Yields 59, 36, 17 maunds/acre ("Hybrid" FSD)	130.08	148.17	168.08
Yields 50, 36, 17 maunds/acre ("Hybrid" SSD)	79.04	96.76	113.05
Yields 50, 26, 17 maunds/acre ("Hybrid" TSD)	66.11	81.86	97.62
Medium duration (120-135 days)	-19.23	-8.76	0.23
Long duration (more than 135 days)	-34.16	-24.55	-15.73
Grain can be stored and reused as seed	71.10	84.00	97.70
High seeding rate (12-16 kg/acre)	-68.58	-59.93	-50.95

Note: Confidence intervals derived using parametric bootstrap procedure introduced in Krinsky and Robb (1986).

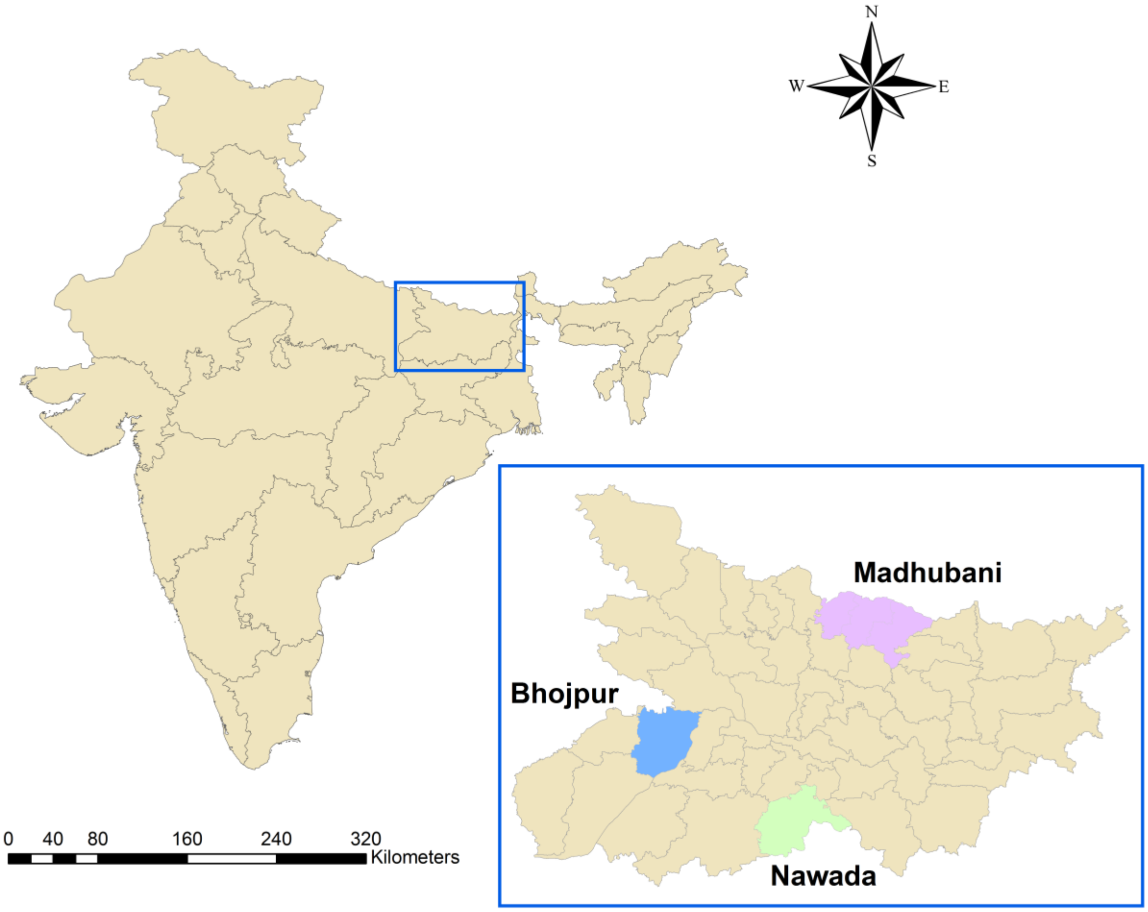
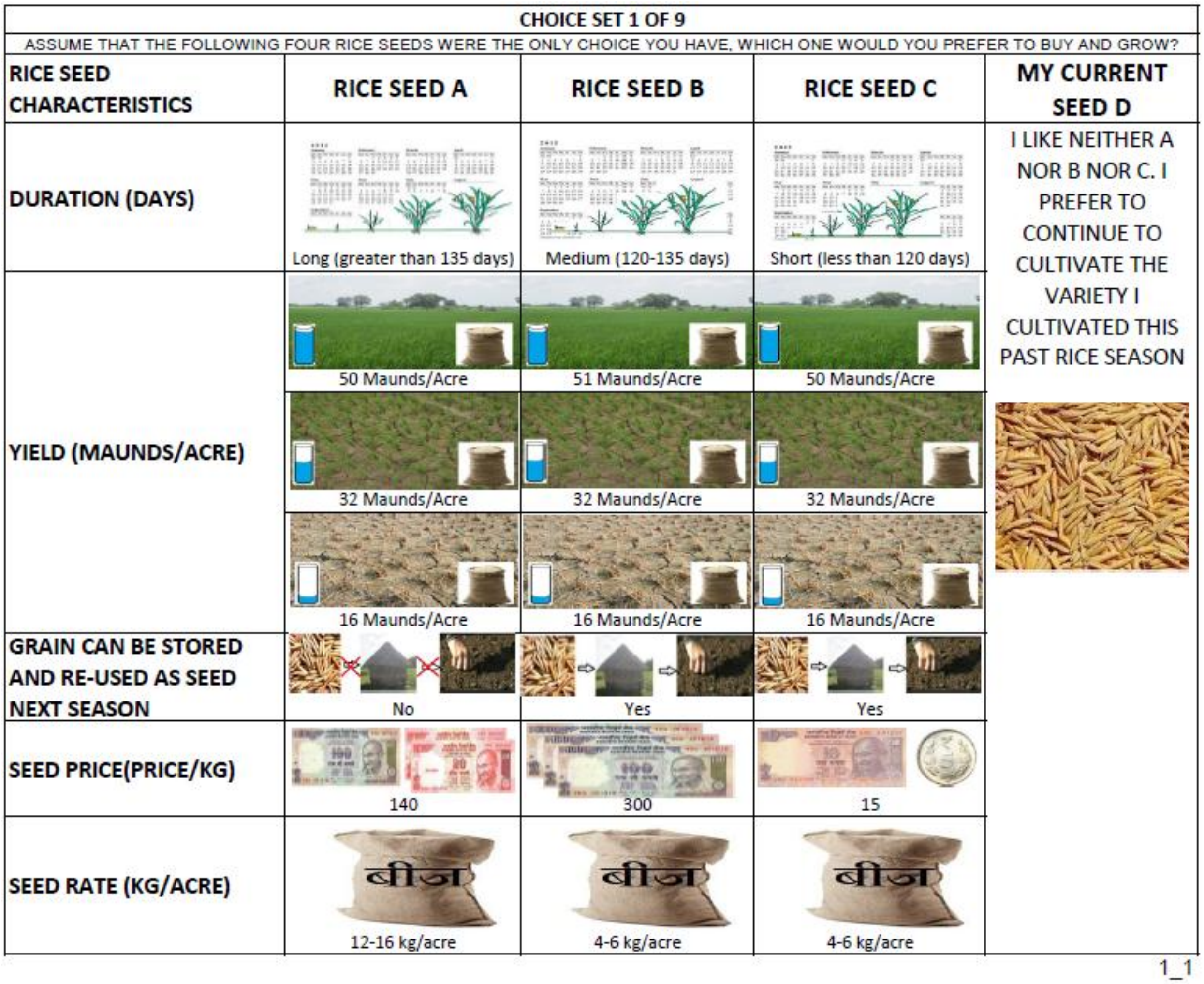


Figure 1. Location of sample districts



CHOICE SET 1 OF 9

ASSUME THAT THE FOLLOWING FOUR RICE SEEDS WERE THE ONLY CHOICE YOU HAVE, WHICH ONE WOULD YOU PREFER TO BUY AND GROW?

RICE SEED CHARACTERISTICS	RICE SEED A	RICE SEED B	RICE SEED C	MY CURRENT SEED D
DURATION (DAYS)	Long (greater than 135 days)	Medium (120-135 days)	Short (less than 120 days)	I LIKE NEITHER A NOR B NOR C. I PREFER TO CONTINUE TO CULTIVATE THE VARIETY I CULTIVATED THIS PAST RICE SEASON
YIELD (MAUNDS/ACRE)	50 Maunds/Acre	51 Maunds/Acre	50 Maunds/Acre	
	32 Maunds/Acre	32 Maunds/Acre	32 Maunds/Acre	
	16 Maunds/Acre	16 Maunds/Acre	16 Maunds/Acre	
GRAIN CAN BE STORED AND RE-USED AS SEED NEXT SEASON	No	Yes	Yes	
SEED PRICE(PRICE/KG)	140	300	15	
SEED RATE (KG/ACRE)	12-16 kg/acre	4-6 kg/acre	4-6 kg/acre	

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Figure 2. Example of choice set presented to survey respondents