Overcoming quality uncertainty of hybrid maize seeds:
An individually-randomized trial of labeling information in Chiapas, Mexico

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Abstract

Adoption of new seeds or other inputs is a major driver of change in agriculture and nutrition, but farmers cannot observe performance directly and must rely on reputation to choose among available options. This study uses a choice experiment to test the role of seed companies' national origin in brand loyalty among farmers in Chiapas, Mexico. We find that, when the yield potential of hybrid seeds is conveyed in vague words ("bueno" or "alto") instead of numerical terms (kg/ha), respondents are likely to choose only seeds from the same kind of company. With verbal descriptions respondents were most likely to choose only seeds from international brands (OR 63, *p*-value .01), but some chose only seeds from local companies (OR 21.36, *p*-value .01), as opposed to the most cost-effective choices which were a mix of the two. We conclude that pre-existing loyalties can be replaced with factual information to improve seed choice, even in a setting with strong beliefs about the role of national origin in product quality.

Background

Maize is a significant component of the Mexican diet and agricultural economy. For 2.5 million smallholders it plays an important role in income generation and food security (Coneval, 2015). However, for over 50 percent of maize growers production levels have remained stagnant leaving a large gap in production between the technology inclined growers in Northern states compared to smallholders in Southern states (CIMMYT, 2018; García-Salazar, 2016). The yield gap among smallholders means at the household level there are unrealized endowments when agricultural production is not maximized, while at the national level when surplus on average is low there is increased dependency on imports (Donovan, 2020; Turrent, Wise, & Garvey, 2012). There is evidence that adoption of hybrid seeds, which are bred to be high yielding and resistant to environmental issues like drought, and pest, increases maize production and functions as an important pathway to raising household income and reducing poverty for smallholders, at the same time contributing to the overall availability of maize at the national level (Becerril & Abdulai, 2010; Bellon & Risopoulos, 2001; Mignouna, Manyong, Rusike, Mutabazi, & Senkondo, 2011). To this end, the Mexican Government has invested in developing the formal national seed market as part of a broader strategy to increase the amount of seed available at lower prices and promote better farming practices among smallholders (Donovan, 2020). The national seed industry coexists with the international seed industry. The major distinction between these two groups is international companies have their headquarters outside of Mexico, while national companies are based in Mexico. The former has been in place for over 40 years, has a strong hold of the market in Mexico and established strong brand recognition. After 20 years of sustained efforts to create and disseminate nationally branded seed there is still low

adoption of national seed, and low yields. The national average is about 3 t, while large-scale farmers achieve 10 mt/ha , and the average in the study region is 1.7 mt/ha (SIAP, 2016, 2019; Zepeda, 2018).

To produce maize, farmers may use maize seed that was saved from their previous harvest, purchase seeds like hybrids, or a mix of both saved and purchased seed. In Mexico, hybrids from international companies have been available since the early 1990s, while national seed companies entered the market in the last 20 years. Of the hybrids planted in Mexico, about 40 percent of maize hectares planted are from hybrids seed, just four international brands account for 80 percent of sales. Data from seed sales showing higher international seed sales relative to national seed sales suggests farmers have strong preference for international seed brands though national brands offer seeds with comparable yield potential at lower prices (CIMMYT, 2018; Domínguez, 2019; MasAgro, 2018; SIAP, 2019). The price gap between local seeds and international seeds, on average 1000 pesos. As such, seed brand and price are closely intertwined, the price point of a seed reveals if it is an national brand or not.

When choosing among seeds why do farmers so often opt for the most expensive option, international brands? Seeds are a type of product with attributes that do not reveal their characteristics or quality to a consumer at the time of purchase (Allaire, 2010). That information has to be communicated through other means like labels. It may be that information about cost-effective options and overall about the breath of seeds available may be missing in the market. Specifically, at seed point of sales like agrodealers limited information is available on the product like a 20 Kg seed bags, which results in asymmetric information about agronomic traits or quality, and cost-effectiveness of each seed. This gap in knowledge may contribute to strong purchasing preferences based on brand towards international brands. One repercussion of

missing information regarding quality is using price or brand as a signal of quality (Wolinsky, 1983). With the obvious price gap between local seeds and international seeds noted above, if producers are using price to make a choice among seeds international brands would be chosen over national brands. However, it remains unclear how asymmetric information about national seed options interacts with efforts to expand national hybrid seed use among smallholders.

Can better information and labeling help to expand sales of national seed industry in a competitive market? Despite low market shares of national seed and sustained investment in the national seed market, few studies have investigated farmers' preference for seed and options to shift preferences towards national brands. Studies to date from Mexico and from other maize growing regions in Africa and Asia largely focus on willingness to adopt hybrid seed, and preferences for hybrid relative to non-hybrid seed (Groenewald & Van Den Berg, 2012; Li, van Bueren, Jiggins, & Leeuwis, 2012; Maredia et al., 2018; Sánchez, Kallas, & Gil, 2017; Sinyolo, 2020). Data specific to seed preferences of adopters has been collected at demonstration plots where the agronomic traits between full grown plants can be compared visually. However, data at the point of purchase, where physical evidence of agronomic traits is not available, is lacking. Both types of data are needed to better inform policies and programs that aim to increase use of national seed and production amongst farmers (Maredia et al., 2018).

Therefore, we sought to fill this knowledge gap by examining how farmers respond to different yield performance information when presented qualitatively or numerically. Randomized information treatments in a choice experiment (CE) were administered among 207 farmers who purchased inputs at agrodealers in the Frailesca region of Chiapas, Mexico, creating two groups for comparison, a group who received qualitative information and a group who received numerical information. The goal was to understand how different forms of yield

performance information impacted farmers' choice among hybrid maize seeds. We tested how yield information per seed bag, conveyed in qualitative form (e.g. "bueno") versus numeric form (e.g.7.6 mt/ha), influenced seed purchasing decisions. We hypothesized that farmers who received numeric data about the yield performance of seeds would be more likely to select a cost-effective seed, regardless of brand type.

Our approach is guided by the conceptual framework around the value of information to consumers when making purchasing decision about food, which posits that consumers make different decisions about a product depending on the information available at the time of purchase (Foster & Just, 1989; Lusk, 2013). In seed transactions specifically, the seller knows more about the quality of the seed than the consumer. If a national seed company has strategically committed to producing high quality seed that is comparable to international brands, the absence of information like that on labels leaves the companies without a means of communicating the level of quality of the product. Communicating quality may occur through labeling, among other marketing practices, to call attention to characteristics of products. Without the label information to assert the quality of the product, a consumer may judge a product through a simplified assessment, a product is either of high or low quality. Adding to the complexity of seed choice is the number of seed brands which available in the Mexican market without the information needed for product differentiation.

An important quality characteristic of seed to communicate is yield potential. When speaking of yield, generally how many metric tons per hectare (mt/ha) is used to assess high from low yielding seed. However, a numerical assessment does not appear on labels or any marketing material, though qualitative categories can be found in the market. Historically, for food labels, numerical or descriptive categories have been used in USDA standards and

regulations (Armbruster, Henderson, & Knutson, 1983). Borrowing from food labels we explore how numerical information contributes to decisions of seed selection. If more information is available to farmers about the yield of international and nationals seeds, what does that do to their seed choice?

Methods

Study setting, population and data collection

The Frailesca region was considered an appropriate study setting due to the number of smallholders in the area with low productivity, the main constituency at which the government investment in a national sector development is aimed. A recent study at the state level in Chiapas estimated about 54 percent of its sample used hybrid seed (Zepeda, 2018). In terms of sales of national seed, Chiapas has the fourth highest sales (CIMMYT, 2018). Thus, the state has a higher hybrid adoption rate among its farmers than nationally and a high potential to grow (CIMMYT, 2019a; García-Salazar, 2016; Sánchez, Kallas, & Gil Roig, 2017).

Productivity in this region is low, the average yield at the state level is estimated to be 1.7 mt/ha with some small-scale farmers experiencing even lower yields (Zepeda, 2018). Additionally, production in this region is almost exclusively rain fed, and counts on the most limiting conditions for increasing maize production, which make an increase in production difficult. However, there is evidence that suggests the conditions under which hybrid seeds thrive exists in Chiapas. Trials from both on farm and demonstration plots suggest yields from seed developed by MasAgro and sold by national brands on average are higher than non-hybrid (CIMMYT, 2019b).

Farmers who purchase hybrids at agrodealers were our population of interest. We surveyed farmers at six agrodealers in three municipalities. A map highlighting these

municipalities, two urban-Villa Flores (VF) and Villa Corzo (VC) and one rural-La Concordia (LC), is included in supplemental materials, Figure 1. Data was collected during the planting season peek of the summer season in the month of June in 2019. Farmers were eligible to participate if they reported buying maize hybrid seeds for the harvest year (2019), made decisions about crop inputs, and purchased their hybrid seed at an agrodealer.

We used a purposive sample to provide randomized information treatments to respondents. Individual random draws assigned 115 respondents into a numerical yield information group and 92 respondents to a qualitative yield information group. A total of 207 farmers make up the analytic sample. A Consolidated Standards of Reporting Trials (CONSORT) figure illustrating this breakout is included in supplemental materials, Figure 2.

Two instruments were used to collect data. First, an intercept survey was used to ask 31 questions about household characteristics on wealth, household size, education, occupation, input use (e.g. fertilizer, irrigation), spending on inputs both seed and non-seed inputs, soil quality, land type and size, production yield and use, and an assessment of risk, to capture factors affecting operations related to environment, production, and market. Subsequently, through a choice experiment (CE), four pairwise seed information profiles were used to ask about seed choice.

Choice experiment and seed profiles

Choice experiments aim to elicit respondents' preferences among items with diverse characteristics (Baltussen & Niessen, 2006; Breidert, Hahsler, & Reutterer, 2006). In this study, our focus is the information conveyed by the national origin of a seed company, as a factor in farmers' choice of one seed over another at their local agro-dealer. Our CE was designed for brevity and simplicity, offering a series of four pairwise comparisons between eight different

packages of hybrid maize seed. Each profile included actual information about real seeds available for sale, but the cards used to represent each type of seed conveyed only selected information about it. All choices were hypothetical but farmers were interviewed through market intercepts at each agro-dealership, ensuring the salience of their choice. In each pair, one of the two seed types was by far the more cost-effective choice, offering much higher yields or lower price or both. In Chiapas one bag of seed is used to plant one hectare of maize on average (Bellon & Hellin, 2011). Therefore we use one bag of 20 kg seed per hectare to estimate how much each the cost of seed per kg delivers per hectare based on the mt/ha figure associated with each profile. For choice 1, 3 and 4 the cost-effective option is unambiguous. For choice 2, option B is more expensive per bag but gives higher yield, so is more cost-effective at 270 pesos per ton harvested than option A which costs 350 pesos per ton harvested. It is conceivable that option B requires more inputs other than seed, but those our omitted from our choice experiment and our calculation. A summary of the options is provided in Table 1 and the actual profiles used are provided in Figures 3-6.

The information in each profile, numeric or qualitative, was meant to mimic the information which could be found on a seed bag label. During formative work we found labels on seed bags to be the primary medium through which seed information is available at agrodealer shops. For both brand types, international or national, labels provide similar details about seed – whether seed is a hybrid, if seed is certified, the seed company's origin, brand name, price, type of seed treatments, number of seeds and weight of the bag. To create the seed profiles we selected existing seed international and national seed brands available in the market in the Frailesca and for which we had on farm trial data. Therefore, each profile corresponds to a

seed that farmers currently have access to. A full explanation of the agronomic data used in developing the profiles is included in the supplemental materials.

Table 1 | Summary of the four pairwise seed profiles used in the choice experiment

Choice	Option A (National brand)	Option B (International brand)	Note: most cost-effective option
1	1500 pesos 7.9 mt/ha	2500 pesos 6.3 mt/ha	A
2	1600 pesos 5.9 mt/ha	2550 pesos 7.3 mt/ha	B
3	1350 pesos 7.35 mt/ha	2400 pesos 7.35 mt/ha	A
4	1400 pesos 7.9 mt/ha	2850 pesos 6.3 mt/ha	A

Note: Data shown are each option's price per 20 kg bag (60,000 seeds), in Mexican pesos. In the choice experiment, for respondents randomized to receive only qualitative information about performance, the yield levels shown are replaced with a verbal description as "alto" if above 7 mt/ha , and "bueno" otherwise. All respondents see whether the company is national or international, but column 4 indicating which is the more cost-effective option is shown here only for ease of interpretation. All profiles are derived from actual seeds being sold, but no trade names or markings were visible to respondents. Farmers who always choose multinational would choose only option B, while those who always choose national brands would choose only A.

Respondents who received qualitative cues via the seed profiles were presented with a label like summary that included the following: notification seed was a hybrid, certification label, origin of seed company, price, type of seed treatment, number of seeds, price and a general assessment of yield, which was captured in two categories good "bueno" or very good "alto".

By contrast, respondents who received numerical cues were presented with the same information as the qualitative cues but instead of yield in qualitative form were given yield in numerical form, which was laid out visually using a numerical line that underscored where on the line the characteristic fell as seen in Figures 3-6. The numerical line itself represented true

minimum and maximum values. As part of the visual representation plant height, ear size, and price per 20 Kg bag were also included. The variation of plant height and ear size vary very little among profiles and were used as filler in the visualization; and the price visualization was a repetition of the price included in the summary.

The qualitative and numerical methods used as described above were motivated by current practices and the desire to contrast them with different forms of information. Describing yield in a categorical way like "bueno" is used in cataloguing of varieties at CIMMYT and by some marketing practices of both international and national brands. It allows for a general assessment about the yield potential of a seed. Providing specific yield information for seed is not a standard practice as production practices and environmental characteristics vary vastly between farmers. In our study, to contrast the qualitative information we use numerical information in order to add a layer of specificity in the comparisons between profiles. As such, our goal was to bring attention to more granular information about yield potential and overall information available to producers. The metric mt/ha fulfilled that role in the CE.

Primary outcome: seed choice

Our main outcome of interest was a respondent's seed choice from the pairwise seed profiles. Each pairwise comparisons had outcome – 1) respondent chose the cost-effective seed profile or 2) the alternative seed profile, and there were a total of four comparisons. Those results were transformed into multiple variables for analysis. First, the data was transformed into a binary variable for each comparison. Subsequently, into a categorical variable that denotes choice for all four comparisons combined, which results in a maximum of 16 nominal groups as seen in Table 2. Only one of these groups, NTNN, represents the set in which each of the four

choices was the least expensive option. Of the 16 groups, four accounted for over 92 percent of observations as seen in Table 3. With this in mind, a categorical variable was created that included a category for each of those four groups (NNNN – which is equivalent to selecting all national seeds; TTTT – which is equivalent to selecting all international seed; NTTN a mix that was 75 percent cost effective and the NTNN which was the most cost effective option) and an additional category for the other 12 nominal groups with fewer observations. In addition, an ordinal categorical variable was created that accounts for cost-effective choice made across the four pairwise comparisons in percent - 100, 75, 50, and 25, which are laid out in Table 4. These transformations allowed us to estimate the fraction of the farm population who would switch to the cost-effective seed, regardless of brand type (international or national), if information about yield was provided in numerical form at the time of purchase, when comparing the treatment group that received numeric yield information with the control group that received qualitative yield information.

Key independent variables

Treatment was included in regression models as a dichotomous variable to denote if numeric or qualitative information on yield was provided. Socioeconomic variables which may also be associated with adoption of technology were included in our analysis (Auriol & Schilizzi, 2015). A wealth index score was derived from principal component analysis of self-reported household asset ownership using an adapted version of the national demographic and household survey, Encuesta Intercensal, from 2015 (INEGI, 2015). The number of livestock owned was included as continuous variable. Household size and the age of respondent were each included as a continuous variable. The reported cost of inputs, seed and non-seed (e.g. fertilizer), purchased for the summer harvest the previous year was collected in Mexican pesos as a

continuous variable. What seed type respondents planted in the previous summer harvest was recorded as a binary variable, national versus international.

Table 2 | Nominal groups created by combining choices from four pairwise seed profiles

Comparisons	Groups (16 total)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Choice 1	N	N	T	N	N	N	T	T	T	N	N	T	N	N	N	N
Choice 2	N	T	T	T	T	N	N	T	T	N	N	N	T	T	N	T
Choice 3	N	N	T	T	N	T	N	T	N	N	N	T	T	N	T	T
Choice 4	N	N	T	N	T	N	N	N	N	T	T	N	N	T	T	T

*N= seed choice from national brand type; T= seed choice from international brand type

Table 3 | Nominal groups created by combining choices from four pairwise seed profiles

Groups	Freq.	Percent
NNNN	76	36.71
NTNN	61	29.47
TTTT	43	20.77
NTTN	11	5.31
NTNT	4	1.93
NNTN	3	1.45
TNNN	2	0.97
TTTN	2	0.97
TTNN	2	0.97
NNNT	1	0.48
NTTT	1	0.48
TNTN	1	0.48

Note: 12 out of 16, four choices were not selected (NTTN, NTNT, NNTT and NTTT)
N= seed choice from national brand type; T= seed choice from international brand type.
NTNN is the reference category, which is the most cost-effective across the four choices.

Table 4 | Percent cost-effective across four choices by nominal groups

% cost-effective choice	Top four nominal groups plus other					
	NNNN	NTNN	TTTT	NTTN	Other	Total
100%	0	61	0	0	0	61
75%	76	0	43	11	7	137
50%	0	0	0	0	7	7
25%	0	0	0	0	2	2
Total	76	61	43	11	16	207

Note: N= seed choice from national brand type; T= seed choice from international brand type.
NTNN is the reference category, which is the most cost-effective across the four choices.

Potential confounders

We assume confounders related to hybrid seed adoption technology may play a similar role when analyzing seed choice among hybrids seed. Information on six known confounders was collected. Whether or not a respondent used fertilizer or had irrigation infrastructure was collected as a binary variable. Farm size in ha was collected as continuous variable. An assessment of risk was collected as a scale (1-5) for three different aspects the uncertainties faced in agriculture, production (e.g. disease), market (e.g. price), and environmental (e.g. drought). A composite of these three was used to create total risk score (1-15). Perceptions of soil quality for maize production was collected as a scale (1-5). Yield, mt/ha , in maize for the last summer harvest the previous year was collected as a continuous variable.

Analyses were completed using Stata 16 (StataCorp, College Station, TX). We used primary data from the intercept interviews to explore relationships between seed choice among pairwise profiles and four groups of characteristics, agronomic, farm, demographic and seed use. We then built multinomial and logistic regression models controlling for covariates that were significant at $p<0.2$ in bivariate analysis.

Results

In our sample, a large proportion of farmers, 66 percent, planted only hybrids seed, the rest planted both non-hybrids and hybrids. Over 80 percent of farmers planted international brands. In comparing the two randomized groups, one that received numerical information and one that received qualitative information, we find characteristics like age, farm size and reported yield are similar. Statistically significant differences among the two groups exist in two area, education and wealth. The mean (sd) for characteristics assessed are reported in Table 5. Mean

age for the sample was 49.2, it was a lower for treatment 48.8, and slightly higher for the control group 49.3. The size of a farm was 19.4 ha on average, with the treatment group having larger farms by about 2 ha and the control group having smaller farms by about .5 ha. The mean reported yield from the previous harvest was 5.42 mt/ha for the sample and similar for each of the study groups. The treatment group was on average more educated, had a larger household size, spent more on seed and other inputs and reported higher soil quality than the control group. The control group owned more livestock than the treatment group. In terms of choice, when presented with information on yield in numerical form versus qualitative form, over 50 percent of producers in the treatment group selected the cost-effective choice compared to the control group in which 4 percent selected the cost-effective choice.

We expected respondents who were assigned into the numerical group to select the cost-effective choice more than 50 percent of the time. The results show they did so over 59 percent of the time in each of the four comparison, as detailed in Table 6. Respondents who received qualitative yield data however only chose the cost-effective 23-40 percent of the time for each choice and did not reach 50 percent in any of the comparisons.

Regression

In this section we present results from a multinomial regression model, odds ratios and *p*-values are reported in Tables 7-9. Findings from logistic and ordered logistic regression models are reported in supplemental materials Tables 10 and 11. Across the models, we find treatment of numerical yield information had a strong positive association with choosing cost-effective seeds regardless of brand type.

In the multinomial regression model, using the nominal group in which each of the four outcomes were the cost-effective choice as the reference group (NTNN), we find when yield

information was conveyed verbally, as opposed to numerically, farmers were likely to choose only seeds from one brand type (national or international). They were over 60 times more likely to choose only seeds from an international brand (OR 63, *p*-value .01), and over 20 times more likely to choose only seeds from a national brand (OR 21.36, *p*-value .01), as opposed to the most cost- effective choices which involved a mix of the two brand types. Of the covariates included in the model, other than treatment, only the cost of seed had a significant association with seed choice, but just for respondents who only selected seed from national brands (OR .99, *p*-value .05).

Table 5 |Difference between respondents who received numerical data versus verbal data

Characteristic	Numerical yield data (n=115)			Qualitative yield data (n=92)				
	n	mean	sd	n	mean	sd	difference in mean (T-C)	
Respondent age	115	48.77	14.18	92	49.27	12.62	-0.51	
Respondent education	114	2.91	1.80	91	3.14	2.15	.23	**
Household size	114	4.64	2.33	92	4.38	2.43	0.26	**
Wealth quintile	114	3.09	1.44	90	2.9	1.38	0.19	***
Farm size ha	115	21.69	36.91	92	19.93	44.2	1.76	
Yield mt/ha	84	5.39	1.92	69	5.51	2.41	-0.13	
Livestock	115	37.43	60.5	92	49.5	113.75	-12.07	***
Spending seed inputs	114	2123.87	371.47	92	2057.28	508.94	66.59	***
Spending non-seed inputs	114	8357.04	6230.14	92	7211.74	3783.8	1145.3	***
Total risk level	115	10.67	2.30	92	10.63	2.8	0.04	
Environmental risk	115	3.73	1.20	92	3.73	1.27	0	
Market risk	115	3.93	1.17	92	3.88	1.27	0.05	
Production risk	115	3.01	1.28	92	3.02	1.37	-0.01	
Soil quality	112	3.64	0.85	92	3.57	0.89	0.07	*

*** $p< 0.01$ ** $p< 0.05$, or * $p< 0.1$

Table 6 | Frequency and percent of respondent who selected the cost-effective option in each choice by type of information treatment, verbal or numerical

	Choice 1		Choice 2		Choice 3		Choice 4	
	Verbal	Numbers	Verbal	Numbers	Verbal	Numbers	Verbal	Numbers
Count	50	157	83	124	61	146	49	158
Percent	24.15	75.85	40.10	59.90	29.47	70.53	23.67	76.33

Looking at the results at the municipality level we find farmers in Villa Corzo and La Concordia had a lower probability of choosing only national brands than farmers in Villa Flores, with highly significant odds ratios around one-tenth the likelihood that all four choices were national seed brands.

Nominal group differences

We find household and farm characteristics in this sample did not predict which respondents were likely to make choices that led to selected groups of national seed only, international seed only, or the most cost-effective group which included both. However, there were differences among some the nominal groups.

Choosing only seeds of national brand – For respondents who selected only national seed, we find the amount spent on seed during the previous harvest was significantly and positively associated with seed choice but only at .99 OR (*p*-value .05). Respondents in this group also reported experiencing higher risk compared to the other four groups including the reference group that selected the most cost-effective seeds which were a mix of national and international seeds.

Choosing only seeds of international brand – The respondents who chose only international seeds, which were the most expensive combination across the four pairwise choices, reported the highest yields but also the least amount of wealth with a mean (sd) -0.35

(1.56). This group was also older, 53 years (14.6), and the least educated among the five nominal groups.

Choosing the cost-effective options regardless of brand – The respondents who selected a mix of national and international options, which were the lowest priced, had the largest farm size and most livestock. That group was made up of 95 percent of growers who reported planting international brands. For comparison, the national only group had over 70 percent of respondents who reported planting international brands over national brands.

Discussion

This study is the first to investigate how different forms of yield performance information, numerical versus qualitative, impact farmers' choice for hybrid maize seeds in the Frailesca region of Chiapas, Mexico. Results from this study add to the knowledge base around demand related issues: information and how farmers process it for making purchasing decisions, price and its role in signaling quality, and brand loyalty. Our main finding demonstrates treatment of numerical information on yield performance tended to result in farmers selecting the cost-effective choices regardless of brand type, producers in the treatment group were less likely to select seeds based on brand compared to producers who were not provided numerical information.

Primary outcome: numerical yield information moved farmers to make cost-effective choices

We hypothesized providing yield information in numerical form would result in respondent's choosing cost-effective seeds regardless of brand type. The results of our models indicate that providing yield performance data in numerical form to producers at the point of sale leads to an increase in selecting cost-effective hybrid maize seeds, moving respondents from selecting seed based on brand type to doing so based on expected yield. Thus, suggesting that

Table 7 | Multinomial regression output for nominal groups 1 and 2

	(1) a	(1) b	(1) c	(1) d	(1) e	(2) a	(2) b	(2) c	(2) d	(2) e
Treatment 1=numeric 0=verbal	21.36***		63.00***	3.1	11.76***	25.73***		60.22***	2.8	14.35***
	0.0		0.0	0.2	0.0	0.0		0.0	0.3	0.0
Municipalities = 2, Villa Corzo	0.137***		1.9	1.4	0.3	0.138***		2.0	1.3	0.150*
	0.0		0.3	0.7	0.2	0.0		0.3	0.7	0.1
Municipalities = 3, La Concordia	0.0882***		1.2	1.7	0.3	0.0966***		1.5	1.4	0.3
	0.0		0.8	0.5	0.1	0.0		0.5	0.7	0.2
o._cons		1.0					1.0			
Soil quality (1-5, bad to very good)						0.9		0.7	1.3	0.7
						0.6		0.4	0.5	0.4
Yield mt/ha						0.817*		0.9	1.0	0.8
						0.1		0.6	0.9	0.1
Farm size Ha										
Livestock										
Wealth Index Score										
Household size										
Age										
Cost of seed										
Cost of non-seed inputs										
Brand type user / national or international										
Constant	1.0		0.110***	0.123***	0.252***	5.2		0.4	0.0537*	2.7
	0.9		0.0	0.0	0.0	0.1		0.5	0.1	0.5
Observations	207.0	207.0	207.0	207.0	207.0	198.0	198.0	198.0	198.0	198.0

Note: Five types of characteristics were assessed (1-5); 1= treatment; 2= agronomic traits; a= selected all national seed across four choices; b= selected cost effective seed across four choices with a mix of national and international seed (multinomial base); c= selected all international seed; d= selected half national and international seed across four choices; e= selected another combination of a mix of national and international seed across four choices

Table 8 | Multinomial regression output for nominal groups 3 and 4

	(3) a	(3) b	(3) c	(3) d	(3) e	(4) a	(4) b	(4) c	(4) d	(4) e

Treatment 1=numeric 0=verbal	26.26***		64.00***	3.1	12.57***	26.78***		72.38***	3.0	13.20***
	0.0		0.0	0.3	0.0	0.0		0.0	0.3	0.0
Municipalities = 2, Villa Corzo	0.142***		2.0	1.0	0.2	0.125***		2.1	0.5	0.2
	0.0		0.3	1.0	0.1	0.0		0.3	0.5	0.2
Municipalities = 3, La Concordia	0.101***		1.6	1.3	0.2	0.105***		1.9	1.0	0.2
	0.0		0.5	0.7	0.1	0.0		0.4	1.0	0.1
o._cons		1.0					1.0			
Soil quality (1-5, bad to very good)	0.8		0.8	1.3	0.7	0.9		0.8	1.3	0.7
	0.5		0.4	0.5	0.3	0.7		0.4	0.5	0.4
Yield mt/ha	0.83*		0.9	1.0	0.8	0.9		1.0	1.1	0.9
	0.1		0.6	0.9	0.3	0.2		0.9	0.8	0.3
Farm size Ha	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0
	0.3		0.8	0.4	0.2	0.3		0.6	0.3	0.2
Livestock	1.0		1.0	1.0	1.0	1.0		1.0	1.0	1.0
	0.8		0.7	0.2	0.3	0.6		0.9	0.2	0.2
Wealth Index Score						0.9		0.9	0.7	0.9
						0.5		0.4	0.2	0.7
Household size						1.0		0.9	1.1	1.0
						0.7		0.4	0.4	0.9
Age						1.0		1.0	1.04*	1.0
						0.9		0.1	0.1	0.4
Cost of seed										
Cost of non-seed inputs										
Brand type user / national or international										
Constant	5.5		0.5	0.0671*	3.3	3.9		0.1	0.00409**	7.0
	0.1		0.5	0.1	0.4	0.3		0.2	0.0	0.3
Observations	198.0	198.0	198.0	198.0	198.0	194.0	194.0	194.0	194.0	194.0

Note: Five types of characteristics were assessed (1-5); 3=farm size characteristics and 4= demographics; a= selected all national seed across four choices; b= selected cost effective seed across four choices with a mix of national and international seed (multinomial base); c= selected all international seed; d= selected half national and international seed across four choices; e= selected another combination of a mix of national and international seed across four choices

Table 9 | Multinomial regression output for nominal group 5

	(5) a	(5) b	(5) c	(5) d	(5) e
Treatment 1=numeric 0=verbal	30.45***		76.68***	3.6	13.93***
	0.0		0.0	0.2	0.0
Municipalities = 2, Villa Corzo	0.173**		2.3	0.7	0.2
	0.0		0.2	0.7	0.2
Municipalities = 3, La Concordia	0.114***		1.9	1.1	0.2
	0.0		0.4	0.9	0.1
o._cons		1.0			
Soil quality (1-5, bad to very good)	1.0		0.8	1.2	0.8
	0.9		0.6	0.7	0.5
Yield mt/ha	0.9		1.0	1.1	0.8
	0.2		0.7	0.7	0.3
Farm size Ha	1.0		1.0	1.0	1.0
	0.5		0.7	0.5	0.2
Livestock	1.0		1.0	1.0	1.0
	0.7		0.8	0.2	0.3
Wealth Index Score	0.9		0.9	0.7	0.9
	0.4		0.4	0.3	0.6
Household size	0.9		0.8	0.9	1.0
	0.4		0.2	0.6	0.8
Age	1.0		1.0	1.0	1.0
	1.0		0.2	0.3	0.4
Cost of seed	0.99**		1.0	1.0	1.0
	0.0		1.0	0.7	0.4
Cost of non-seed inputs	1.0		1.0	1.0	1.0
	0.9		0.4	0.6	0.8
Brand type user / national or international	1.4		2.7	7.6	1.2
	0.7		0.4	0.2	0.9
Constant	296.3**		0.1	0.0	83.7
	0.0		0.4	0.2	0.2
Observations	193.0	193.0	193.0	193.0	193.0

Note: Five types of characteristics were assessed (1-5); 5= seed characteristics; a= selected all national seed across four choices; b= selected cost effective seed across four choices with a mix of national and international seed (multinomial base); c= selected all international seed; d= selected half national and international seed across four choices; e= selected another combination of a mix of national and international seed across four choices.

by providing numerical yield information, smallholders may make cost-effective choices when selecting seeds at agrodealers, including selecting seeds produced by local seed companies when those products are the cost-effective option. We interpret these findings by looking first at quality uncertainty over national seed and then price as a signal of quality.

Quality uncertainty over national seed – Providing numerical information about yield seems to have aided in product differentiation between international and national brands. In the absence of information about yield buyers may have been attributing low quality to national seed. Thus suggesting there is an information failure around the available information about quality of national seed, underlining the need for national companies to find ways to communicate the quality of their product.

Our study used labeling to test how numerical information was received. Importantly, neither international nor national brands currently provide this information on their labels. However, findings do underline that providing farmers with more information about key characteristics of national seed may help them assess seeds whose attributes are not tangible otherwise. International companies may be communicating quality through extension services delivered post-sale, which national brands currently do not have the capacity to deliver. However, agricultural extension networks and technical professional services like post-sale services are widely thought to be an important marketing channel and an important component of a seed company's growth (FAO, 2018; Mafuru, 1999).

Recently, findings from a study on improved maize seed adoption in South Africa among 415 smallholders concluded that contact with extension officers was associated with about 8 percent higher likelihood of adopting improved maize seeds. Additionally, farmers who were in contact with extension officers planted 0.194 ha more of improved seed than farmers who did not

connect with extension workers (Sinyolo, 2020). Dibba et al (2015) find the adoption rate of NERICA varieties by rice producers in Gambia was lower by 10 percent due to lack of awareness of technology and information about specific technology traits. They concluded awareness of technology and it's attributes and access are prerequisites of adoption. They also find extension is a significant determinant of access and adoption (Dibba, Zeller, Diagne, & Nielsen, 2015). In Eastern Kenya extension was found to be significant to the adoption process (Ouma, Bett, & Mbataru, 2014). While these studies did not focus on choice among hybrid seeds directly, the common thread about the importance of extension in hybrid seed adoption may be relevant still. Thus, investing in technical services post-sale services may be one way for national companies to communicate quality.

Price as a signal of quality – in the absence of detailed information on seed quality like yield performance or extension service, farmers make choices based on other factors like certification or price. Certification by third parties, or in the case of Mexico, a government body, is a common way to offer a stamp of quality and a certification process is in place in Mexico however is not widely used by national seed companies. National brands rely largely on a auto declaring quality of seed that is less costly, whereas international seeds are largely certified. In this study when respondents were asked about the importance of certification not one respondent listed it as an important attribute. Therefore, when considering national seed, producers need to make seed purchasing decisions with other factors other than yield performance information or certification to asses quality. The cost of seed seems to be used as a substitute for quality. This behavior is consistent with literature around price as a signal of quality in the absence of information (Wolinsky, 1983). With a significant price gap between local seeds and international seeds, on average 1000 pesos, if producers are using price to make a choice among seeds, based

on this criterion the international seeds will be selected given its price is higher. While lower priced seed was once a driver in the national seed industry development it may be that as national companies adjust their marketing activities to communicate quality they also adjust their prices, which may allow for the increased connection with customers.

Other findings

Differences between municipalities – our findings at the municipality level suggest there are differences among farmers within the Frailesca contributing to their seed choice. Farmers in Villa Corzo and La Concordia appeared to have systematically different experiences, incentives or exposure to marketing than farmers in our other study region, Villa Flores. There was a lower preference for buying only national-brand seeds in Villa Corzo and La Concordia. The difference was significant at about the same magnitude even when controlling for a wide range of farmer characteristics.

Some differences between the study sites that may contribute to these results include location type and wealth. Villa Flores was the largest urban area of the three municipalities, followed by Villa Corzo, which was a peri-urban area 7KM outside of Villa Flores, and La Concordia was a rural area about 85 KM from Villa Flores. The greatest variety of seeds from either national or international brands was available at Villa Flores. The differences in location impact population and market size, as such, Villa Corzo and La Concordia both had fewer agrodealer shops with fewer seed options and largely international seeds. It is possible that having less access to national brand seeds leads these municipalities to have stronger preferences for the international brands with which they are familiar.

Another difference in our sample between municipalities is wealth. Villa Flores was the wealthiest municipality of the three with the most diverse income opportunities, which may lead

them try different agriculture products like national seed where respondents from the other two municipalities reported agriculture as their source of income. Our findings are in line with those in the Zepeda (2018) study in which Villa Flores had higher income which came from both agriculture (74 percent) and cattle (16 percent); compared to Villa Corzo and La Concordia which were almost exclusively reliant on agriculture (Zepeda, 2018). The municipality differences underscore the need to understand the local context as part of efforts to understand seed choice among smallholders.

Characteristics of respondents with preferences for a brand type – we hypothesized household characteristics associated with choosing among hybrids seed may the same as those associated with choosing to adopt the technology. Wealth, farm size and age have been shown to contribute to agricultural technology adoption (Kafle, 2010). When evaluating hybrid seed adoption, switching from using non-hybrid seed to using any amount of hybrid seed these sociodemographic factors help differentiate adopters from non-adopters (Sinyolo, 2020). Though household and farm characteristics in this sample do not predict which respondents were likely to select have a preference for national seed or international seed as categorized in the nominal groups, there are characteristics about the respondents who selected the cost-effective group which selected a mix of national and international seeds (NTNN) which may help elucidate characteristics about respondents' who have preferences for a particular brand type.

This group of respondents almost entirely reported planting international brands with only 5 percent reporting the planted national seed during the previous summer harvest . Though they use international brands, in the CE these farmers were open to switching to national seed if that was the cost-effective choices. This group also had an average of 46, younger than mean, 49 years and was wealthier and more educated than the sample overall – both characteristics that are

consistent with willingness to adopt new technology. Yet, this data is encouraging in light of the strong seed preferences which farmers in Mexico seem to have, which currently tilt seed sales heavily in favor of international seeds.

Seed choice and covariates – household characteristics did not predict seed choice in this sample. However, when looking at characteristics by treatment, we find numerical information may have contributed to seed choice in the treatment group in ways socioeconomic factors like education and wealth did in the control group. For example, in the case of education, the respondents who received qualitative data and who selected the nominal group with all cost-effective choices across the four pairwise were more educated compared to the other groups. In the treatment group, education level was distributed more evenly among the nominal groups. Similarly, looking at yield, in the qualitative group, the respondents who selected the nominal group with all cost-effective choices across the four pairwise had a higher mean yield compared to those in the other three categories. Higher yield in the control group predicts if a respondent will chose the cost-effective options. In the treatment group yield average did not predict if the cost-effective choice was selected. Of the respondents who chose only international brand/origin, 81 percent were from the control group. These farmers were three times more likely than those in the treatment group to make a selection that was non-cost effective. Thus, treatment moved farmers from diverse education and production levels to make similar choices, which may indicate providing more detailed information would be beneficial to many smallholders, given this group is highly heterogeneous, it is encouraging that more information has a broad reach.

Limitations

This study like other studies is subject to biases. Firstly, this study operated under two main assumptions, seeds quality is as purported, we did not test seeds sold at agrodealers; and

farmers, their plots and their practices are heterogenous, resulting in heterogeneity in agronomic performance of each seed, and there is heterogeneity in the performance of very similar seeds. In terms of fake seed in the market, there is evidence of this occurring widely in African markets (Gharib, 2018; Toro, 2014). However, our study did not find evidence of fake seed being an issue in Mexico. Nevertheless, it was not a factor that was controlled for here. In terms of heterogeneity, we were able to match up the yield mt/ha reported by farmers with the average yields reported in yield distribution tables from farm trials and plot demonstrations done by MasAgro extension work in the same Frailesca region for national and international seed which are sold in the Frailesca. As such, though there is heterogeneity, the different practices and distribution of yields seem to be very similar for hybrids across the three municipalities. Furthermore, unlike in some studies in which increase hybrid adoption does not result in increased yields due to variable yield performance under smallholder environments, there is evidence that in the study setting different brands of hybrids are on average providing higher yields than non-hybrids. Also, peer influence on technology adoption among farming households, which has been documented in the case of maize seed adoption, was not directly measured here (Case, 1992). Randomization at the individual level was used to account for unobservable differences like this one among others.

Biases specific to the stated-preference method in choice experiments used here include hypothetical bias, ordering effect, and framing effect. To minimize hypothetical bias, pairwise profiles were based on existing seed profiles in the market, using average agronomic data from the Frailesca region itself, yet the lack of op-out option might have decreased the realistic nature of the choice exercise. To minimize ordering effects, choices for each participant were randomized. To minimize framing effects, during pre-testing the main statements used to

introduce the study and the CE was monitored and word choice adjusted. As for our sample size, our total sample was of 207 farmers, which means that when grouping respondents by choices across categories like brand type user or nominal groups, some categories had very few observations or zero observations. Furthermore, the dispersion of our confidence intervals was also affected the sample size. Nevertheless, the data from this study accounted for confounding variables, which leads us to believe the internal validity of the survey was strong; and the results from our work may be applied to farming communities like those in the Frailesca, for whom agriculture is at the center of their livelihoods but do not yet have access to information to make optimal choices about inputs.

Conclusion

This study reveals the role numeric yield data has compared to qualitative data in seed selection among smallholders and provides a novel contribution to the literature on adoption of a key farm input, nationally branded hybrids seed, at the center of agricultural interventions in Mexico. Findings suggest providing information about yield potential in numeric form helps farmers select the cost-effective seed; Importantly, we find current international seed users in our sample will consider national seed when it is the cost-effective seed. Importantly, the information treatment moved respondents from selecting seed based on brand type to doing so based on expected yield. Thus, providing yield information in numerical form to smallholders may aid in making cost-effective choices when making purchases at agrodealers, including selecting seeds produced by national seed companies when those products are the cost-effective option.

As farmers make cost-effective choices among hybrid seeds it may contribute to increasing the number of national seeds purchased. Further work is needed to understand the void of agronomic information at the point of sale, what agronomic information is currently available and how it is presented to farmers in order to identify the right information to provide farmers to aid their decision making and how that information should be communicated (e.g. label). For programs like MasAgro, reexamining their strategies around how information about agronomic traits is used in marketing activities would be in order. For the Mexican Government, aligning their marketing activities across the public private partnership under which the MasAgro initiative operates would strengthen the delivery of pertinent detailed information missing in decision making around seed inputs. In sum, these activities may contribute to increasing the sales of national seed and thereby the adoption rate of a key technology at the base of potential increases in production, income and food security for smallholders in Chiapas, Mexico.

Supplemental materials

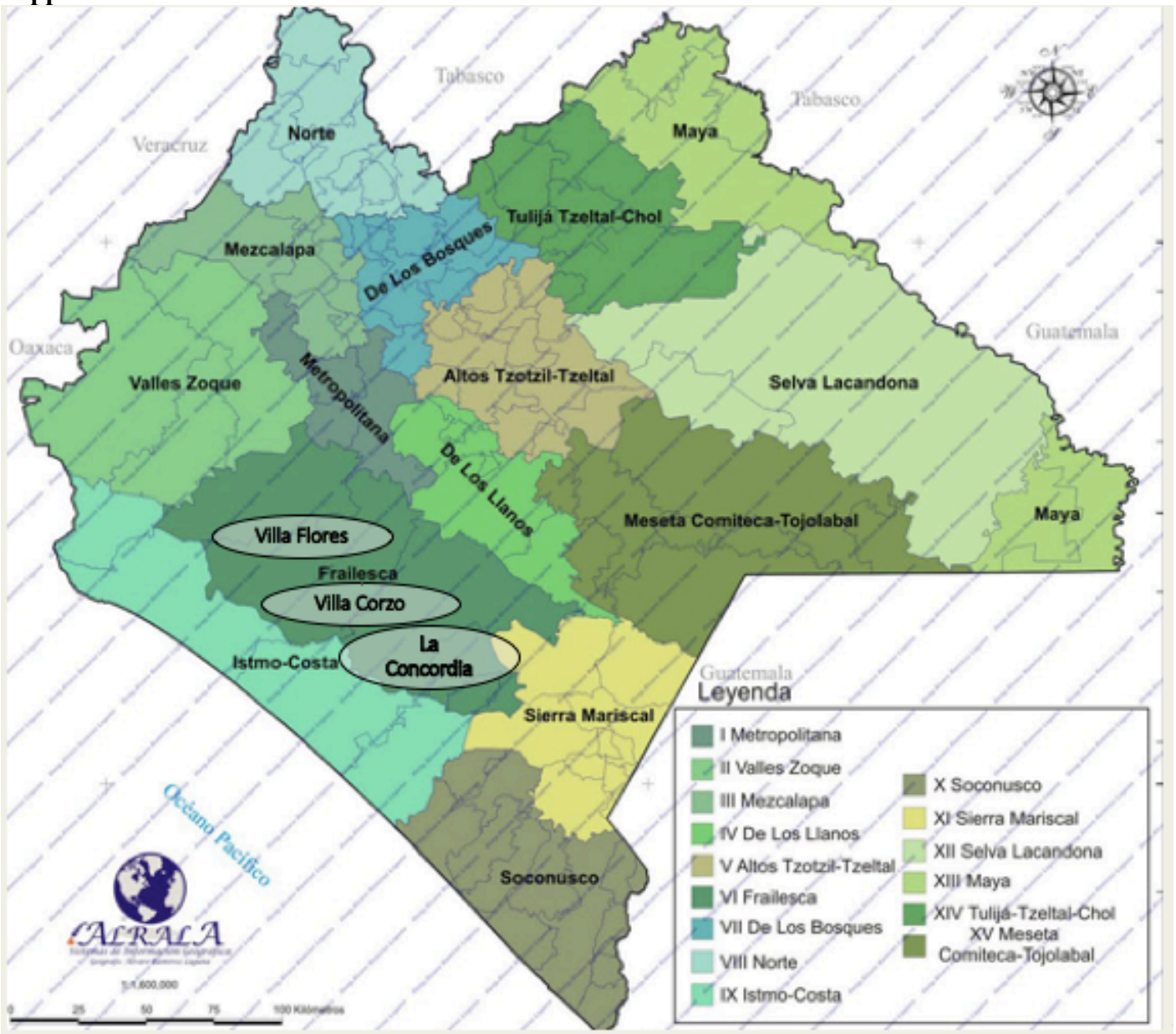

Figure 1 | Map of municipalities where study took place: Villa Flores (urban), Villa Corzo (urban), and La Concordia (rural)

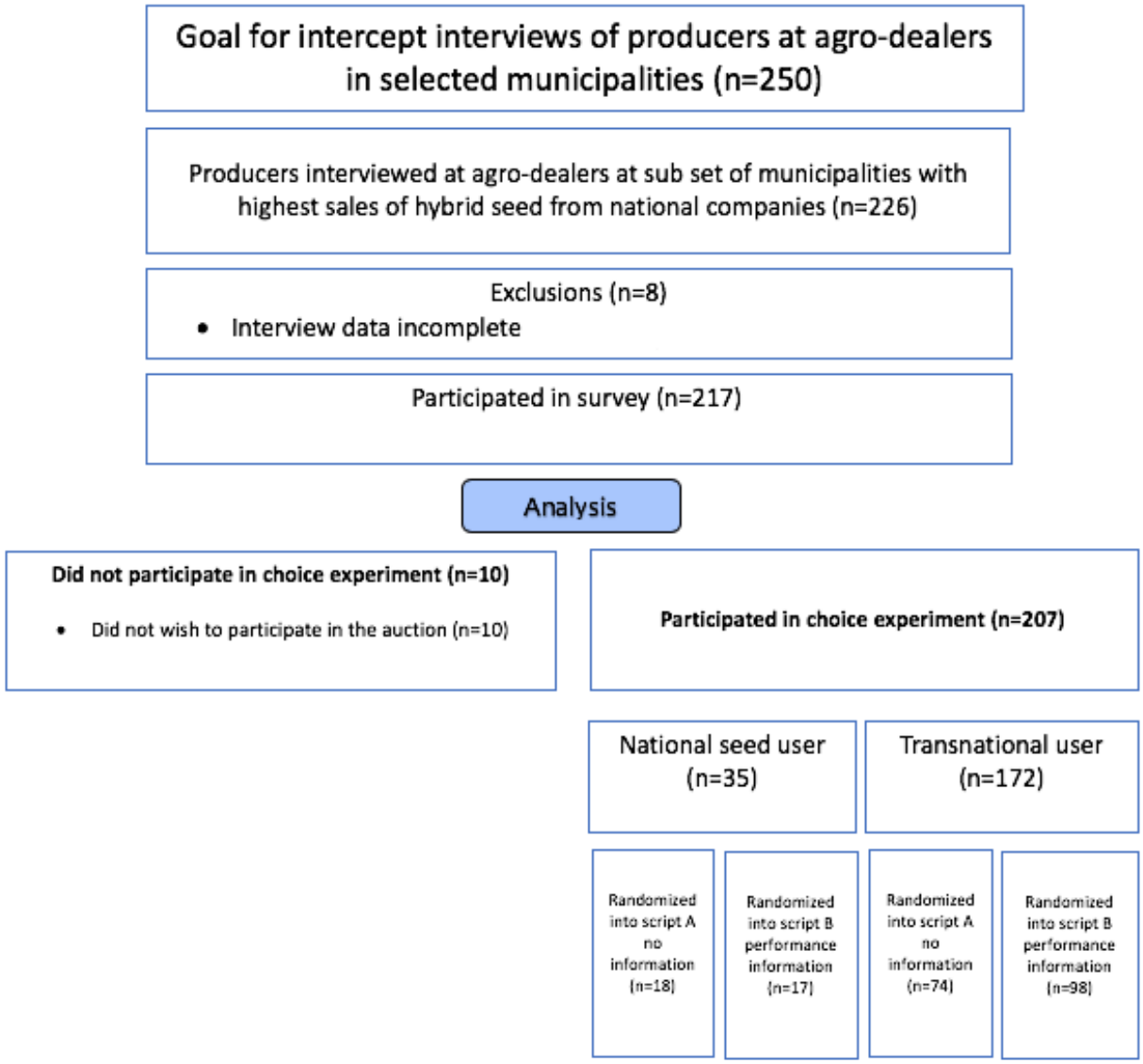

Figure 2 | Consolidated Standards of Reporting Trials (CONSORT) Table

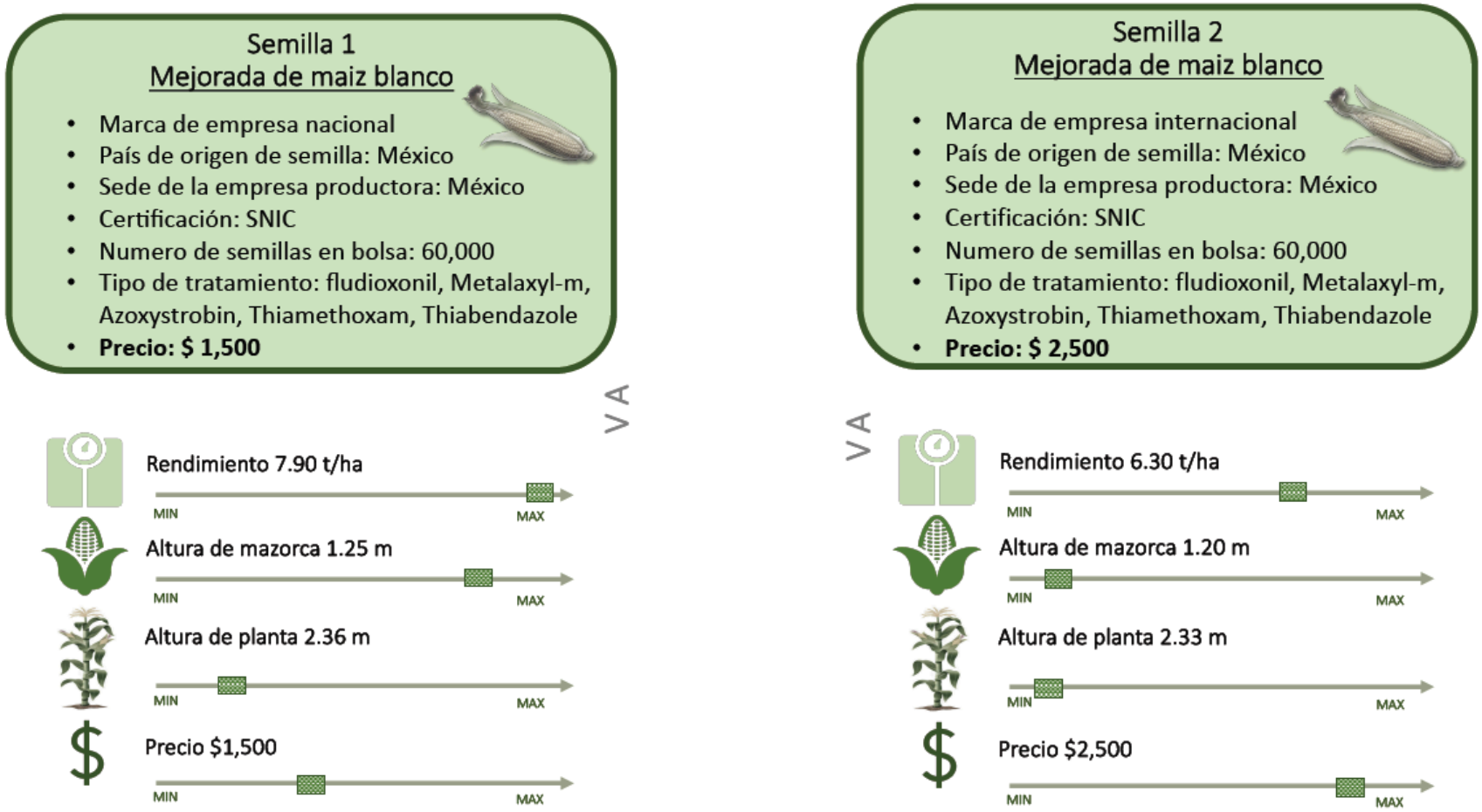

Figure 3 | Choice 1; The numerical group received this choice card; the verbal group received only the information in the green box and a verbal yield of good "bueno" or very good "alto".

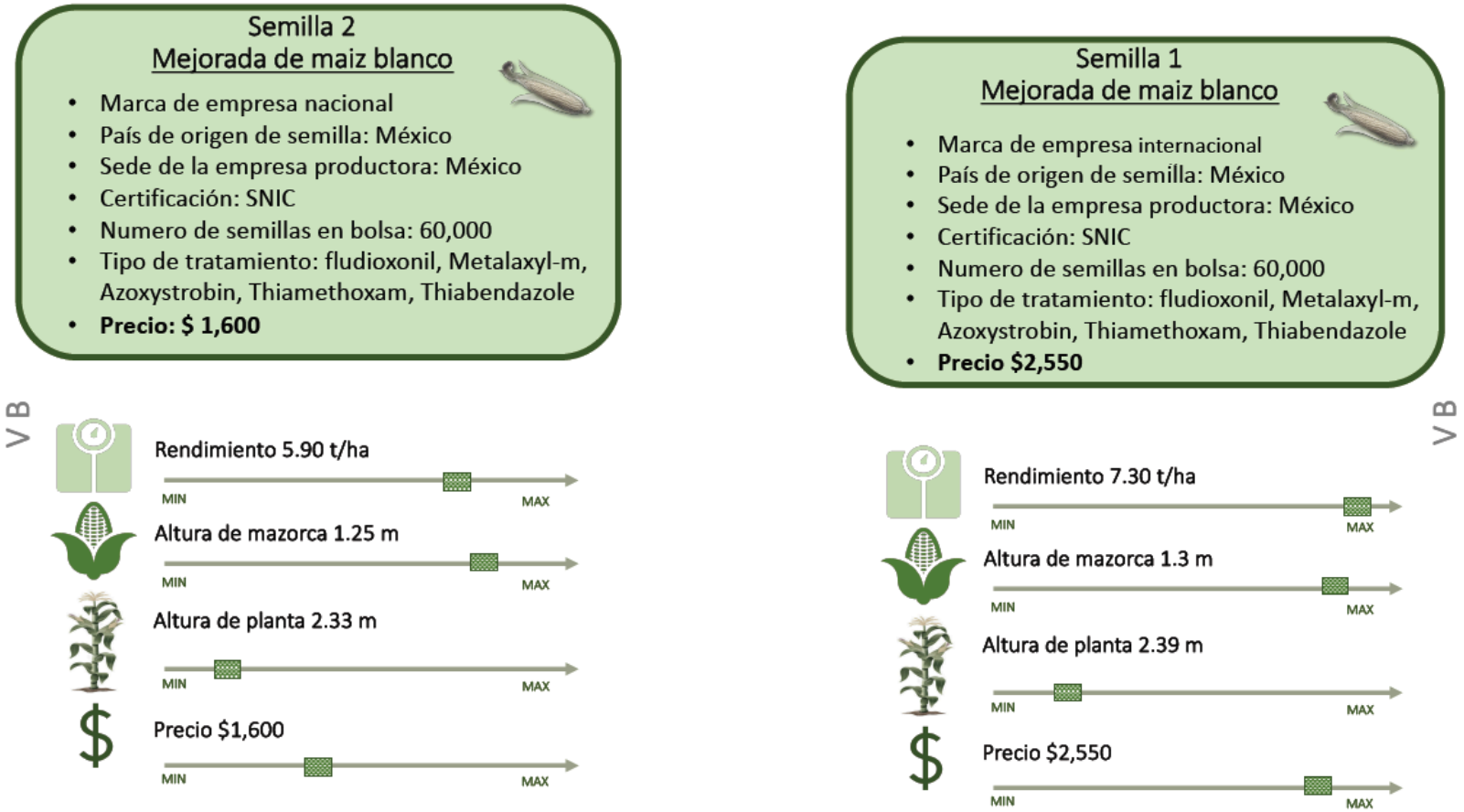

Figure 4 | Choice2; The numerical group received this choice card; the verbal group received only the information in the green box and a verbal yield of good "bueno" or very good "alto".

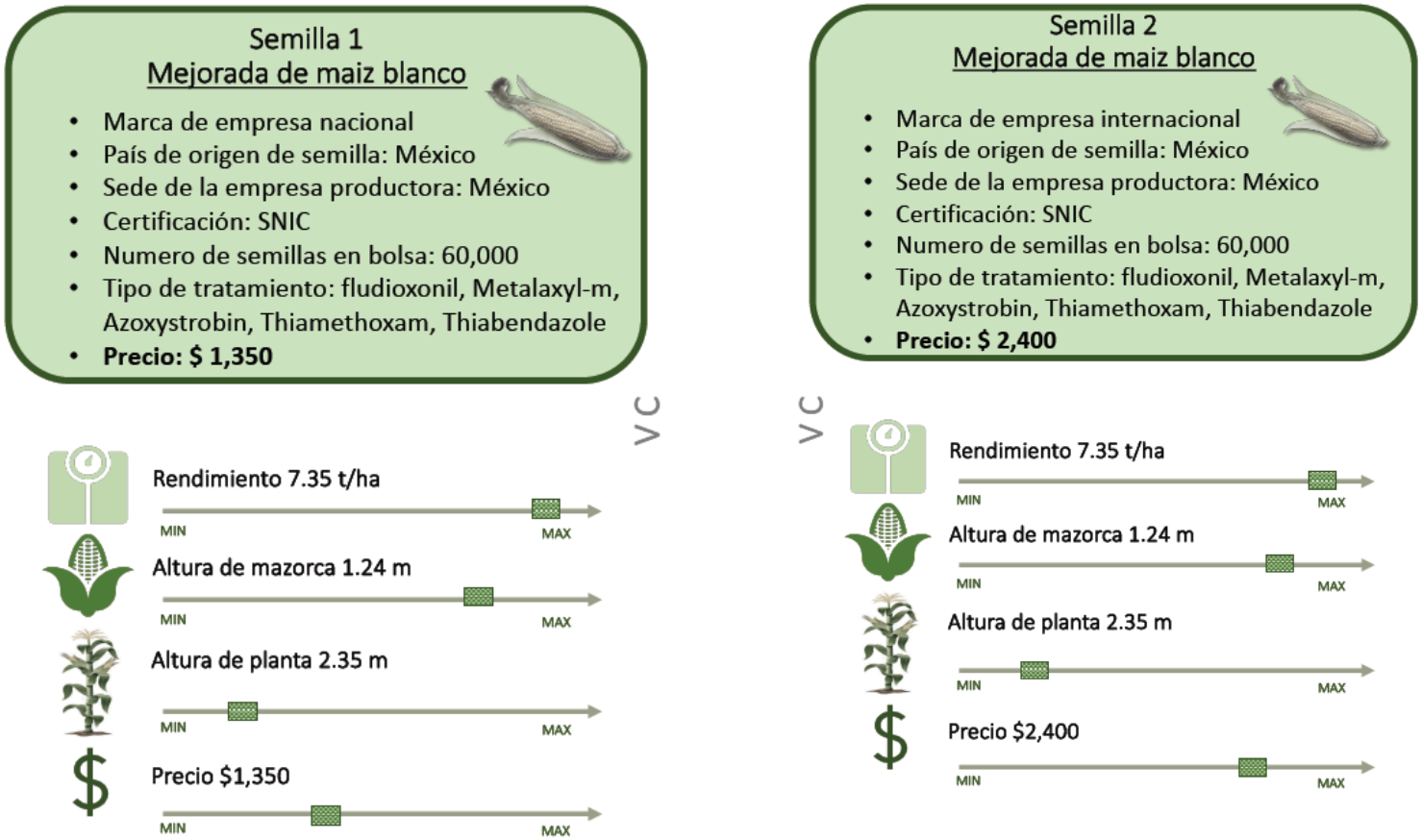

Figure 5 | Choice 3; The numerical group received this choice card; the verbal group received only the information in the green box and a verbal yield of "good "bueno" or very good "alto".

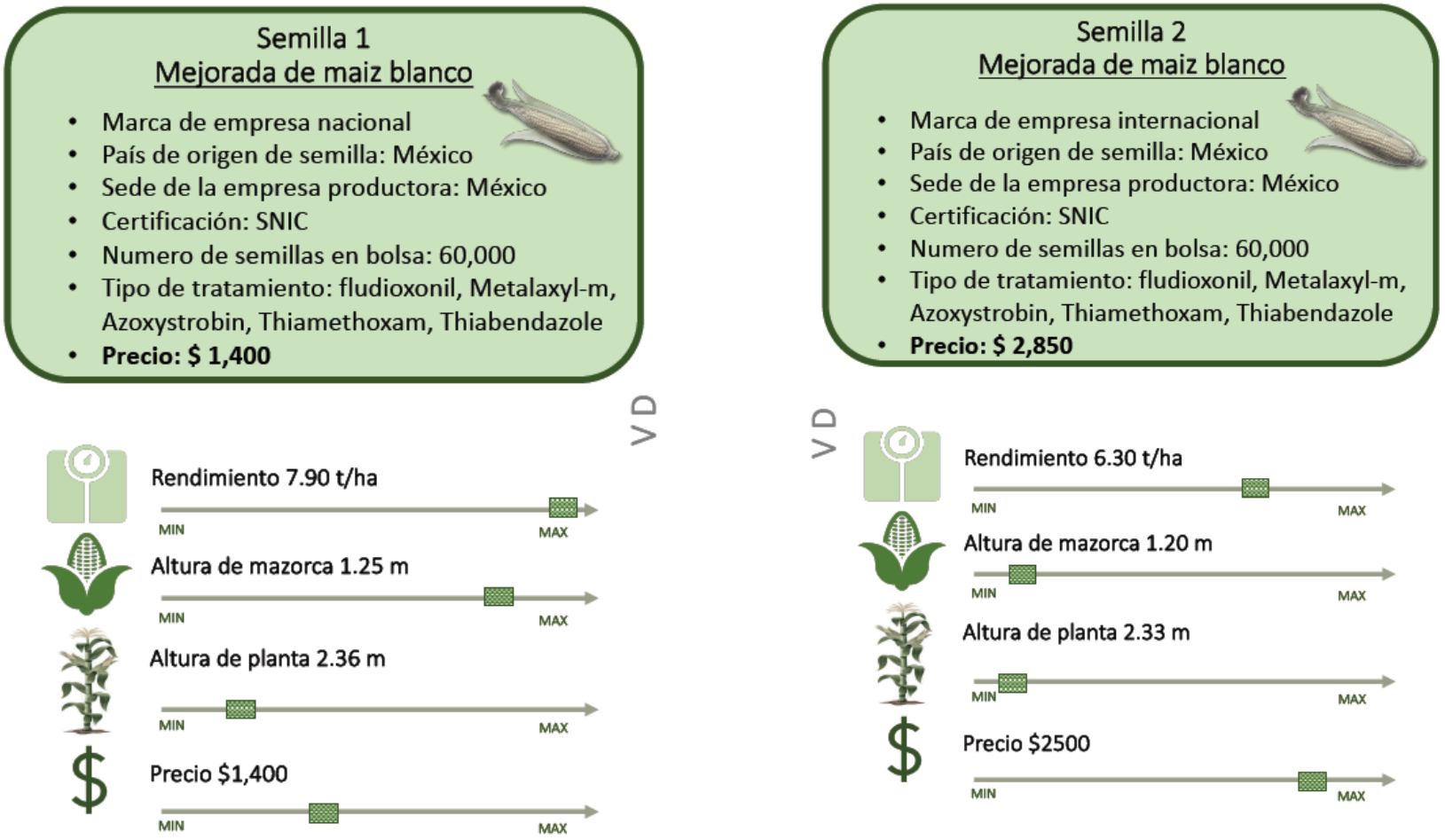

Figure 6 | Choice 4; The numerical group received this choice card; the verbal group received only the information in the green box and a verbal yield of good "bueno" or very good "alto".

Supplemental materials

Table 9 | Logistic regression output

	(1)	(2)	(3)	(4)	(5)
Treatment 1=numeric 0=verbal	23.66***	26.55***	27.52***	28.06***	32.22***
	0.00	0.00	0.00	0.00	0.00
Soil quality					
(1-5, 1 - bad 5 - very good)		0.90	0.91	0.91	0.98
		0.64	0.67	0.68	0.93
Yield mt/ha		0.86	0.88	0.91	0.92
		0.11	0.18	0.32	0.39
Farm size Ha			1.00	1.00	1.00
			0.42	0.46	0.48
Livestock			1.00	1.00	1.00
			0.87	0.99	0.99
Wealth Index Score				0.86	0.85
				0.18	0.15
Household size				1.00	0.88
				1.00	0.20
Age				1.02	1.01
				0.24	0.48
Cost of seed					1.00
					0.17
Cost of non-seed inputs					1.00
					0.82
Seed type user / national or international					2.06
					0.42
Municipalities = 2,					
Villa Corzo	0.40**	0.40*	0.41 *	0.37*	0.51
	0.05	0.06	0.06	0.05	0.22
Municipalities = 3,					
La Concordia	0.33**	0.37**	0.36**	0.38*	0.38*
	0.02	0.04	0.04	0.06	0.07
Constant	1.52*	4.82*	4.64*	1.75	31.62
	0.08	0.07	0.08	0.62	0.13
Observations	207	198	198	194	193

Note: binary outcome variable, 100% cost-effective choice compared to less than 100% cost-effective choice; models are staggered: 1= treatment; 2= agronomic traits; 3=farm size characteristics; 4= demographics; and 5= seed characteristics;
*** p<0.01, ** p<0.05, * p<0.1

Table 10 | Ordinal logistic regression output

	(1)	(2)	(3)	(4)	(5)
Treatment 1=numeric 0=verbal	14.13***	15.11***	15.12***	15.06***	16.19***
	0.00	0.00	0.00	0.00	0.00
Soil quality					
(1-5, 1 - bad 5 - very good)		0.99	0.96	0.97	0.99
		0.94	0.85	0.90	0.97
Yield mt/ha		0.87*	0.90	0.92	0.93
		0.08	0.20	0.35	0.42
Farm size Ha			0.99	0.99	0.99
			0.10	0.13	0.13
Livestock			1.00**	1.00**	1.00*
			0.04	0.02	0.05
Wealth Index Score				0.86	0.86
				0.12	0.13
Household size				1.01	0.92
				0.94	0.30
Age				1.01	1.01
				0.41	0.62
Cost of seed					1.00
					0.67
Cost of non-seed inputs					1.00
					0.40
Seed type user / national or international					1.93
					0.33
Municipalities = 2, Villa Corzo	0.42**	0.43*	0.46*	0.43*	0.47
	0.04	0.05	0.07	0.06	0.11
Municipalities = 3, La Concordia	0.41**	0.44*	0.39**	0.40**	0.37**
	0.04	0.06	0.04	0.05	0.04
/cut1	0.668*	0.31	0.32	0.67	0.35
	0.08	0.12	0.14	0.69	0.53
/cut2	114.7***	56.11***	66.25***	140.8***	85.06***
	0.00	0.00	0.00	0.00	0.01
/cut3	546.1***	268.9***	344.5***	744.3***	462.9***
	0.00	0.00	0.00	0.00	0.00
Observations	207.00	198.00	198.00	194.00	193.00

Note: ordinal outcome variable, 100, 75, 50 and 25 percent cost-effective; models are staggered: 1= treatment; 2= agronomic traits; 3=farm size characteristics; 4= demographics; and 5= seed characteristics;
*** p<0.01, ** p<0.05, * p<0.1

Supplemental information on agronomic data and profiles

The extra information provided to the treatment group (average yield, average plant height, average ear size, price per 20 Kg bag) was selected from formative work with growers, breeders and extension workers. The exact figures used in the number lines came from data collected at CIMMYT that record yield for seeds from germplasm produced at the research center, which includes information from on farm trials run by MasAgro program extension workers, demonstration plots run directly by the center, and farmer reported output from their independent use collected through a self-reported MasAgro online-database. This information is tracked in excel sheets in various ways, for example by seed number, brand and use geographic use. A list of potential seeds and agronomic performance related to those seeds was created using the tables for the state of Chiapas and the municipalities in which this study was carried out. That list, which included both on farm trials and demonstration plots, was matched up with the seeds sold at the agrodealers in the Southeast marketing region of the MasAgro program for the last three years. The information which overlapped, in other words the number of potential seed profiles available for use in the CE, a total of eight, was then matched with the number of tasks that had been identified as sufficient to obtain attribute information without presenting a cognitive burden and plausible in the amount of time designated for the CE, ten minutes. A total of four pairwise profiles were selected. The final pairwise comparisons were reviewed with breeders to confirm the averages taken and values for each numeric line for each trait were in line with the profiles selected. Only the principal investigator of this study had access to the brand and seed number that corresponds to the CE profiles.

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