APPROPRIATE TECHNOLOGY USE AND AUTONOMY: EVIDENCE FROM MEXICO *

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December 27, 2022

Abstract

We explore the role of autonomy – defined as the freedom to choose how to spend an in-kind grant – in a context where farmers overuse fertilizer. We design and implement a field experiment that combines tailored input recommendations, extension services and an in-kind grant. The intervention decreased overall fertilizer use without reducing yields, reducing CO_2 equivalent emissions by 14%. While autonomy did not adversely affect the adoption of recommended practices during the intervention, it led to substantially higher adoption two years after the intervention ended.

JEL: D01, Q12, O33

*We are grateful to Qué Funciona para el Desarrollo (QFD) for managing the entire project, to Fertilab for the soil analyses, to Agropecuaria Amozoc for providing and mixing fertilizers and to Ipampa S.C. for the provision of agricultural extension services. We would also like to thank Pranab Bardhan, Chico Ferreira, Andy Foster, and Berk Özler for very helpful comments and suggestions. We also thank seminar participants at various workshops for their comments and suggestions. Michelle Infanzón, Meritxell Martínez, Victor Manuel Pérez, Bernardo Ribeiro, Mónica Vargas and Victor Vergara provided outstanding research assistance. We also gratefully acknowledge funding from 3ie, BASIS (UC Davis), the World Bank and ISPC-SPIA (under the grant "Strengthening Impact Assessment in the CGIAR System (SIAC)"). Views expressed in this paper are those of the authors, and do not necessarily reflect the opinions of the World Bank, its executive directors, or the countries they represent.This project was reviewed and approved by the ITAM IRB and UCLA IRB # 12–001756. This study is registered in the AEA RCT Registry with the unique identifying number AEARCTR-0006264. Enrique Seira thanks the Asociacion Mexicana de Cultura

1 Introduction

In recent years, there has been substantial interest in using subsidies to encourage the sustained adoption of improved technologies. While much of the literature has focused on subsidizing new technologies, limited attention has been paid to subsidies encouraging the *appropriate* use of familiar technologies, for example recommending a change in the fertilizer mix to farmers already using fertilizer, as in our study. In such cases, subjects may have deep-seated views on how the technology should be used and may consequently be reluctant to follow recommendations at odds with their beliefs.

In such settings, subsidies narrowly targeting specific technologies or products (e.g. specific fertilizers) may not be optimal if beneficiaries dislike the restrictions on choices, as emphasized for instance by the reactance literature in psychology.[1] Narrowly targeted subsidies in this context may induce short-term adoption of the subsidized recommendations but may not result in longer-term adoption once the subsidies are removed.

In contrast, more broadly targeted subsidies – e.g. a voucher or grant redeemable for any product sold at an agro-dealer store – may better allow for experimentation and the subsequent updating of beliefs. Such untargeted subsidies may result in lower short-term adoption of the recommendations as beneficiaries can purchase other inputs, but may also lead to more sustained adoption in the long run as beneficiaries make active product purchase decisions.[2]

Ultimately, the degree to which subsidies should be targeted is an empirical question. In this paper, we compare a targeted subsidy with an untargeted one to encourage the adoption of recommended agricultural practices among smallholder farmers in Mexico, a setting where persuading farmers to alter their fertilizing practices is receiving increasing interest (see e.g. Millar et al., 2018). We thus focus on an aspect of the design of subsidies (e.g. the degree of

[1] Reactance in this literature is defined as "when something threatens or eliminates people's freedom of behavior, they experience psychological reactance, a motivational state that drives freedom restoration"(Rosenberg and Siegel, 2018, p.1). Reactance may thus limit subjects' willingness to follow expert advice (Stolper and Walter, 2017) or nudges (Bruns and Perino, 2019). This behavior is similar to agents' negative responses to constraints imposed by the principal in principal-agent laboratory experiments (Falk and Kosfeld, 2006).

[2] Active decisions have been found to increase episodic memory and learning (see e.g. Mirty et al., 2019); see below.

targeting) that has not received as much attention as others (e.g. their magnitude).[3]

We design a field experiment that provides tailored input recommendations and two different subsidies: an inflexible (targeted) subsidy or grant exclusively for the recommended inputs (i.e. fertilizer in specified proportions) and a flexible (untargeted) one that can be used to purchase any inputs at a specified agro-dealer store. These two different subsidies allow us to examine experimentally the effect of autonomy, defined here as the ability to choose which inputs to purchase with the subsidy. Since the value of the subsidy (or grant) was designed to be roughly equal to the amount spent on fertilizer by control farmers, we view the grant as primarily encouraging experimentation rather than relaxing liquidity constraints.[4] Importantly, unlike smallholder farmers in Sub-Saharan Africa but similar to their counterparts in China and India, fertilizer use is common among Mexican smallholder farmers, although yields remain low.[5]

The experiment was conducted in 2015 and consists of a control group and three treatment arms. Farmers in all three treatment arms were offered a soil analysis report, a set of tailored input recommendations and a package of agricultural extension services designed to help them implement the recommendations. Two of the three treatment arms were offered, in addition, an in-kind grant of $2,000$ pesos (roughly U.S. \$150 at the time). Arm $E1$ (or the "inflexible" arm) received detailed soil analyses with input recommendations and an *inflexible* subsidy that could only be used to purchase the tailored input recommendations. Arm $E2$ differed from $E1$ only in that the subsidy was *flexible* (and is referred to as the "flexible" arm). Farmers in $E2$ could use the grant to purchase any inputs sold by a local agro-dealer rather than just the recommended

[3] A recent literature documents the effect of varying subsidy amounts (and in some cases credit availability) on the adoption and use of new and unfamiliar technologies such as water disinfectant (Ashraf et al., 2010), improved cook-stoves (Mobarak et al., 2012), solar lamps (Meriggi et al., 2021) or insecticide treated nets (Cohen and Dupas, 2010; Tarozzi et al., 2014). Relevant to the context here, many Sub-Saharan African countries have implemented input subsidy programs (see e.g. Carter et al., 2021; Jayne and Rashid, 2013). Evaluations of such programs typically compare an arm that offers subsidies for a specific agricultural input with a "no-subsidy" arm.

[4] The subsidy could also be viewed as an implicit endorsement of the recommendations or as a means for the research team to differentiate itself from cheap talk. We do not attempt to distinguish between these alternative explanations.

[5] Almost three-quarters of Mexican farmers report using chemical fertilizers in the past growing year (authors' calculations from INEGI, 2007) and the figure was 98% for our study sample for the year 2014. Maize yields for rain-fed farms, however, remain relatively low at only about 2–3 metric tons per hectare (mt/ha). By comparison, rain-fed maize yields in the United States are approximately 8 mt/ha (Fernández et al. 2012; Sweeney et al. 2013). For recent overviews of technology adoption in agriculture in developing countries see Magruder (2018) and Macours (2019).

inputs. A comparison between farmers in the flexible and inflexible arms thus measures the effect of autonomy as defined above. The conditions for arm $E3$ are the same as those for $E2$ (or $E1$) except that no grant was provided (and we refer to this as the "no-grant" arm). Comparisons between the no-grant arm and the flexible arm (or the inflexible arm) measure the effect of providing the grant among farmers that all received localized soil analyses, recommendations and extension services. Finally, a control group C of farmers did not receive any interventions during the experiment. They received soil analyses and recommendations one year after the intervention (but no extension services).

We begin by documenting substantial chemical fertilizer use prior to the intervention, consistent with national level data. There is a wide gap between the actual and recommended input mix: farmers used 92% more urea on average (per hectare) than the recommended amount and about 164% more diammonium phosphate (DAP) while using only about 31% of the recommended Potassium Chloride (KCl). An implication of the recommendations is that farmers should *reduce* overall fertilizer use and change its composition. This contrasts with the bulk of the literature examining fertilizer under-use as an explanation for low yields. The recommendation to limit fertilizer raises the concern of yield declines and we address this explicitly in Section 5.4.

We next examine adoption, our main outcome of interest, using a standardized index of "new" agricultural practices introduced by the intervention.[6] By this metric, farmers in the no-grant arm (i.e. who only received the recommendations and extension services) adopted 0.33 more practices (measured in standard deviations or *s.d.*) relative to control farmers. Farmers that received any kind of grant adopted considerably more practices, ranging from 1.68 to 1.96 *s.d.* depending on the arm. Surprisingly, farmers in the flexible arm, who could ignore the recommendations at no cost, adopted new practices at the same rate as farmers in the inflexible arm who were forced to adopt the recommendations or forego the grant entirely.

The impacts of the intervention on productivity largely mirror those on adoption. Average

[6] We classify six practices as "new" since they were uncommon at baseline and recommended by the extension workers. Details of the index construction are in Table 6 and Appendix **??**. See Bloom et al. (2013) for a similar classification of practices in the context of a management intervention.

yields for no-grant farmers (i.e. those receiving only soil analyses, recommendations and extension services) are not statistically different from those in the control group. In contrast, we find substantial effects of the subsidies. Despite a drought, yields in the two grant arms were 0.2–0.4 metric tonnes/hectare (mt/ha) higher relative to control yields, corresponding to an increase of approximately 12%–17%. Yields were statistically indistinguishable between the flexible and the inflexible arms implying that in the short run there was no downside to providing farmers with autonomy over spending the grant in terms of adoption or productivity.

Crucially, this improvement in yields among farmers in both grant arms were accompanied by a reduction in fertilizer use (the mean reduction was 36 kg/ha of urea or about 19%). A back-of-the-envelope calculation suggests that this reduction in fertilizer reduced CO_2 equivalent emissions by 14% per hectare. To our knowledge, this is one of the first studies to document a decline in emissions from a reduction in fertilizer use without a decline in yields in a field experimental setting in a developing country.

Finally, we examine the *persistence* of the recommended practices in the 2017 growing season, two years after the intervention ended and subsidies were no longer available. Farmers who only received the recommendations and extension services in 2015 adopted 0.39 *s.d*. more practices in 2017 relative to control farmers.

More interestingly, farmers with the flexible in-kind grant, and thus with autonomy to choose which recommendations to follow in 2015, were substantially more likely to persist with the new practices in 2017 relative to both farmers with the inflexible grant (an increase of 0.55 *s.d*.) and farmers in the control group (an increase of 1.08 *s.d*.). Since some farmers continued to use the new practices two years after the intervention, they were likely perceived as valuable. We conclude that providing program beneficiaries with a measure of autonomy may be desirable, particularly if the technology is familiar and the program is "top-down" involving expert advice.

We next explore various mechanisms behind this result. Consistent with the hypothesis that autonomy induced farmers to pay more attention to the recommendations, we find that farmers with autonomy were more likely to remember the recommendations, to trust project partners more, and to have a more positive attitude towards experimentation.

Our results contribute most directly to the recent literature on the impact of tailored input recommendations on farmer behavior. Gars et al. (2022) provided plot-level soil analyses and fertilizer recommendations to farmers in Bihar (India). Most farmers were recommended increases in fertilizer use and changes to the timing of application. While farmers changed when they applied fertilizer, they did not increase the amount of fertilizer used, on average.[7] It is possible that the amount of fertilizer did not increase because farmers did not understand the information, lacked confidence in its reliability or that the recommended fertilizer amounts were too expensive. In our study, we spent a substantial amount of time and resources facilitating farmer comprehension of the soil analyses and recommendations and used a well-known and trusted agricultural extension services firm to convey the information. Tjernström (2017) also documents soil quality heterogeneity in a sample of Kenyan farms and examines the difficulties it creates for social learning about new technologies. Murphy et al. (2019) find that providing plot-level soil information to farmers in Western Kenya (using SoilDoc, a low-cost soil testing tool) has a positive effect on the willingness to pay for inputs (DAP and manure, among others) but they do not measure fertilizer use or productivity. Ayalew et al. (2021) use the Nutrient Expert tool to generate site-specific input recommendations in Ethiopia while Harou et al. (2018) offer soil analyses, fertilizer recommendations (using SoilDoc) and an in-kind grant that covers the cost of fertilizer for approximately 0.2 ha in Tanzania. In contrast to our setting, fertilizer usage is low in these settings and thus the recommendations suggest substantial increases in input use. Cole et al. (2020) provided customized fertilizer recommendations based on soil analyses to cotton farmers in Gujarat (India) in a setting where fertilizer under-use (relative to recommendations) was common.

We complement this work by assessing the effect of autonomy on the willingness to follow expert recommendations and examining longer-term persistence in a context where farmers overuse fertilizers and apply them at non-recommended times. In all the previously mentioned studies, farmers applied less (in some cases much less) fertilizer than expert recommendations,

[7] Interestingly, farmers more confident in the returns to fertilizers were less likely to adopt the recommendations, suggesting that individuals with tight priors are less likely to follow advice when it contradicts their beliefs.

whereas in our context, farmers significantly overused fertilizer relative to tailored recommendations. This difference suggests that certain explanations based on liquidity or credit constraints for the lack of adoption of expert recommendations are less compelling in our context. Lin et al. (2022) and Cui et al. (2018) examine tailored recommendations in a context of fertilizer overuse in China but do not focus on autonomy.

We also provide experimental micro-evidence on reducing emissions by reducing fertilizer use (and changing its mix) without reducing yields under actual field conditions. This is important both from the perspective of the individual farmer who could improve productivity by reallocating inputs, as well as that of the social planner since the over-use of urea and the consequent emissions (both directly and indirectly via leaching and surface run-off) could have significant negative environmental consequences (see e.g. Wang and Li, 2019, for a review of the evidence).[8]

Finally, we contribute to the literature on autonomy, which has emphasized both its intrinsic as well as its instrumental value on participatory decision-making (Dal Bó et al., 2010), compliance (Malesky and Taussig, 2019), effort (Sjöström et al., 2018) and productivity (e.g. Black and Lynch, 2001; Bonin et al., 1993; Spector, 1986).[9] Using observational data from an agricultural context, Bardhan (2000) finds that Indian farmers are less likely to violate irrigation rules when they themselves enacted those rules. We show experimentally that providing autonomy in the decision to follow expert recommendations leads to higher adherence in the long-run. [10]

From a policy perspective, understanding whether and how autonomy encourages the use

[8]More broadly, improving nitrogen fertilizer use is widely seen as key to achieving several of the Sustainable Development Goals (see e.g. Ladha et al., 2020).

[9]Dal Bó et al. (2010) is a well-identified laboratory experiment exploring the effect of group choice on group coordination, while we study the effect of individual choice on persistence in a field-setting. On the intrinsic importance of autonomy see e.g. Bartling et al. (2014); Ferreira et al. (2020); Sen (1999). On the instrumental value of autonomy see e.g. Chaudhry and Klinowski (2016).

[10]Autonomy could affect persistence in several ways. First, it encourages active decisions, and these have been found to increase episodic memory and learning (Mirty et al., 2019). Second, self-determination theory in psychology has documented (in school settings) that more autonomous choice predicts engagement, positive affect, conceptual learning, and perseverance (Black and Deci, 2000; Vansteenkiste et al., 2004). Third, work on choice-induced preferences documents that the act of choosing something increases the liking for it, through cognitive dissonance or the sunk cost fallacy (Ariely and Norton, 2008; Brehm, 1956; Coppin et al., 2010; Gerard and White, 1983; Sharot et al., 2009). While we cannot distinguish between these alternative channels, we find some evidence consistent with the first channel given that farmers were more likely to remember recommendations and have a more positive attitude towards study partners as well as experimentation in general.

of agricultural best practices is important as policy makers re-design agricultural input subsidy and extension programs, ubiquitous in developing countries. From an academic perspective, we contribute to the debate by documenting the importance of autonomy for technology adoption and providing some evidence on the possible mechanisms at play.

The rest of the paper is organized as follows. Section 2 describes the context and data used while Section 3 provides the details of the design and rationale for the various experimental arms. Section 4 describes the empirical strategy and Section 5 and Section 6 present the short and long term results, respectively. Section 7 concludes.

2 Context

This project was a collaborative effort between three organizations: our partner NGO "Qué Funciona para el Desarrollo" or QFD; Ipampa S.C., a long-standing local private extension service company, and Agropecuaria Amozoc, a commercial fertilizer dealer. The project was implemented in 13 municipalities of the Mexican state of Tlaxcala, chosen for having substantial rainfed smallholder farmer populations (see Figure 1) with relatively low maize yields (2.7 mt/ha on average).

In January 2015, QFD advertised the program widely by displaying posters prominently in public locations and handing out informational leaflets. QFD also organized a total of 34 promotional meetings in the principal towns in each municipality. The promotional meetings lasted between 60–90 minutes and typically took place in a large public space (e.g. a municipal auditorium). During the meetings, the research team introduced and explained the intervention, described the eligibility requirements and the grant lottery. Potentially interested farmers were asked to complete a short form.

Between February and March 2015, interested farmers were visited by the research team. During the visit, the team collected a detailed baseline survey on a range of farmer characteristics and agricultural practices during the previous growing season of 2014. After the survey, farmers were asked to register a subplot of one hectare for the program where they planned to grow maize. QFD cordoned off this subplot, recorded its GPS coordinates, and collected soil samples.

Table 1 presents the timeline of the intervention. In March 2015, the team collected yield expectations and field activities to date. Farmers were divided into 26 strata or clusters based on their location and agro-climatic conditions.[11] Individual randomization was done at the stratum level and announced at the end of the March survey.[12]

A first mid-line survey was carried out in August 2015 focusing on labor inputs and agricultural practices to date during the growing season of the intervention. We also collected administrative data on fertilizer purchases from our partner agro-dealer. A second mid-line survey was fielded in October 2015, just before the harvest, to measure yield expectations and to record agricultural activities since the first mid-line. In January 2016, we collected yield data for the 2015 growing season. Finally, we collected further information on grain sales from the 2015 harvest in June 2016. In May 2017, two years after the experiment, we carried out a final end-line survey to collect information on practices for the 2017 growing season, which allow us to measure persistence.

To be considered eligible for the program, farmers had to cultivate maize in at least one hectare of owned or rented land (and in no more than 15 hectares), to be between 18 and 70 years old and had to sow maize in the 2015 growing season. We have consistent panel data on agricultural practices in 2014, 2015 and 2017 and yield information for 2014 and 2015 for 540 farmers and they comprise the core sample for the study.[13]

[11] Specifically, study farmers came from 54 localities (*localidades*) of which 29 were quite small and thus merged with the closest *localidad* using distance between centroids from INEGI's geographic databases. If there were ties, we chose to merge *localidades* with the closest altitude. Two of the small *localidades* were merged into one to give us a total of 26 clusters. The median cluster had 21 farmers, the 25th percentile had 15, and the 75th had 32.

[12] We note that with individual level randomization, there could be spillovers across farmers in different treatments. We study the potential spillovers in Section 5.2.

[13] The panel data includes a total of 678 farmers but 138 of them were offered individualized recommendations based on the soil analysis of their own plots. In this paper we focus on the sample of farmers that received recommendations based on averages of the soil analyses in their cluster. Corral et al. (2020) explores the impact of specificity of recommendations and does not find substantive differences in outcomes for an arm that received individual plot-based recommendations. In addition, we lack data for some farmers because they did not sow maize in a particular year (less than 5%) or because they could not be located. Appendix Table A2 column 1 shows that attrition was not differential across experimental arms. Attrition in 2017 was also uncorrelated with self-reported yields in 2014 or 2015

Table 2 provides summary statistics for the study sample of 540 farmers and their registered plots. Panel A reports farmer characteristics. Incomes were low by Mexican standards with an average self-reported annual income of 29,414 pesos (US$ 2,200). Panel B of Table 2 reports cultivation characteristics. Farmers cultivate about 2 plots and an average total area of 5.8 hectares. In 2014 (the year before the intervention) fertilizer use in their registered plot was near universal (98%) with farmers carrying out 1.6 fertilizations on average though only 6% fertilized at sowing. Average self-reported yields were about 2 mt/ha and about half of the sample sold maize in the market. Only 6% had used agricultural extension services in the past and only 15% had paid for a soil analysis.

Appendix Table A1 compares our study sample to respondents from the nationally representative INEGI survey, both in Mexico and in Tlaxcala. In Panel A we include all farmers, while Panel B restricts the sample to rainfed farmers. Study farmers have lower yields than both the national and the Tlaxcala sample. In terms of agricultural practices, study farmers are less likely to use hybrid seeds relative to the national average (but comparable to the Tlaxcala sample) and are more likely to have used fertilizer and herbicide than either of the INEGI samples. They are also more likely to have used extension services in the past. Panel B shows similar patterns and both panels suggests that farmers with greater experience and perhaps those interested in improved inputs were more likely to select into the study.

3 Experimental Design

The experimental arms combine three components: (a) soil analysis and tailored recommendations, (b) extension services and (c) and in-kind grants (flexible or inflexible) as outlined in the introduction. To summarize:

- **E1** : soil analysis, tailored input recommendations, extension services; inflexible in-kind grant. ("Inflexible" arm).
- **E2** : soil analysis, tailored input recommendations, extension services; *flexible* in-kind grant. (i.e. same as **E1** but with a flexible instead of inflexible in-kind grant). ("Flexible" arm).

E3 : soil analysis, tailored input recommendations; extension services. (i.e. same as **E1** or **E2** but with *no grant*). ("No Grant" arm).

C : No intervention. Control Arm received soil analysis and recommendations the year after the intervention ended (in early 2016).

Budgetary constraints prevented us from using a full factorial design.[14] As mentioned before, we chose to include agricultural extension services in all treatment arms because a pilot in the same study area with a comparable sample had suggested limited value of the soil analysis and recommendations without the extension services, as farmers appeared to greatly value the ability to question and discuss the recommendations with the extension agents. Grants were provided in-kind (rather than in cash) for three reasons. First, because agro-dealers did not typically stock fertilizers in the blends required by the recommendations, we partnered with Agropecuaria Amozoc, who agreed to offer the tailored high-quality fertilizer packages to farmers as long as we guaranteed a minimum volume of sales.[15] Second, the in-kind grant was intended as a "push" for farmers to experiment with higher quality inputs (fertilizers manufactured by a reputable high-quality firm). Finally and perhaps most importantly, cash grants were simply not possible because organizations such as QFD were not allowed by law to disburse cash grants. We next discuss the three sub-interventions in greater detail.

3.1 Soil Analysis and Recommendations

Soil analysis: The research team collected soil samples from the registered sub-plot of every study farmer (treatments and control). The samples were analyzed by Fertilab, a well known and respected soil testing laboratory in Mexico. Online Appendix B provides details of the soil analysis protocol. The soil analysis recorded for each plot the soil texture (percentage of sand, silt and clay), its ability to retain and transfer nutrients (pH levels, sand and lime concentrations, saturation points and cationic exchange capacity or CEC) as well as the levels of the primary

[14] A full factorial design would have 12 arms: from the two possible choices of soil analysis and recommendations, two choices for extension services, and three choices for the grant intervention.

[15] The dealer was able to blend fertilizers on-site. Packages were available for pick-up from the dealer store which was on average 17.2 km (s.d. 6.7) away from the average farmer. All study farmers had access to the dealer.

macronutrients (nitrogen N, phosphorous P and potassium K), secondary macronutrients (calcium, magnesium, and sulfur), selected micronutrients and the level of organic matter in the soil. Figure OA2 in the Online Appendix provides an example of the soil analysis produced by Fertilab. Although not the focus of the paper, Appendix Table A3 documents substantial heterogeneity in soil quality both within and across clusters.

Recommendations: Treated farmers received soil analyses and recommendations based on the averaged soil analyses in their cluster. This averaging was expressly conveyed to them in the report as well as verbally when describing the recommendations.[16] Control farmers received the analogous recommendations in February 2016, after the intervention had ended.

The recommendations included the nutrient levels and corresponding fertilizer dosages required to produce maize yields of 4.5 mt/ha under normal rain and temperature conditions. Recommendations were based on a proprietary model used by Fertilab that assumed that a certain quantity of N, P, K and micronutrients were needed to reach a target yield per hectare. In theory, the target yield should be chosen to maximize farmer profits. The model, however, assumed that yields were roughly linear in inputs and we chose the target of 4.5 mt/ha because it equated the average cost of fertilizers (according to the model) to the average baseline farmer expenditure in fertilizer .

The fertilizer dosages recommended by Fertilab were divided into two packages corresponding to the timing of application: the first package at sowing, and the second 30 to 35 days after sowing depending on plant growth. Fertilab recommended the adoption of deep tillage, a form of tilling carried out below normal depths to improve soil quality which is an important component of regenerative agriculture. Fertilab also recommended the use of a precision sowing drill at planting to ensure optimal fertilizer use at sowing as well as optimal plant spacing. Finally, the recommendations included the use of pre-emergent herbicides 2 to 40 days after sowing to reduce weeds that could compete for nutrients with the young maize plants.

Based on focus group discussions, the research team used the information provided by Fer-

[16] We provided averaged recommendations (instead of recommendations based on each farmer's individual program sub-plot) since these would be cheaper to provide (per farmer) in any scale-up and are commonly used.

tilab to design a report for farmers that was intuitive and easy to read. The report contained information on (a) plot physical characteristics and nutrient levels; (b) the recommended nutrient amounts needed to achieve a maize yield of 4.5 mt/ha under normal weather conditions; (c) recommended fertilizer quantities that met the nutrient recommendations in (b) and their costs at our partner agro-dealer which we refer to as the"shopping list"; and (d) a comparison between the farmer's own 2014 fertilizer costs and the costs of the recommendations. The research team and the extension agents were careful to explain the assumptions underlying the recommendations. More details are available in OA B.4 of Online Appendix B.

Fertilizer Balance: Column 1 of Table 3 presents usage of urea, DAP and KCl, the three main fertilizers, and the total cost of application for farmers in the control group in 2014 (the year before the intervention). Column 2 reports the p-value of the joint balance test that 2014 usage and costs in the treatment groups $E1$–$E3$ are not different from those in the control group. Column 3 reports p-value of the balance test for $E1$ vs. $E2$, the two treatment groups with the grant. Column 4 reports the average tailored recommendations (and cost) for arms $E1$, $E2$ and $E3$. Column 5 in turn checks that the amounts and costs of the recommendations for treated farmers are not different from those in the control group had the latter received the recommendations (recall that the research team carried out the soil analysis and developed recommendations for control farmers but did not provide them the information until after the intervention). Finally, Column 6 checks that the recommendations and costs are not different between $E1$ and $E2$. These results suggest that farmers in all four groups were quite similar in terms of actual and recommended fertilizer use.

Panel B of Table 2 reports that farmers in 2014 waited 36.3 days on average between sowing and the first fertilizer application. The recommendations, however, suggest applying fertilizer much earlier, at sowing and with a precision drill. As a result, not only is the recommended input mix quite different from baseline usage, but so is the timing and method of fertilizer application (despite the fact that the cost of fertilizers is roughly the same). In our context, precision drills (which are tractor attachments) are the only implement that can sow and fertilize at the same time as they have separate chambers for seeds and fertilizer. However, only 11% of study farmers had used a precision drill prior to 2015.[17]

Recommendations conflict with actual fertilizer usage. It is also clear from Table 3 that farmers use fertilizers in proportions that are quite different from the recommended ones. On average, farmers in 2014 used 92% more urea and 164% more DAP than required by the recommendations . In contrast, they used only 31% of the recommended dosage of KCl.[18] These substantive differences between status quo fertilization and tailored recommendations are also statistically significant. The total cost of tailored fertilizer is similar to the investment made by farmers in 2014 (p-value 0.55). This is unsurprising because, as mentioned earlier, the target yield of 4.5 mt/ha was chosen to equate the cost of the recommended fertilizer package with the fertilizer cost of the average farmer. We note that farmers may use less fertilizer while spending the same amount because the recommendations may increase the proportions of more exensive fertilizers.

Fertilizer quality: In addition to differences in the fertilizer mix and timing, farmers were unfamiliar with the recommended fertilizer brand YARA, a reputed, high-quality manufacturer, stocked by the agro-dealer. In order to assess fertilizer quality, the research team tested samples in a laboratory for each of the three main fertilizers (urea, DAP and KCl) manufactured by YARA (from five different locations) and by the most popular manufacturer of government subsidized fertilizer. We found that the urea and KCl content was comparable across the two types of manufacturer and generally matched the labelled concentrations. However, DAP concentrations were lower than advertised in the commonly subsidized brand relative to YARA. In fact after accounting for differences in concentrations, the cost per kilogram of nutrient was actually lower for YARA. See Online Appendix C for more details.

[17] The majority used either draft animal labor (40%) or a semi-precision drill (40%). The semi-precision drill (also attached to a tractor) or the seed drill used with draft animals can only sow and thus, when used, farmers need to fertilize manually at sowing, which is an arduous process. Precision and semi-precision drills are typically owned by large local landowners that may rent them out when not in use.

[18] On average farmers used 267.8 Kg/ha of Urea and the recommendations were 138.9 kg/ha. Farmers used 49.4 kg/ha of DAP while the recommendations were 18.7 kg/ha. The corresponding figures for KCl are 9.45 kg/ha and 30.3 kg/ha. Both urea and DAP are subsidized by the Mexican government which may explain why farmers use them in such large quantities (prices for urea and DAP sold by the government were approximately 6% lower than prices at our partner dealer, see Appendix Table A5).

3.2 Agricultural Extension Services

The extension services package offered at no cost to farmers comprised three group training sessions and three plot visits by Ipampa agricultural extension workers (AEWs). The first group meeting introduced farmers to the precision sowing drill and covered the sowing recommendations. The second group meeting covered the application of fertilizer post-sowing and provided strategies to correct nutrient deficiencies. The final meeting was held just before the harvest and emphasized field preparation. In addition to these group meetings, AEWs also visited the registered subplots of interested farmers thrice, just before and after sowing and just before harvest. AEWs used these visits to monitor nutrient deficiencies and other problems with the maize crop. AEWs were allocated by geographic zones and thus balanced across treatment arms within zones. They were also blinded to the experiment as they were not informed about project objectives, treatments nor treatment assignments. It is thus unlikely that AEWs played any role in explaining different results across arms.

3.3 Autonomy in In-Kind Grants

Farmers were provided in-kind grants worth 2,000 pesos (approximately US$150 at the time) to cover approximately half of the average per-hectare input costs (based on last season prices) for the 2015 growing season. To make this clear to farmers, they were given vouchers (see Figure OA8 for an example).[19]

Farmers in $E1$ received an *inflexible* grant that could only be used to purchase items on their shopping list. The inflexible grant was applied sequentially to first cover the sowing costs (i.e. the rental cost of 800 pesos for the precision sowing drill and the initial fertilizer package) while the remaining amount went towards the second fertilizer package. The farmer was responsible for paying the difference between the total cost of inputs and the grant. For the typical farmer in $E1$, the grant covered the cost of the sowing machinery, the first fertilizer package and ap-

[19]Farmers could not save the in-kind grant in the sense that the fertilizer packages provided by the agro-dealer were only provided for the 2015 season. In addition, farmers do not report picking up and saving fertilizer packages for subsequent seasons.

proximately half of the cost of the second fertilizer package. A farmer in the inflexible arm who chose not to rent the precision drill or to forego the first or second package would forfeit the subsidy for that input – that is, the farmers could not temporally reallocate the grant. Finally, farmers (in all arms) could not purchase fractions of the input recommendations (e.g. half a bag).[20]

Farmers in $E2$ were offered a *flexible* grant that did not require the purchase of items on the shopping list nor to follow the recommended timing of application. Instead, farmers could use the 2,000 pesos to purchase any inputs of their own choosing from our partner agro-dealer. They could, of course, use the grant to purchase items on the shopping list but were under no obligation to do so and this was made explicit during the intervention. Figure 2 displays the shopping list form given to farmers in $E2$ which is the same for farmers in $E1$, except for column "total requested" ("Total solicitado"). This column was pre-filled for farmers in $E1$, whereas it was left blank for farmers in $E2$. On multiple occasions, farmers in $E2$ were informed by the research team that they could specify any quantity in the column, including zero, up to the amount of the grant. They were also free to specify whether they wanted to use the funds to pay for the rental of the precision drill ("Renta de maquinaria a la siembra") or not. The research team did their utmost to ensure that there was no pressure to fill in any particular numbers and farmers completed the forms alone, without the presence of any research or implementation team members.

All Farmers were informed about the high quality fertilizer agro-dealer, and given its address and a map. Farmers in the no-grant arm $E3$ had to pay for the machine rental as well as the recommended fertilizer packages and other inputs using their own funds.

The grant amounts were directly transferred to our partner agro-dealer who deducted them from the costs of each farmer's shopping list. All farmers were informed about the in-kind grant both by the research team (orally and in writing) as well as by the agro-dealer, and it was also reflected in the paper-work filled out by farmers at the dealer. The research team coordinated

[20]The inflexible grant is most similar to the targeted input subsidy of many African large scale input subsidy programs. See e.g. Carter et al. (2019); Giné et al. (ming) for randomized evaluations in Tanzania and Mozambique, respectively, and Jayne and Rashid (2013) for a critical review of such programs.

the logistics of renting the precision sowing drill for interested farmers in all three arms $E1$–$E3$.

3.4 Rationale for the Interventions and Hypotheses

In this sub-section we specify and discuss hypotheses for the effect of tailored recommendations and extension services (H1), the effects of the in-kind grant (H2) and the effect of autonomy in the use of the grant (H3). Hypotheses H1 and H3 are, to the best of knowledge, new to the literature.

H1: Tailored recommendations paired with extension services increase adoption ($E3$ vs C)
The extant research on providing farmers with tailored recommendations based on soil-analysis (e.g Gars et al., 2022; Harou et al., 2018) suggests limited adoption. However, such recommendations appear to be difficult to interpret and implement in isolation. We provide detailed soil analyses and recommendations (more detailed for instance than those provided by SoilDoc) in an easy-to-understand format developed after extensive discussions with extension agents (see the discussion and exhibits in Appendix OA B.4). In addition, we pair the recommendations with high quality extension services to improve implementation. The hypothesis is that the joint provision increases adoption relative to control farmers in 2015.

Since control farmers received the recommendations at the start of the 2016 growing season, by the 2017 end-line survey the no-grant arm ($E3$) and the control arm differ only in that $E3$ had received both extension services and tailored recommendations in 2015. We hypothesize that $E3$ increases practice adoption in 2017 relative to Control.

H2: The in-kind grant increases practice adoption ($E1$–$E2$ vs $E3$)
The effect of the in-kind grant could work through multiple channels: (a) a direct income effect, (b) an endorsement effect (i.e. signalling that the team's specific recommendations were not just cheap talk) and (c) directly incentivizing experimentation. Since the tailored recommendations differed dramatically from business-as-usual, focus group discussions with farmers and Ipampa S.C. suggested that some form of subsidy would be helpful for adoption. While we cannot separately identify the relative role of these (and other) mechanisms, we do not believe

that the in-kind grant operates mainly through an income effect since, prior to the intervention, farmers were already spending on agricultural inputs an amount equivalent to the grant. For this same reason, we do not believe that the grant's primary effect was to relax liquidity or credit constraints.

H3a: Autonomy limits adoption in the short run: ($E1$ vs $E2$ in 2015)

Farmers with autonomy are encouraged to make an active decision with the flexible grant and thus may adopt fewer recommended practices than farmers offered the inflexible grant who risk forfeiting the grant if they reject the recommendations.

H3b: Autonomy increases adoption in the longer run: ($E1$ vs $E2$ in 2017)

By virtue of making an active decision, and consistent with other studies showing that autonomy increases performance and positive affect, farmers offered the flexible grant may be more likely to persist with the recommended practices.

The testing of Hypotheses 3 is most novel contribution of the paper.

4 Empirical Framework

We study the effects of our experimental interventions on the following outcomes for the 2015 season: take up of subsidized inputs and extension services, agricultural practices, changes in the input mix and yields. We also study longer term effects on agricultural practices and knowledge and attitudes towards innovation in 2017, two years after the program ended.

We present the experimental results using two complementary specifications. First, we use a standard RCT specification with indicator variables for each experimental arm (omitting the control group when appropriate). Tables OA3 to OA9 in Online Appendix E present the analysis using this specification. The second specification directly tests the hypotheses laid out in Section 3.4. Each treatment arm is the combination of multiple interventions and in this specification we present the effects of their components rather than the treatment arms themselves. In this second specification, we map the experimental arms into a set of three indicator variables and a constant: (a) *"Recommendation"* which is equal to one if the farmer received tailored input recommendations and extension services ($E1$–$E3$); (b) *"Grant"*, which is equal to one if farmer received the in-kind grant ($E1$–$E2$) and (c) *"Flexible"*, which is equal to one if the grant was flexible ($E2$). Table 4 summarizes the mapping between these dummies and the treatment arms. We then run the following specification:

$$Y_{it} = \beta_0 + \beta_R \text{Recommendation}_i + \beta_G \text{Grant}_i + \beta_F \text{Flexible}_i + \alpha_s + \epsilon_{it} \quad (1)$$

where i denotes a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects α_s and compute robust standard errors.[21]

Given the presence of the other indicators in specification eq. (1), the coefficient β_R on the Recommendation dummy compares outcomes for farmers in the no-grant arm relative to those in the control group (H1). It therefore measures the combined impact of the recommendations and agricultural extension services. β_G measures the impact of the inflexible grant ($E1$) comparing it to farmers in the no-grant arm (a subset of H2). Finally, β_F measures the impact of flexibility or autonomy by comparing farmers in the flexible grant arm ($E2$) with those in the inflexible grant arm ($E1$) testing H3. For completeness, in all results we also provide the p-value associated with the test that the treatment effects for $E1$ and $E2$ are different from zero.[22] Unless otherwise stated, we use the study sample of 540 farmers and we focus on intent-to-treat (ITT) estimates.

5 Short-Term Results

5.1 Take Up

Table 5 uses the sample of farmers that received soil analyses and recommendations during the intervention (arms $E1 - E3$) and examines the take up of the precision drill during sowing

[21] Note that eq. (1) and the standard experimental specifications estimated in Online Appendix E, in Tables OA3 to OA9 are equivalent in that the former does not impose any homogeneity restrictions and thus it is not subject to the critique in e.g. Muralidharan et al. (2019).

[22] Note that we can recover the overall impact of being in any treatment arm by combining the β-coefficients: the test that the coefficient on $E1 = 0$ is equivalent to $\beta_R + \beta_G = 0$, that the coefficient on $E2 = 0$ is equivalent to $\beta_R + \beta_G + \beta_F = 0$ and finally, and that the coefficient on $E3 = 0$ is equivalent to $\beta_R = 0$.

(column 1), the two fertilizer packages (columns 2 and 3), attendance at AEW group meetings and the total number of AEW plot visits (columns 5 and 6). Column 7 uses as the dependent variable the sum of the dependent variables in columns 1-3, 5 and 6 while column 8 uses a standardized index of the outcome in column 7. The take up of these items was verified both from farmer reports as well as administrative data and as a result, we do not believe misclassification is a serious concern. The penultimate row of Table 5 reports the mean of the dependent variable among farmers in the no-grant arm ($E3$) with the corresponding standard error.[23]

Precision drill. The take up of the precision drill among farmers in the no-grant arm was 8%. Receiving the grant increased the probability of take up (among farmers in $E1$) by 78 percentage points (pp), a near ten-fold increase. Recall that farmers with the inflexible grant forfeited the rental amount for the precision drill if they did not use it, unlike farmers with the flexible grant ($E2$). Perhaps unsurprisingly, farmers with the flexible grant were 13pp less likely to rent the precision drill than farmers with the inflexible grant although 57pp more likely to rent the drill relative to no-grant farmers.

Fertilizer packages. The take up of the first fertilizer package (column 2) among farmers in the no-grant arm ($E3$) is 7%, but increases by 83pp for farmers with the inflexible grant, a more than a ten-fold increase. The increase was comparably large, at 89pp, for farmers with the flexible grant.[24] Take-up rates for the second package (column 3) are somewhat lower than those for the first package: 4% for farmers who received just the recommendations and extension services ($E3$) and an increase of 75pp for farmers who received the inflexible grant. Farmers with the flexible grant took up the second package at very similar rates.

The extremely high and comparable take-up rates between grant farmers with and without flexibility provides sharp evidence that autonomy in grant use did not decrease take-up of the tailored recommendations. Despite having the freedom to purchase any inputs from the agro-

[23] The control group is not included in these regressions as no intervention was offered to them.

[24] While the first package was to be applied at sowing with the precision drill to guarantee an optimal spread of fertilizer, farmers who did not use the precision drill were instead advised to use the first package 30-60 days after sowing depending upon plant growth.

dealer (including additional fertilizer), farmers with the flexible grant chose not to do so.

Costs of Second fertilizer package. Take-up rates for the second package among grant recipients are lower than those for the precision drill and the first package likely because the grant typically did not cover the full cost of the second fertilizer package (while it typically fully covered the costs of the sowing machinery rental and the first package). In fact, farmers with the inflexible grant needed to pay 319 pesos (on average) out-of-pocket to purchase the second package. Column 4 shows these out-of-pocket expenses that farmers with the grant made to cover the cost of the second package. As expected, farmers with autonomy spend less out of pocket on the second package compared to farmers without autonomy because they were less likely to rent the precision sowing drill and thus used the rental amount towards the second package.

Extension services. Turning next to extension services, columns 5 and 6 record the number of AEW led group sessions attended by the farmer and the number of visits by AEWs at farmer plots where the farmer was present, respectively. These sessions and plot visits were described in Section 3 and functioned as tutorials and Q&A sessions on best practices for maize cultivation. Farmers in the no-grant arm attended an average of 0.76 sessions (column 5) and had 1.4 plot visits (column 6). Farmers with the inflexible grant attended 1.28 additional sessions and had 1.25 additional plot visits. Strikingly, farmers with the flexible grant attended 1.47 more sessions (relative to no-grant farmers), about a fifth of a session more than farmers with the inflexible grant (the number of AEW plot visits were the same for both groups). Autonomy, therefore, seems to generate more engagement.[25]

Indices of practices. Column 7 summarizes the previous columns by simply recording the total number of adopted program components (nine in total).[26] Farmers with just the recommendations and extension services adopted 2.34 components while farmers who also received the inflexible grant adopted an additional 4.89 components, confirming the importance of the

[25]The overall take up of the group training sessions declines over time with the most attendance around sowing and the least attendance before the harvest (results available upon request).

[26]These were the use of precision drill, 1st and 2nd fertilizer package, 3 group sessions and being present in the 3 plot visits by AEWs.

in-kind grant. Interestingly, farmers with the flexible grant (who had no obligation to choose any of the nine components) adopted the same number on average as those who did not have autonomy – the point-estimate is in fact slightly higher (4.97 components). It thus appears that there was no trade-off between autonomy and short-term compliance. Finally, column 8 reports results using a standardized index (measured in standard deviations) with similar results .[27]

To summarize, **H2 cannot be rejected as the in kind grant increases adoption.** Farmers that received the in-kind grant were substantially more likely to take-up the recommended packages and to avail services relative to farmers who were offered only recommendations and extension services. In addition, **H3a is rejected as autonomy does not decrease adoption.** There is no substantive difference in take-up rates between flexible and inflexible grant farmers.

5.2 Practices in 2015

We now turn to the adoption of agricultural practices recommended by the program. We divide practices into those that were prevalent before the intervention (which we label as *"Existing Practices"*) and those that were uncommon and that the intervention tried to promote (labelled *"New Practices"*).

Appendix Table A4 lists all of the recommended practices and reports their prevalence before the intervention for farmers in each treatment $E1$-$E3$ and control groups (columns 1-4), and during the intervention for the control group (column 5).[28] Column 6 reports the p-value of a joint F-test that adoption rates are similar among all treatment and control groups in 2014, while Column 7 reports the p-value of a t-test that adoption rates among control farmers in 2014 and 2015 are similar. In Column 6, there is balance across experimental arms for all practices except for "Ripping". In Column 7 there are no substantial differences (the lowest p-value is 0.17), suggesting that spillovers between treated and control farmers during the intervention were

[27] We follow the convention of standardizing each variable, summing the standardized variables, and re-standardizing again so that the index has mean zero and variance 1 in $E3$.

[28] Existing practices comprise ploughing (56% in 2015), the use of inorganic fertilizers (97%) and covering the applied fertilizer (85%). New practices included deep tillage or ripping (5% in 2015), using hybrid seeds (5%), sowing with a precision drill (10%), fertilizing at sowing (9%), application of pre-emergent herbicide (2%) and using high-quality fertilizers (manufactured by YARA) (0%). We did not ask about covering the fertilizer, using high-quality fertilizers or using pre-emergent herbicide after sowing at baseline, so they are only available in 2015.

limited.[29]

We aggregate practices for each of the two sets into corresponding indices to mitigate the need for multiple hypothesis testing. "Total Practices Applied" simply counts the number of adopted practices, while "Standardized Index" subtracts the control mean from the total number of practices applied and divides by the control standard deviation (for each element as well as the sum). Table 6 reports the results for the indices while Appendix Table A6 reports the result for the individual practices.

Existing practices. Columns 1 and 2 of Table 6 show that our interventions had no effect on *existing* practices, which is unsurprising as most farmers in the control group were already using all three practices (the mean number of existing practices is 2.4).

New practices. Turning to new practices, farmers who received only the recommendations and extension services adopt an additional 0.34 practices over the 0.32 practices in the control group, consistent with H1. Farmers who, in addition, were offered an inflexible grant ($E1$) adopt 2.58 more practices, an almost seven-fold increase and approximately the same increase as the 2.5 additional practices by farmers with a flexible grant (the numbers are not statistically distinguishable). These results reinforce the patterns of program take up documented in the previous section: the importance of the in-kind grant (consistent with H2), and the fact that autonomy did not decrease adoption (contra H3a). The results for the standardized index of new practices in column 4 are consistent with those in column 3 and so we omit a discussion.

5.3 Fertilizer Usage

In Table 7 we examine fertilizer usage. To focus on compliance with recommendations, we first examine the *absolute* difference between the amount of fertilizer applied and the amount recommended for each of the three main fertilizers (urea, DAP and KCl). We expect treatments

[29] Using the GPS coordinates, we also assessed whether control farmers with plots located close to those of treated farmers (controlling for the total number of nearby study plots defined with reference to a 500m or 1000m radius) are more likely to adopt the new practices. The intuition is that while the density of study farmers nearby is endogenous, the share of those farmers that is treated is exogenous by virtue of randomization, and so if spillovers were significant, one should detect larger changes in the adoption of recommended practices among control farmers near treated farmers. We find no evidence of any such spillovers.

to reduce the gap between actual and recommended use.[30] Columns 1–3 report application at sowing while columns 4–6 report total fertilizer application. For brevity we only focus on the results for the total fertilizer applied (the results for fertilizer at sowing are similar).[31] Fertilizer usage did not change relative to controls for no-grant farmers (i.e. those who received only the tailored recommendations and extension services, arm *E*3). By contrast and perhaps unsurprisingly, farmers who were, in addition, offered an inflexible in-kind grant (*E*1) mostly earmarked for fertilizer, show a dramatic change in fertilizer application. The overall gap for urea reduced by 81.9 Kg/ha (a 71% reduction relative to the mean control gap of 114.9 Kg/ha), the gap in DAP by 30.2 Kg/ha (80% reduction) and the gap in KCl by 28.8 Kg/ha (88%). More interestingly, these dramatic reductions were also achieved by farmers with the flexible in-kind grant who had autonomy and thus were not required to adjust their fertilizer usage as a pre-condition for the grant. In fact, we cannot reject the null that the reductions are the same for these two arms for Urea and DAP. For KCl, the gap was reduced by 23.6 kg/ha for *E*2, slightly less than for those offered the inflexible in-kind grant. Comparing the amounts of fertilizer received and used, we find that around 80% of farmers with a grant used the amounts purchased or received in their entirety, for all three types of fertilizer. Side sales therefore are not a concern.

Perhaps most importantly, the closing of the gap for Urea and DAP led to substantial *reductions* in fertilizer use by farmers in the grant arms. In Table 8 we examine total fertilizer usage. Control farmers used an average of 188 kgs/ha of Urea and the figure remains substantively unchanged for farmers in the no-grant arm (*E*3). In contrast, farmers with the in-kind grants reduced their average urea application by 36 kg/ha, a decrease of 19% . As we show below,

[30] We also measure this gap for the control arm. As noted above, we performed soil analyses and recommendations for control plots but did not share these with control farmers in 2015.

[31] Recall that the recommendations encouraged farmers to change both the fertilizer mix and the timing of application. Since control farmers carried out their first fertilization about 36 days from the time of sowing on average (see panel B Table 2), columns 1 to 3 show a deficit of fertilizer application among controls of 38.7 Kg/ha of urea, 19.4 Kg/ha of DAP and 16.4 Kg/ha of KCl at the time of sowing. Most farmers offered the in-kind grant (in *E*1–*E*2) used the precision drill and fertilized at sowing, reducing the absolute gap between recommendation and application at sowing. Among farmers with the flexible grant, these reductions were 28.7 Kg/ha of urea (a 74% reduction), 13.6 Kg/ha of DAP (a 70% reduction) and by 11.5 Kg/ha of KCl (a 70% reduction). The reductions are broadly similar for farmers in *E*1 as well. Farmers with the flexible grant apply 3.73 Kg/ha less of urea compared to farmers in *E*1, thus increasing the gap between the amount of fertilizer recommended and applied (recall that urea was underused at sowing according to the recommendations). In column 3, farmers in *E*2 also apply 3.6 Kg/ha less of KCl than farmers in *E*1. Thus, farmers in *E*1 followed the fertilizer recommendations at sowing most closely, followed by farmers in *E*2.

this reduction in fertilizer did not reduce yields.[32] A back-of-the-envelope calculation shows that the reduction in fertilizer use translates to 119 kg/ha or 14% reduction in CO2e (carbon-dioxide equivalent) emissions using emission factors from the IPCC (Penman et al., 2000). Thus the intervention achieved a reduction in CO2e emissions with no negative effects on yields.

To summarize the two subsections above, we document a doubling of new agricultural practice adoption by farmers who received recommendations and extension services only (relative to control), consistent with H1, but no change in their fertilizer input mix or timing of application. By contrast, farmers who also received the in-kind grant increased new practice adoption rates almost eight-fold and also changed both their fertilizer input mix and timing of application consistent with H2. Finally, we find substantively similar patterns for farmers with and without autonomy, thus rejecting H3a as autonomy did not lead to lower adoption in 2015.

5.4 Yields

We now turn to measuring the impact of the program on yields. Column 1 in Table 9 presents the self-reported measure of yields for the full sample of 540 farmers.[33] Yields for control farmers were 2,360 Kg/ha. The provision of tailored recommendations and extension services increased yields by 220 Kg/ha (a 9% increase relative to the control mean) but the estimate is not statistically significant at conventional levels. The in-kind grant, however, increased yields significantly (both in an economic and statistical sense) relative to those in the control group. For farmers with the inflexible grant, yields rose by 300 Kg/ha (a 12% increase relative to the control mean). The corresponding treatment effect for farmers who received the flexible grant

[32] In Appendix OA E.1 Table OA10 we explore whether the changes in fertilizer use in 2015 were related to the gap between fertilizer used and recommended at baseline and whether there was variation in the effectiveness of the various treatments for a given baseline gap. We find that farmers with larger gaps were not more responsive to the intervention and there was no variation across treatment arms.

[33] As discussed in Desiere and Jolliffe (2017) among others, self-reported yields are plagued by measurement error both in the numerator (the quantity harvested) as well as in the denominator (area sown). We took two steps to minimize this problem. First, the research team demarcated the registered subplot (which was one hectare in most cases) using GPS devices.For farmers with a plot area of less than 1 ha, the research team measured how much they had and adjusted the denominator appropriately. Results are robust to excluding these plots. Second, we attempted to verify self-reported yields by transporting the harvested grain to a nearby weighing station. We were able to do so for a subset of plots (see Online Appendix D and Table A7 for details). The results from using these measures are quite similar to those from the self-reports used here.

was 370 Kg/ha (a 15% increase). The two numbers are not statistically distinguishable from one another. These results allow us to make two substantive conclusions. First, yields did not decrease (in fact they increased) in both grant arms despite reduced fertilizer use. It is thus possible to reduce fertilizer usage (and emissions) without decreasing yields. Second, yields were the same for farmers with and without autonomy suggesting that allowing autonomy in input choice did not affect yields.[34] In Online Appendix A we show that the changes in input use patterns did not affect profits.[35]

6 Long-Term Practice Persistence

In February 2016, after the conclusion of the harvest, farmers in the control group received the soil analyses and recommendations. We subsequently returned in the summer of 2016 for a short survey. Even though the control group had only received their recommendations a few months earlier, they were substantially less likely to have it on hand (58%) compared to farmers who had also received extension services in 2015 (87%). The figures were comparably high for the other arms as well. Finally, we returned in May 2017 to examine whether any of the practices introduced in 2015 had persisted into the second growing season after the intervention. The survey took place after sowing but prior to harvest, and we asked about a range of outcomes, including practices in the 2017 season and agricultural knowledge more broadly.

Table 10 examines practices in 2017. Turning to new practices in Column 3, control group farmers reported using 0.42 new practices on average, statistically indistinguishable from the 0.32 new practices used by the same group in the year of the intervention, suggesting that the provision of only the soil analyses and recommendations a year later (without extension services) did little to change practices, and that spillovers from treatment farmers were likely minimal. Farmers in the no-grant arm ($E3$) had also received extension services in 2015 and adopted 0.24 additional practices, an increase of 0.4 *s.d.* (Column 4). Thus, the provision of extension ser-

[34] We note that after July, rainfall was below normal in all of the study municipalities, during a critical period for plant development. See e.g. Sinclair and Rawlins (1993) and Appendix Table A8 for details.

[35] Power calculations suggest that with our sample we have 83% power to detect a 20 percent increase in mean yields, but only 9% power to detect a 20 percent increase in profits net of the subsidy.

vices had persistent effects into the second growing season relative to controls, consistent with hypothesis H1 for 2017. We view this as encouraging evidence of the longer-term effectiveness of extension services when paired with tailored recommendations.[36] Farmers who, in addition to the recommendations and services, were offered an inflexible grant ($E1$) adopt 0.32 more practices (statistically indistinguishable from the treatment effect for the no-grant arm).

Interestingly, **Hypothesis H3b cannot be rejected as autonomy causes persistence.** Farmers who received the flexible grant adopted 0.77 more practices (a 1.07 standard deviation increase) compared to farmers in the control group, substantively more than farmers with the inflexible grant. Thus farmers with autonomy were more likely to persist with new practices introduced by the project two years after the intervention ended, consistent with H3b. We explore this result in greater detail by examining each individual practice (reported in Appendix Table A9). In 2017, farmers in the flexible grant arm are more likely (than those in the inflexible grant arm) to use hybrid seeds, sow with a precision drill and use YARA fertilizers. Intriguingly, while the rental of the precision drill and YARA fertilizers were subsidized by the in-kind grant, hybrid seeds, while recommended, were not subsidized. It thus appears that during the intervention, farmers with the flexible grant spent perhaps more time evaluating different options and made decisions accordingly, adopting in 2017 some practices that were mandatory in 2015 for farmers with the inflexible grant and others that were not.

6.1 Understanding the Role of Autonomy

In this subsection we seek to better understand the reasons for adoption by farmers with autonomy, both during and after the intervention. As noted above, although farmers with

[36]This result is consistent with work in other contexts. For example, in an experiment providing management consulting to large firms in India, Bloom et al. (2013) find that merely providing recommendations (as they did to the control firms) had relatively limited effects compared to pairing the recommendations with consultants that helped firms in implementing the recommendations. For related work on agricultural extension services, see Beaman et al. (2018); Kondylis et al. (2017) on learning in the contact farmer extension model and Cole and Fernando (2020) on the effectiveness of mobile-phone based extension services in India. Also see Magruder (2018) for a summary of the past decade of work on the effectiveness of extension services in developing country contexts (see e.g Anderson and Feder, 2007, for a review of older work). We note that since farmers in $E3$ received their analyses and recommendations a year before the control group, the differences in outcomes between them and the controls reflect both the effect of the extension services as well as the effect of having had the recommendations for an extra year.

autonomy were not required to follow any of the tailored recommendations, most did so at rates comparable to those of farmers without autonomy. This was true both for the purchase of inputs (precision drill rental, fertilizer) as well as extension services (AEW training sessions and plot visits) which were free of charge. During the intervention farmers with autonomy appeared to trust the recommendations enough to follow them without being required to do so and that this effect persisted into subsequent growing seasons. We provide two pieces of evidence in support of hypotheses H3a and H3b in Tables 11 and 12.

Trust. First and most directly, Column 4 of Table 11 reports that during the intervention farmers with autonomy (i.e. the flexible grant) were 0.35 standard deviations more likely to report trusting recommendations from the implementing partners (Ipampa and the local agro-dealer) relative to farmers with the inflexible grant ($E1$).[37]

Memory. Second, we find that farmers with autonomy were more likely to report remembering the recommendations and state that they would follow them in the next growing season (consistent with Mirty et al., 2019). According to Column 1 of Table 11 farmers in the flexible grant arm were 5pp more likely to report that they remembered the sowing recommendations (relative to farmers with the inflexible grant) and in Column 3, they were 13pp more likely to report intending to follow the program recommendations in the next growing season.

Use of Unfamiliar Fertilizer. Finally in 2017, farmers with autonomy expressed the highest willingness to pay for (high-quality) KCl, the least known and used fertilizer at baseline, and hence the one whose increased usage was most recommended by the program (see Table 12).

These results are consistent with choice-induced preference theories (Ariely and Norton, 2008; Brehm, 1956; Coppin et al., 2010; Gerard and White, 1983; Sharot et al., 2009). Also consistent with laboratory studies showing that greater autonomy increases effort (Sjöström et al., 2018), we find a 6% increase in hired labor when the grant is flexible compared to when it is inflexible (Column 5 of Table 11). Farmers with autonomy also showed a more open attitude towards change and experimentation. In 2017, flexible grant farmers were 0.28 $s.d.$ more likely to

[37] Trust was measured on a five-point Likert scale that ranged from "Always trust" to "Never trust." See Appendix Table A10 for definition of the variables.

exhibit a positive attitude towards change compared to their inflexible grant counterparts. This last finding is interesting since it is consistent with the flexible grant leading to a willingness to experiment (perhaps by giving farmers a greater sense of agency). Such inferences, although speculative, do suggest fruitful areas for further research.

To summarize, farmers with the flexible grant in 2015 were more likely to exhibit increased knowledge of and trust in the program after it ended and display a more positive attitude towards experimentation. These changes could help explain why we see a greater persistence in program practices among this group two years after the program ended. Testing the mechanisms through which autonomy matters is important for future research (see e.g. Sen, 1999).[38]

7 Conclusion

Encouraging the appropriate use of technology among smallholder farmers that overuse it is an increasingly active research area and a first-order policy issue. In this paper we explore the role of autonomy in the short-term and long-term use of fertilizers. Based on plot-level soil analyses, we find that farmers' apply fertilizers at a time and with amounts and proportions that deviate markedly from tailored recommendations, with substantial overuse of urea and DAP.

We conduct a randomized experiment with a control and three treatment arms that provides a combination of localized soil analyses, recommendations and extension services, and an in-kind grant. We vary the degree of autonomy in the spending of the grant. The experimental design allows for a credible test of the effects of (a) pairing localized recommendations with extension services, (b) an in-kind grant and (c) autonomy, with (a) and (c) being, to the best of our knowledge, novel to the literature.

We find that pairing localized recommendations with extension services had modest but

[38]We note that the difference in outcomes between the flexible and inflexible grant arms cannot be explained by liquidity or income effects alone since both grants had equivalent amounts and were given at the same time. A more promising explanation is based on psychology and provided by self-determination theory. Future research should try to determine whether persistence happens through attention-driven learning or through choice-induced preferences (e.g. via a sunk cost fallacy or cognitive dissonance).

persistent effects on agricultural practices. Adding an inflexible in-kind grant had important short-term effects with improved practice adoption and yields during the intervention but not in the longer term compared to the arm that received only recommendations and extension services.

However, farmers with autonomy in spending the in-kind grant showed substantially greater persistence relative to farmers without such autonomy. We provide some evidence that farmers with greater autonomy had greater trust in the project partners, better remembered the recommendations and exhibited a more positive attitude towards experimentation after the intervention ended. The results suggest an important instrumental role for autonomy in increasing adherence to expert advice. Based on these findings, we consider examining the mechanisms through which autonomy may matter as well as the interaction between autonomy and the adherence to expert advice as fruitful avenues for future research.

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Tables and Figures

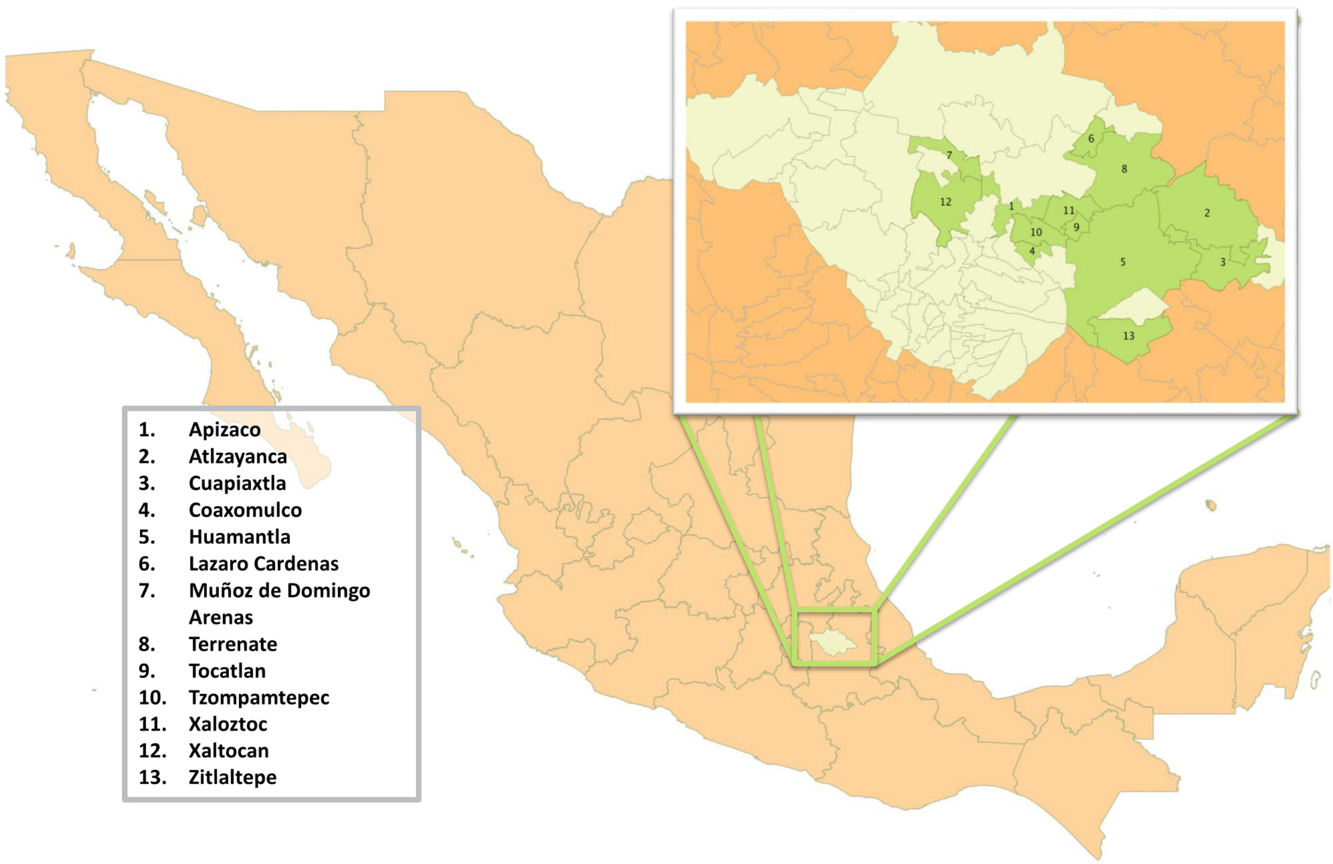


Figure 1: Map of Tlaxcala

¿Renta de maquinaria para la siembra? ☐ SÍ ☐ NO

PAQUETE SIEMBRA

	Dosis de fertilizantes en kg/ha				
Fertilizante	Marca Producto	**Total solicitado**	**Costo unitario**	**Costo total**	**A pagar por QFD**
Sembradora de precisión	YARA	X	X pesos	**X**	**X**
Urea (Blanco)	YARA	X	X pesos	**X**	**X**
DAP (Negro)	YARA	X	X pesos	**X**	**X**
Cloruro de Potasio (Rojo)	YARA	X	X pesos	**X**	**X**
Microelementos	AGROQUÍMICA	X	X pesos	**X**	**X**
Gastos total en fertilizantes por hectárea (aproximado)			**X pesos**		
Gastos total por hectárea Siembra (siembra aprox SUMANDO LOS HERBIDAS SELLADORES Y MAQUINARIA)			**X pesos**		

Remanente **A LA SIEMBRA de los 2000 pesos**: **X** pesos, si es negativo lo tienen que pagar el día que van a buscar el paquete SIEMBRA a YARA HUAMANTLA.

PAQUETE PRIMERA FERTILIZACIÓN DESPUÉS DE LA SIEMBRA (30-35 días)

	Dosis de fertilizantes en kg/ha				
Fertilizante	Marca Producto	**Total solicitado**	**Costo unitario (por kg)**	**Costo total**	**A pagar por QFD**
Urea (Blanco)	YARA	**X**	X pesos	**X pesos**	
Cloruro de Potasio (Rojo)	YARA	X	X pesos	**X pesos**	
Gastos total en fertilizantes por hectárea (aproximado)			**X pesos**		

Remanente a pagar por el productor **A LA PRIMERA FERTILIZACIÓN X** pesos, si es negativo lo tienen que pagar el día que van a buscar el paquete FERTILIZACIÓN 30 DÍAS a YARA HUAMANTLA.

Figure 2: Shopping list

Table 1: Timeline of Activities

Season/Date	**Activity**
Pre-planting 2015	
January 2015	Farmer Registration
February 2015	Soil sampling
	Baseline survey (farmer characteristics and 2014 practices)
Planting 2015	
March 2015	Delivery of soil analysis
	Orders of fertilizers
April-July 2015	Intervention
August 2015	Follow-up survey (2015 practices)
Harvest 2015	
October-December 2015	Yield estimation
February 2016	2015 Self-reported yields survey
Commercialization 2015	
June 2016	2015 Commercialization survey (prices, sales and costs)
Planting 2017	
May 2017	Follow-up survey (2017 practices)

Table 2: Summary Statistics

	Mean (SD)	p-value		Mean (SD)	p-value
Panel A: Farmer Characteristics					
Male (1=Yes)	0.83	0.78	Annual income in 2014 (000s pesos)	29.41	0.49
	(0.38)			(30.88)	
Age (years)	56.95	0.70	Reported liquidity constraints (1=Yes)	0.52	0.74
	(13.52)			(0.50)	
Years as farmer	34.90	0.31	Ever applied for a loan (1=Yes)	0.20	0.75
	(16.15)			(0.40)	
Completed primary school (1=Yes)	0.60	0.90	Never takes risks (1=Yes)	0.13	0.21
	(0.49)			(0.34)	
Panel B: 2014 Cultivation Characteristics & Yields					
Number of plots cultivated in 2014	2.09	0.33	Farmer sold maize in 2014 (1=Yes)	0.50	0.55
	(1.27)			(0.50)	
Total area cultivated (ha) in 2014	5.77	0.89	Share of maize production sold in 2014	0.28	0.97
	(4.45)			(0.34)	
Number of fertilizations in 2014	1.58	0.93	Ever had extension services (1=Yes)	0.06	0.09
	(0.54)			(0.24)	
Number of days between sowing and 1st fertilization in 2014	36.32	0.94	Ever done soil analysis (1=Yes)	0.15	0.59
	(21.48)			(0.35)	
Self-reported yield (ton/ha) in 2014	2.06	0.92	Supported by a government program in 2014 (1=Yes)	0.87	0.90
	(1.16)			(0.33)	
Panel C: Plot Characteristics					
Sand (%)	70.93	0.96	Nitrogen (N) (ppm)	14.14	0.04
	(9.96)			(7.00)	
Clay (%)	14.71	0.95	Phosphorus (P) (ppm)	28.18	0.40
	(5.43)			(25.54)	
Slope (degrees)	3.24	0.06	Potassium (K) (ppm)	198.98	0.11
	(3.43)			(137.43)	
pH (1:2 water)	6.07	0.02	CEC (cmolc/kg)	9.60	0.33
	(0.71)			(8.54)	
Coal (	(0.45)			(0.45)	

Note: This table reports summary statistics for the study sample of 540 farmers in 2014. For each variable, we report the mean and standard deviations. We also regress the baseline values of each variable on a set of treatment dummies and report the p-value of a F-test that all treatment coefficients are jointly equal to zero. The data were collected using our Baseline survey conducted in February 2015, before the start of the intervention. See Appendix Table reftab:defvars for the definition of the variables.

Table 3: Fertilizer application in 2014 vs. average recommendations

	(1)	(2)	(3)	(4)	(5)	(6)
	Fertilizer application			Average recomm. in 2015		
	Control mean in 2014	p-value E1-E3 vs. C	p-value E1 vs E2	Mean E1-E3	p-value E1-E3 vs. C	p-value E1 vs E2
Urea(kg/ha)	267.81	0.59	0.31	138.90	0.94	0.83
	(135.25)			(12.38)		
DAP(kg/ha)	49.41	0.79	0.62	18.67	0.91	0.67
	(65.27)			(16.73)		
KCL(kg/ha)	9.45	0.81	0.95	30.34	0.98	0.79
	(26.15)			(17.45)		
Cost(pesos/ha)	1,895.49	0.91	0.55	1,672.13	0.94	0.80
	(1,181.91)			(214.53)		
Observations	130			407		

Note: This table reports average amounts of fertilizers and costs and balance checks for the 537 farmers in our study sample. Column 1 reports self-reported average amounts applied and total cost of fertilizers in 2014 by the control group (SDs in parentheses). We regress each variable on our set of treatment dummies and report in column 2 the p-value of an F-test that the dummies are jointly equal to zero and in column 3 the p-value of a T-test that inflexible grant is equal to flexible. Column 4 reports the average input recommendations and the corresponding input costs for E1-E3 farmers. In column 5 we report again the p-value of the corresponding F-test and in column 6 we compare the average recommendations of inflexible grant farmers to those of flexible grant farmers by reporting the p-values of a T-test analogous to those in column 3. We use administrative data on recommendations given to farmers and Baseline survey data collected in February 2014.

Table 4: Definition of dummies

	Recommendation	Grant	Flexible
$E1$ ("inflexible")	Yes	Yes	No
$E2$ ("flexible")	Yes	Yes	Yes
$E3$ ("no-grant")	Yes	No	No
C ("control")	No	No	No

Note: This table shows how the dummies used are defined from the original treatment arms.

Table 5: Take up

	(1) Precision drill (1=Yes)	(2) 1^{st} Package (1=Yes)	(3) 2^{nd} Package (1=Yes)	(4) Out-of-pocket (Mex$/ha)	(5) # training sessions (0-3)	(6) # AEW visits (0-3)	(7) Total (0-9)	(8) Total (Std. Index)
Grant (1=Yes)	0.78***	0.83***	0.75***	319.59***	1.28***	1.25***	4.89***	3.73***
	(0.04)	(0.03)	(0.04)	(22.13)	(0.11)	(0.13)	(0.26)	(0.16)
Flexible (1=Yes)	-0.13**	0.06**	-0.02	-107.21***	0.19**	-0.01	0.08	-0.06
	(0.05)	(0.03)	(0.05)	(28.00)	(0.09)	(0.09)	(0.24)	(0.16)
Observations	410	410	410	410	410	410	410	410
R-squared	0.50	0.75	0.54	0.41	0.44	0.40	0.62	0.69
Mean dep. var. E3	0.08	0.07	0.04	0.00	0.76	1.40	2.34	0.00
SD dep. var. E3	0.27	0.25	0.19	0.00	0.95	1.28	2.11	1.00

Note: this table reports results on the take-up of our proposed treatment by farmers in our sample. Using only the set of 410 treated farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome variable for the group of farmers who did not receive the grant (T3), the omitted category in our regression. In column 1, the dependent variable is a dummy that takes value 1 if the farmer used the precision machinery provided by our team to fertilize at sowing. In column 2, the dependent variable is a dummy that takes value 1 if the farmer took up the first package of YARA fertilizers, that should be applied at sowing using the precision machinery. Farmers who did not use the sowing machinery were advised to use this package 30-60 days after sowing depending on how their crop grew. In column 3, the dependent variable is a dummy that takes value 1 if the farmer took up the second package of YARA fertilizers, that should be applied 45 days after sowing. In column 4, the dependent variable is the amount that each farmer had to pay for the packages of fertilizers, on top of the QFD subsidies, if they received them. In column 5, the dependent variable counts the number of training sessions each farmer attended, out of 3 our team organized. The first training session introduced farmers on how to fertilize at sowing. The second one aimed at on harvesting and preparations for yield measurement, as well as soil preparation for the following season. The third training session covered the importance of using quality fertilizers and herbicides, as well as on the right timing to fertilize during plant development. In column 6, the dependent variable counts how many times the farmer was visited by the our team to be provided with technical assistance (out of 3 scheduled visits). In column 7, the dependent variable is the sum of columns 1, 2, 3, 5 and 6, varying from 0 to 9. In column 8, the dependent variable is a standardized index of the outcome in column 8, computed by standardizing each variable recommidually, adding them all and standardizing the sum. We use the mean and standard deviation of T3 as reference for the standardized index. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Practices 2015

	(1)	(2)	(3)	(4)
	Existing practices		All new practices	
	Total practices applied	Standardized Index	Total practices applied	Standardized Index
Recommendation (1=Yes)	0.04	0.06	0.34**	0.32**
	(0.08)	(0.13)	(0.11)	(0.14)
Grant (1=Yes)	0.04	0.12	2.24***	1.66***
	(0.08)	(0.11)	(0.14)	(0.16)
Flexible (1=Yes)	-0.02	-0.01	-0.08	-0.07
	(0.07)	(0.08)	(0.14)	(0.19)
Observations	540	540	540	540
R-squared	0.07	0.07	0.60	0.38
Mean dep. var. control	2.38	0.00	0.32	0.00
SD dep. var. control	0.61	1.00	0.69	1.00
T1: $\beta_R + \beta_G = 0$	0.24	0.09	0.00	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.32	0.09	0.00	0.00

Note: this table reports results on the agricultural practices performed by the farmers in our study in the 2015 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Follow-up survey conducted in August 2015. The dependent variable in column 1 is a sum of recommidual dummies. Each dummy takes value of 1 if the farmer performed one of the so-called existing agricultural practices. In column 2, the dependent variable is the standardized index of the outcome in column 1, computed by standardizing each dummy recommidually, adding them all and standardizing the sum. We use the mean and standard deviation of the control group as reference for the standardized index. In columns 3 and 4, the dependent variables are analogous to the outcomes in columns 1 and 2, computed for the so-called new practices. The existing practices are: (a) ploughing, (b) using inorganic fertilizer and (c) covering the fertilizer. The new practices are: (a) deep tilling (ripping), (b) using hybrid seeds, (c) fertilizing at sowing, (d) sowing with precision machinery, (e) using pre-emergent herbicide and (f) using high-quality fertilizers. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Fertilizer usage in 2015: applied vs. recommended

	(1)	(2)	(3)	(4)	(5)	(6)
	Absolute difference, applied vs. recommended					
	At sowing			Total		
	Urea (kg/ha)	DAP (kg/ha)	KCl (kg/ha)	Urea (kg/ha)	DAP (kg/ha)	KCl (kg/ha)
Recommendation (1=Yes)	-1.83	0.52	-1.47	-4.83	1.77	-0.93
	(1.97)	(2.37)	(1.28)	(10.87)	(5.73)	(3.79)
Grant (1=Yes)	-30.59***	-16.81***	-13.62***	-77.02***	-31.98***	-27.85***
	(2.00)	(2.25)	(0.86)	(9.40)	(4.97)	(2.69)
Flexible (1=Yes)	3.73**	2.70*	3.58***	2.74	-1.55	5.15**
	(1.89)	(1.62)	(1.07)	(7.59)	(3.40)	(2.32)
Observations	532	532	532	532	532	532
R-squared	0.52	0.39	0.44	0.25	0.21	0.28
Mean dep. var. control	38.69	19.40	16.44	114.90	37.83	32.66
SD dep. var. control	14.64	21.36	14.42	82.62	47.92	33.98
T1: $\beta_R + \beta_G = 0$	0.00	0.00	0.00	0.00	0.00	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.00	0.00	0.00	0.00	0.00	0.00

Note: This table reports results on the usage of fertilizers by the farmers in our study in the 2015 season, compared to the recommended dosages. Using the sample for the full sample of 540 farmers, except for 13 farmers for which we do not have data on usage of fertilizers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Commercialization survey conducted in June 2016. In columns 1-3, the dependent variables are the absolute differences between the amount applied by farmers at sowing and the recommended dosages of Urea, DAP and KCl, respectively. In columns 4-6, we report analogous outcomes for the total amount of fertilizers applied in the full season. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Fertilizer usage in 2015: applied

	(1)	(2)	(3)	(4)	(5)	(6)
	Applied fertilizer, 2015					
	At sowing			Total		
	Urea (kg/ha)	DAP (kg/ha)	KCl (kg/ha)	Urea (kg/ha)	DAP (kg/ha)	KCl (kg/ha)
Recommendation	3.74	1.64	-1.25	10.38	3.71	3.93
	(3.45)	(2.83)	(1.74)	(15.70)	(6.81)	(5.24)
Grant (1=Yes)	23.54***	10.06***	11.81***	-36.07**	-14.37**	9.56**
	(3.00)	(2.48)	(1.03)	(12.46)	(5.58)	(3.78)
Flexible (1=Yes)	-5.15**	-1.71	-1.01	0.55	-0.64	3.97
	(2.12)	(1.70)	(1.10)	(8.59)	(3.53)	(2.55)
Observations	540	540	540	540	540	540
R-squared	0.28	0.26	0.30	0.10	0.13	0.13
Mean dep. var. control	5.77	4.50	2.88	188.35	34.65	14.96
SD dep. var. control	26.88	21.85	16.95	131.38	57.21	42.06
T1: $\beta_R + \beta_G = 0$	0.00	0.00	0.00	0.04	0.06	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.00	0.00	0.00	0.05	0.04	0.00

Note: This table reports results on the usage of fertilizers by the farmers in our study in the 2015 season, in absolute value dosages. Using the sample for the full sample of 540 farmers, except for 13 farmers for which we do not have data on usage of fertilizers, we run the following regression: $Y_{it} = \beta_0 + \beta_R \text{Recommendation}_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Commercialization survey conducted in June 2016. In columns 1-3, the dependent variables are the amounts applied by farmers at sowing of Urea, DAP and KCl, respectively. In columns 4-6, we report analogous outcomes for the total amount of fertilizers applied in the full season. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Yields and profits 2015

	(1) Self-reported yields (t/ha)	(2) Revenue (Mex$/ha)	(3) Costs (Mex$/ha)	(4) Profits (Mex$/ha)	(5) Profits (no subsidy) (Mex$/ha)	(6) Profits (no subsidy) - Alt. (Mex$/ha)
Recommendation (1=Yes)	0.22	744.96	48.19	696.77	705.94	705.09
	(0.16)	(528.22)	(276.10)	(517.75)	(518.38)	(517.62)
Grant (1=Yes)	0.08	256.62	638.51**	-381.89	1683.35**	1301.12**
	(0.17)	(556.80)	(265.81)	(556.74)	(556.63)	(555.56)
Flexible (1=Yes)	0.07	276.95	318.70	-41.76	-31.44	-104.40
	(0.16)	(546.14)	(250.28)	(536.65)	(542.16)	(538.90)
Observations	540	540	540	540	540	540
R-squared	0.27	0.30	0.20	0.22	0.25	0.24
Mean dep. var. control	2.36	7919.22	5280.02	2639.20	2639.20	2639.20
SD dep. var. control	1.33	4397.72	2351.52	4024.33	4024.33	4024.33
T1: $\beta_R + \beta_G = 0$	0.06	0.05	0.00	0.55	0.00	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.02	0.01	0.00	0.59	0.00	0.00

Note: this table reports results on yields and profits earned by farmers in the 2015 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Commercialization survey conducted in June 2016. In column 1, we use as the dependent variable the maize yields (tons/ha) self-reported by farmers in the 2015 season. In column 2, the dependent variable contains the value of farmers' maize production (per hectare) in the 2015 season. The value of the production (per hectare) is computed by multiplying the total amount of maize harvested by the farmer in the 2015 season by the price the maize could be sold in the market. We take the median price faced by farmers who sold at least a fraction of their production in the market as the price for all farmers when computing the value of the maize production. In column 3, the dependent variable is the total cost of production cost self-reported by each farmer. Total costs include the total investment in soil preparation activities, fertilizers (chemical and organic), herbicides, pesticides, and labor. We also include the cost of renting the sowing and harvest machines paid by QFD (when that was the case), as well as the subsidy for fertilizer packages, also paid by QFD. In column 4, the dependent variable is the difference between the dependent variable in columns 2 and 3. In column 5, the dependent variable is the cost of production, not including the subsidies paid by QFD. We use median market prices at the locality level to calculate revenues and profits. In localities where no farmer sold maize, we use median prices at the municipality level. To account for this imputation of prices (for 20 farmers in our sample), we include an dummy that takes value of one if prices were measured at the municipality level on the RHS of columns 2-5. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 10: Practices 2017

	(1)	(2)	(3)	(4)
	Existing practices 2017		All new practices 2017	
	Total practices applied	Standardized Index	Total practices applied	Standardized Index
Recommendation (1=Yes)	0.11	0.12	0.24**	0.40**
	(0.11)	(0.12)	(0.11)	(0.16)
Grant (1=Yes)	-0.21**	-0.19*	0.08	0.12
	(0.10)	(0.12)	(0.13)	(0.19)
Flexible (1=Yes)	0.05	0.05	0.45**	0.55**
	(0.10)	(0.12)	(0.14)	(0.20)
Observations	540	540	540	540
R-squared	0.09	0.08	0.22	0.18
Mean dep. var. control	2.31	0.00	0.42	0.00
SD dep. var. control	0.89	1.00	0.79	1.00
T1: $\beta_R + \beta_G = 0$	0.38	0.54	0.00	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.65	0.83	0.00	0.00

Note: this table reports results on the agricultural practices performed by the farmers in our study in the 2017 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Final survey conducted in May 2017. The dependent variable in column 1 is a sum of individual dummies. Each dummy takes value of 1 if the farmer performed one of the so-called existing agricultural practices. In column 2, the dependent variable is the standardized index of the outcome in column 1, computed by standardizing each dummy individually, adding them all and standardizing the sum. We use the mean and standard deviation of the control group as reference for the standardized index. In columns 3 and 4, the dependent variables are analogous to the outcomes in columns 1 and 2, computed for the so-called new practices. The existing practices are: (a) ploughing, (b) using inorganic fertilizer and (c) covering the fertilizer. The new practices are: (a) deep tilling (ripping), (b) using hybrid seeds, (c) fertilizing at sowing, (d) sowing with precision machinery, (e) using pre-emergent herbicide and (f) using high-quality fertilizers. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 11: Grant flexibility

	(1)	(2)	(3)	(4)	(5)	(6)
	Knowledge of recommendations					
	Remembers sowing recomm. (1=Yes)	Famers kept soil analysis (1=Yes)	Would follow the recomm. in the following year (1=Yes)	Trust in the recomm. from input supplying institutions: standardized index	Number of workers in 2015 (exc. harvest)	Attitudes towards change: standardized index
Year of data collection	*2015*	*2016*	*2016*	*2015*	*2015*	*2017*
Grant (1=Yes)	-0.01	0.07*	-0.06	0.37**	0.20	0.15
	(0.02)	(0.04)	(0.06)	(0.13)	(0.43)	(0.12)
Flexible (1=Yes)	0.05*	-0.02	0.13**	0.35**	0.71*	0.28**
	(0.03)	(0.03)	(0.06)	(0.12)	(0.42)	(0.11)
Recommendation (1=Yes)		0.29***	-0.04	0.61***	-1.43**	-0.10
		(0.06)	(0.06)	(0.14)	(0.51)	(0.13)
Observations	395	510	540	508	540	540
R-squared	0.09	0.19	0.06	0.29	0.16	0.14
Mean dep. var. control (or T4)	0.03	0.58	0.39	-0.00	11.55	-0.03
SD dep. var. control (or T4)	0.18	0.50	0.49	1.00	4.74	1.12
T1: $\beta_R + \beta_G = 0$	0.79	0.00	0.10	0.00	0.01	0.71
T2: $\beta_R + \beta_G + \beta_F = 0$	0.14	0.00	0.53	0.00	0.29	0.01

Note: this table reports results on the effect of the grant flexibility on a variety of outcomes. Using a subset of 395 among the 410 treated farmers, in Column 1 report the estimates from the following regression: $Y_{it} = \beta_0 + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. In Columns 2-6, we report the point estimates of the following specification: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the omitted group of farmers, which in Column 1 corresponds to those who did not have the grant (E3). In Columns 2-7, the omitted category is the control group of farmers. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. In Column 1, the dependent variable is a dummy that takes value 1 if the farmer reported remembering the sowing recommendations were given ti him or her as part of our intervention. This question was asked in August 2015 during our Follow-up survey. In Column 2, the dependent variable is a dummy that takes value 1 if the farmer kept record of the soil analysis given to him or her as part of our intervention. 30 farmers did not answer this question. In Column 3, the dependent variable is a dummy that takes value 1 if the farmer reported that he or she would probably follow the recommendations in the following season. Data for Columns 2 and 3 were collected as part of the Commercialization survey, conducted in June 2016. In Column 4, the dependent variable is a standardized index of two individual dummies that take value 1 if the farmers reported trusting the recommendations given by their input suppliers and IPAMPA, a local AES company. To compute the index, we standardize each dummy individually, add them all and standardize the sum. We use the mean and standard deviation of the control group as reference for the standardized index. The questions in the index in Column 4 were asked as part of our Follow-up survey conducted in August 2015. 32 farmers did not answer these questions. The dependent variable in Column 5 is the number of people each farmer reported to have worked in the plot registered to be part of our study, excluding harvesting activities. The data for Column 5 were collected as part of our Follow-up survey conducted in August 2015. In Column 6, the dependent variable is a standardized index of 5 questions from the Final Follow-up survey conducted in May 2017 that measured farmers' attitudes towards change. See Appendix Table A10 for the definition of variables. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 12: WTP for fertilizers

	(1) Reported WTP for YARA fertilizers (1=Yes)	(2) WTP for a bag of YARA fertilizer in 2017 (Mex$)	(3)	(4)
		Urea	DAP	KCl
Recommendation (1=Yes)	0.20***	70.43***	64.68**	53.28**
	(0.06)	(19.57)	(24.69)	(20.63)
Grant (1=Yes)	0.37***	111.07***	138.54***	110.00***
	(0.05)	(17.78)	(22.65)	(20.35)
Flexible (1=Yes)	0.04	14.17	25.02	46.15**
	(0.03)	(13.92)	(18.54)	(17.64)
Observations	540	540	540	540
R-squared	0.36	0.31	0.27	0.29
Mean dep. var. control (or T4)	0.33	100.38	121.73	98.46
SD dep. var. control (or T4)	0.47	151.12	185.92	157.18
T1: $\beta_R + \beta_G = 0$	0.00	0.00	0.00	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.00	0.00	0.00	0.00

Note: this table reports results willingness to pay for YARA fertilizers. Using the full sample of 540 farmers in our study, we report the point estimates of the following specification: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Final survey conducted in May 2017. In Column 1, the dependent variable is a dummy that takes value 1 if the farmer reported his or her willingnes to pay for any of the 3 YARA fertilizers (Urea, DAP and KCl). In Columns 2-4, the dependent variables are the self-reported willingness to pay for a bag of each of the 3 YARA fertilizers. We imput WTP equal to zero for those who did not report their WTPs. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Tables

Table A1: Comparing Study Sample to Mexican Farmers

	Mexico		Tlaxcala		Study Sample	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Panel A: All plots						
Plot is rain fed (1=Yes)	0.88	0.21	0.95	0.08	0.96	0.19
Plot owner uses inorganic fertilizers (1=Yes)	0.74	0.28	0.88	0.11	0.97	0.16
Plot owner uses organic fertilizers (1=Yes)	0.20	0.21	0.31	0.20	0.42	0.49
Plot owner uses hybrid seeds (1=Yes)	0.24	0.26	0.08	0.09	0.07	0.25
Plot owner uses herbicides (1=Yes)	0.35	0.30	0.38	0.31	0.72	0.45
Plot owner uses insecticides (1=Yes)	0.21	0.24	0.12	0.12	0.11	0.32
Plot owner has access to extension services (1=Yes)	0.03	0.06	0.01	0.01	0.10	0.31
Maize yields (ton/ha)	2.73	2.50	2.67	1.66	2.01	1.11
Panel B: Rain-fed plots						
Plot owner uses inorganic fertilizers (1=Yes)	0.75	0.30	0.96	0.08	0.97	0.16
Plot owner uses organic fertilizers (1=Yes)	0.18	0.23	0.13	0.13	0.42	0.49
Plot owner uses hybrid seeds (1=Yes)	0.11	0.19	0.06	0.06	0.06	0.24
Plot owner uses herbicides (1=Yes)	0.26	0.32	0.68	0.38	0.73	0.44
Plot owner uses insecticides (1=Yes)	0.12	0.21	0.13	0.15	0.11	0.31
Plot owner has access to extension services (1=Yes)	0.03	0.06	0.05	0.06	0.10	0.30

Note: This table compares the farmers in our sample to farmers Mexican state of Tlaxcala and to Mexican farmers overall. The data on the farmers in our study sample come from the Baseline survey conducted in February 2015, while data on the representative farmers of Tlaxcala and Mexico come from the INEGI Agricultural, Livestock and Forestry Census conducted in 2007. Panel A reports summary statistics of all plots in the data, while in Panel B we report the numbers for rain-fed plots only. In Columns 1 and 2, we report the average and SDs of the variables among all farmers in Mexico, while in Columns 3 and 4 we restrict the INEGI data to farmers in the state of Tlaxcala. In Columns 5 and 6 we report figures for farmers in our study sample of 540 farmers. When calculating yields using the INEGI data, we cannot distinguish between rain-fed and irrigated plots, so we do not report yields in Panel B.

Table A2: Sample attrition

	(1) Main sample	(2) Yield measured with harvester (1=Yes)
Recommendation of any type (1=Yes)	-0.00	-0.02
	(0.05)	(0.06)
Grant (1=Yes)	0.03	0.24***
	(0.05)	(0.05)
Flexible (1=Yes)	0.03	-0.06
	(0.04)	(0.05)
Observations	788	540
R-squared	0.12	0.12
Mean dep. var. control	0.67	0.63
SD dep. var. control	0.47	0.48
T1: $\beta_R + \beta_G = 0$	0.46	0.00
T2: $\beta_R + \beta_G + \beta_F = 0$	0.15	0.00

This table reports results on attrition in different samples of our study. For both columns, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. In Column 1, we use the sample of 981 farmers who expressed interest in participating in our study. The outcome is a dummy that takes value of 1 for farmers in our final study sample of 678 farmers. In Column 2, we use our study sample of 540 farmers and the outcome is a dummy that takes value 1 for farmers who got their yields measured by our own yield measurement machinery and protocols. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A3: Analysis of variation: soil characteristics and recommended nutrient dosages

	(1) $\frac{\sigma_\epsilon}{\sigma_\alpha+\sigma_\epsilon}$	(2) σ_ϵ	(3) σ_α
Panel A: Variation in Soil Quality			
Sand (%)	0.43	7.79	6.78
Clay (%)	0.34	4.48	3.24
Silt (%)	0.39	4.73	3.75
pH (1:2)	0.40	0.52	0.42
Nitrogen (N)	0.08	6.83	2.01
Phosphorus (P)	0.21	18.51	9.64
Potassium (K)	0.21	106.18	55.21
Panel B: Variation in recommended nutrient dosages			
Nitrogen (N)	0.08	15.57	4.72
Phosphorus (P)	0.19	11.59	5.65
Potassium (K)	0.22	14.90	7.92

Note: This table reports heterogeneity between and across Mexican localities in soil characteristics and recommended nutrient dosages for the study sample of 540 farmers. We run a standard analysis of variance (ANOVA) for each of the soil characteristics and we report estimates of variation within (σ_ϵ) and across localities (σ_α) in Columns 2 and 3, as well as the share of the total variation arising from between cluster variation in Column 1. Panel reports numbers for soil characteristics measured at baseline and in Panel B we report number for the recommended dosage of three of the main nutrients provided by inorganic fertilizers.

Table A4: Agricultural practices in 2014 and 2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	E1	E2	E3	Control		P-values	
	2014	2014	2014	2014	2015	(1)-(4)	(4) vs. (5)
Panel A: Existing practices							
Ploughing	0.56	0.59	0.56	0.49	0.56	0.35	0.23
	(0.50)	(0.49)	(0.50)	(0.50)	(0.50)		
Using inorganic fertilizer	0.98	0.96	0.98	0.98	0.97	0.59	0.45
	(0.15)	(0.20)	(0.15)	(0.12)	(0.17)		
Covering fertilizer	.	.	.	.	0.85	.	.
	(.)	(.)	(.)	(.)	(0.36)		
Panel B: New practices							
Ripping	0.15	0.13	0.07	0.05	0.05	0.03	0.77
	(0.36)	(0.33)	(0.25)	(0.23)	(0.21)		
Using hybrid seeds	0.05	0.09	0.08	0.04	0.05	0.24	0.75
	(0.22)	(0.29)	(0.28)	(0.19)	(0.21)		
Fertilizing at sowing	0.09	0.07	0.09	0.06	0.09	0.68	0.17
	(0.29)	(0.26)	(0.28)	(0.24)	(0.29)		
Sowing with precision machinery	0.13	0.11	0.12	0.11	0.10	0.99	0.81
	(0.33)	(0.32)	(0.33)	(0.31)	(0.30)		
Using high-quality fertilizers (YARA)	.	.	.	.	0.00	.	.
	(.)	(.)	(.)	(.)	(0.00)		
Using pre-emergent herbicide after sowing	.	.	.	.	0.02	.	.
	(.)	(.)	(.)	(.)	(0.15)		

Note: This table reports prevalence of existing and new agricultural practices for each treatment and control groups. Columns 1 to 4 report the percentage of farmers in each treatment and control groups that reported doing each of the existing and new practices in 2014. Column 5 reports the same percentage for farmers in the control group in 2015. SDs are in parentheses. In 2014, we did not collect data on 2 of the new practices. For each of the practices, we pool the 2014 data for the farmers in each group and regress a dummy that takes value of 1 if farmers reported doing the corresponding practice against a year dummy and a set of strata fixed effects. Column 6 reports the p-value of the joint F-test that the means in columns 1-4 are equal. Column 7 reports the p-value of the t-test that the means in columns 4 and 5 are equal. Data for 2014 practices come from the Baseline survey conducted in February 2015, while data on 2015 practices were collected in August 2015 in our Follow-up survey.

Table A5: Lab analysis of nutrient content of YARA and government fertilizers

	(1)	(2)	(3)	(4)	(5)
		Government		YARA	
	Label (%)	Lab test (%)	Cost per kg of nutrient (Mex$)	Lab test (%)	Cost per kg of nutrient (Mex$)
Panel A: Urea					
Nitrogen (N)	46	46.72	13.02	47.00	13.62
Phosphorus (P)	0	0.00	.	0.00	.
Potassium (K)	0	0.00	.	0.00	.
Cost of 50kg bag (Mex$)		304		320	
Panel B: DAP					
Nitrogen (N)	18	10.40	82.69	16.70	55.09
Phosphorus (P)	46	14.00	61.43	36.20	25.41
Potassium (K)	0	0.00	.	0.00	.
Cost of 50kg bag (Mex$)		430		460	
Panel C: KCl					
Nitrogen (N)	0	0.00	.	0.00	.
Phosphorus (P)	0	0.00	.	0.00	.
Potassium (K)	60	51.23	12.26	53.10	15.82
Cost of 50kg bag (Mex$)		314		420	

Notes: This table reports the nutrient content advertised by our partner YARA and the fertilizer brand subsidized by the Mexican government to actual nutrient content measured in a laboratory test. Using the price of a 50kg bag of each fertilizer, we also compare the average cost per kg of nutrient between YARA and the government-subsidized brand. Panel A reports the figures for Urea bags, while Panels B and report numbers for DAP and KCl bags. In column 1 we show the percentages of each nutrient (Nitrogen, Phosphorus and Potassium) reported on commercial labels of each bag. In columns 2 and 4 we report the percentages measured in the lab. In the last column of each panel we report the (average) price of each bag of fertilizer. We then divide the price of the bags by the nutrient percentages and report the cost per nutrient percentage in columns 3 and 5.

Table A6: Individual practices 2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Existing practices			New practices					
	Ploughing	Using inorganic fertilizer	Covering fertilizer	Ripping	Using hybrid seeds	Fertilizing at sowing	Sowing with precision machinery	Using high-quality fertilizer (YARA)	Using pre-emergent herbicide after sowing
Recommendation of any type (1=Yes)	0.03	0.00	0.01	0.02	0.05*	0.08**	0.08*	0.10***	0.01
	(0.06)	(0.02)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.02)
Grant (1=Yes)	-0.03	0.02*	0.05	0.05	-0.02	0.69***	0.66***	0.81***	0.04
	(0.06)	(0.01)	(0.04)	(0.03)	(0.03)	(0.04)	(0.05)	(0.04)	(0.03)
Flexible (1=Yes)	-0.04	0.00	0.03	-0.00	0.02	-0.10**	-0.11**	0.06*	0.04
	(0.06)	(0.00)	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.03)	(0.03)
Observations	540	540	540	540	540	540	540	540	540
R-squared	0.09	0.06	0.07	0.21	0.11	0.53	0.47	0.81	0.09
Mean dep. var. control	0.56	0.97	0.85	0.05	0.05	0.09	0.10	0.00	0.02
SD dep. var. control	0.50	0.17	0.36	0.21	0.21	0.29	0.30	0.00	0.15
T1: $\beta_R + \beta_I + \beta_G = 0$	0.92	0.08	0.12	0.04	0.24	0.00	0.00	0.00	0.04
T2: $\beta_R + \beta_G + \beta_F = 0$	0.42	0.07	0.02	0.04	0.08	0.00	0.00	0.00	0.00

Note: this table reports results on the agricultural practices performed by the farmers in our study in the 2015 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Follow-up survey conducted in August 2015. The dependent variable in each column is a dummy that takes value of 1 if farmers reported performing each practice. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A7: Measured yields 2015

	(1) Measured yields (t/ha)	(2) Self-reported yields (t/ha) (Measurement sample)
Recommendation (1=Yes)	0.37*	0.35
	(0.20)	(0.22)
Grant (1=Yes)	-0.12	-0.12
	(0.21)	(0.21)
Flexible (1=Yes)	0.17	0.09
	(0.18)	(0.18)
Observations	392	392
R-squared	0.29	0.26
Mean dep. var. control	2.41	2.30
SD dep. var. control	1.30	1.41
T1: $\beta_R + \beta_G = 0$	0.18	0.22
T2: $\beta_R + \beta_G + \beta_F = 0$	0.02	0.09

Note: this table reports results on the maize yields in the 2015 season, measured by our team. Using only the sample of 392 for which we measured yields using our own machinery, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. In column 1, the outcomes are 2015 yields measured by our team. The yield measurement was only done for a subsample of the farmers in our study. In column 2, the outcome is 2015 self-reported yields, restricting the sample to the set of farmers who had their yields measured by our team. For self-reported yields, we use data from the Commercialization survey conducted in June 2016, while the data on measured yields by our team was collected in February 2016. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A8: Drought throughout the years

	(1)	(2)	(3)	(4)	(5)	(6)
	2014		2015		2016	
	Mean	p-value	Mean	p-value	Mean	p-value
Precipitation at initial stage (mm)	77.51	0.65	78.69	0.92	65.19	0.13
	(38.55)		(36.04)		(40.27)	
Total precipitation (mm)	698.64	0.65	600.29	0.45	659.15	0.67
	(118.99)		(75.31)		(55.49)	
Suffered drought (1=Yes)	.	0.67	0.72	0.29	0.31	0.64
	(.)		(0.45)		(0.46)	

Note: this table shows precipitation measures and drought reports by farmers during the time of our study. For the 2014, 2015 and 2016 seasons, we report the average precipitation (in mm) during the 30 days following sowing and average precipitation (in mm) faced by each farmer during the whole season. For each farmer, the precipitation figures are measured by the closest station to the registered plot. Data is provided by CONAGUA. For the 2015 and 2016, we also report the share of farmers who reported facing a drought at some point in the season. Data for these reports come from the Baseline and Commercialization surveys. Columns 1, 3 and 5 show means and standard deviations of each variable for the 2014, 2015 and 2016 seasons, respectively, for our full sample. For each season, we take each variable and regress it against the set of treatment dummies. In columns 2, 4 and 6, we report the p-values of the F-tests that the dummy coefficients are all equal.

Table A9: Individual practices 2017

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Existing practices			New practices					
	Ploughing	Using inorganic fertilizer	Covering fertilizer	Ripping	Using hybrid seeds	Fertilizing at sowing	Sowing with precision machinery	Using high-quality fertilizer (YARA)	Using pre-emergent herbicide after sowing
Recommendation of any type (1=Yes)	0.05	0.03	0.03	0.02	0.02	0.07**	0.02	0.05	0.03
	(0.06)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)
Grant (1=Yes)	-0.16**	-0.03	-0.02	0.04	0.00	-0.00	-0.05	0.05	0.04
	(0.06)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.05)	(0.03)
Flexible (1=Yes)	0.03	0.01	0.01	0.02	0.07*	0.06	0.10**	0.17**	0.04
	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)
Observations	540	540	540	540	540	540	540	540	540
R-squared	0.12	0.06	0.05	0.08	0.13	0.20	0.22	0.12	0.09
Mean dep. var. control	0.52	0.91	0.88	0.07	0.06	0.06	0.12	0.07	0.04
SD dep. var. control	0.50	0.29	0.32	0.25	0.24	0.24	0.32	0.25	0.19
T1: $\beta_R + \beta_I + \beta_G = 0$	0.09	0.91	0.79	0.08	0.53	0.05	0.37	0.02	0.02
T2: $\beta_R + \beta_G + \beta_F = 0$	0.22	0.95	0.51	0.03	0.01	0.00	0.08	0.00	0.00

Note: this table reports results on the agricultural practices performed by the farmers in our study in the 2017 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Final survey conducted in May 2017. The dependent variable in each column is a dummy that takes value of 1 if farmers reported performing each practice. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A10: Definition of variables

Variable	Definition
Panel A: Farmers characteristics	
Annual income in 2014 (000s pesos)	Total income earned by farmer in 2014, including, but restricted to, sales from agricultural activities, labor earning in agricultural and non-agricultural activities, sales of animals, remmitances, pensions and cash transfers. Collected using our Baseline survey conducted in February 2015.
Reported liquidity constraints (1=Yes)	Dummy that takes value 1 if farmer reported above-average amount when asked the following question: "How much money per hectare were you missing in order to sow the way you would have wanted?". Collected using our Baseline survey conducted in February 2015.
Ever applied for a loan (1=Yes)	Dummy that takes value 1 if farmer answered "Yes" to the following question: "Have you ever, in your entire life, applied for credit or a loan for matters related to agriculture?". Collected using our Baseline survey conducted in February 2015.
Never takes risks (1=Yes)	Dummy that takes value of 1 if farmer selected the first option when asked the question "Do you consider yourself a risk taker? You would say:" and given the following options: "1. Does not like taking risks", "2. Almost never take risks", "3. Sometimes yes, sometimes no", "4. Almost always takes risks", "5. Always likes to take risks". Collected using our Baseline survey conducted in February 2015.
Panel B: 2014 Practices & Yields	
Number of plots cultivated	Number of plots farmers reported working on as owner or tenant in 2014. Collected using our Baseline survey conducted in February 2015.
Total area cultivated (ha)	Number of hectares farmers reported working on as owner or tenant in 2014. Collected using our Baseline survey conducted in February 2015.
Supported by a government program in 2014 (1=Yes)	Dummy that takes value of 1 if farmers reported being supported by any of the following input subsidy programs in 2014: PROCAMPO, PIMAF, MASAGRO or Agroincentivos. Collected using our Baseline survey conducted in February 2015.
Panel C: Grant flexibility outcomes	
Trust in the recommendation from input supplying institutions (standardized index)	Standardized index of two individual dummies that take value 1 if the farmers reported trusting the recommendations given by their input suppliers and IPAMPA, a local AES company. Computed by standardizing each dummy individually, adding them all and standardizing the sum. We use the mean and standard deviation of the control group as reference for the standardized index. Collected in August 2015 using our Follow-up survey. 40 among our sample of 678 farmers fesued to answer these questions.
Attitudes towards change (standardized index)	Standardized count of affirmative answers to 3 questions and the answer given to other 2 on a frequency scale described in Appendix C (non-cognitive measures) of Laajaj and Macours (2017). The 3 first questions are: "When you learn about a new farming technique, compared to most of your neighbours, you: are more willing to try it first" (vs. "[...], you: let others try it first"); "In your plots you prefer: doing something new" (vs. "[...] you prefer: routine things"); and "Generally you prefer: changing things" (vs. "[...] leaving things the way they are"). The last 2 questions are: "You often go to the plots of fellow farmers to observe what they do" and "You have tried to experiment on your own plot some of the techniques learned from fellow farmers". Answers to these 2 last questions were given on the following scale: "1. Always", "2. Almost always", "3. Sometimes". "4. Almost never" and "5. Never". To get a standardized index, we subtract from each variable the control mean and divides by the control standard deviation, then sums the standardized variables and standardizes again with the mean and the standard deviation of the sum among controls. We use data from the Final survey conducted in May 2017.
Panel D: Expectation of soil quality	
Quality (0-10)	Answer given by farmers to the following question: "In a scale from 1 to 10, where 10 is the most productive plot in the town and 0 is the least productive plot of the town. How productive do you think your plot is?". Asked before and after enumerators read the soil analysis report to the farmers in the treatment group. Collected using our Baseline survey conducted in February 2015.
Very sure? (1=Yes)	Dummy that takes value 1 if farmers answered "Absolutely sure" to the following question: "Now I want you to think about the response to the previous question where you graded your plot with a [Quality (0-10)] for its productivity. How sure are you about this grade?". The options given to farmers were "Absolutely sure", "Quite sure", "A bit sure", "Not sure at all". Collected using our Baseline survey conducted in February 2015.

Online Appendix for Appropriate Technology Use and Autonomy: Evidence From Mexico

by Carolina Corral, Xavier Giné, Aprajit Mahajan, and Enrique Seira

FOR ONLINE PUBLICATION

Online Appendix A Profits 2015

Measuring profits is notably challenging for smallholder farmers (see e.g. Foster and Rosenzweig, 2010). We measured revenues and expenditures on a comprehensive set of agricultural inputs using frequent, detailed surveys throughout the growing season.[39] To calculate revenues we multiplied the price received in the sale of maize by the self-reported quantity harvested.[40] Revenues are reported in column 2 of Table 9 and not surprisingly, show a similar pattern to that for yields in column 1. Expenditures are reported in column 3. For each stage of the growing season (soil preparation, sowing, plant maintenance, and harvesting) we measured labor days in the one hectare subplot, whether it was provided by a family member or hired-in labor, and the wage paid for hired labor. We also measured other inputs, including seeds, fertilizers, sowing machinery, pesticides, herbicides, and harvest machinery and whether the cost was paid by the farmer or by the research team (i.e. we include the $2,000$ in-kind grant in the costs and impute harvesting costs if they were paid by the research team).[41] Column 3 shows that grant recipients in $E1$ invested 639 more pesos/ha than farmers in $E3$ or the control group, who spent on average $5,280$ pesos/ha. Column 4 reports profits as the difference between revenues and costs. Although all the point estimates are positive and suggest profit increases in the range of 10% ($E2$), 12% ($E1$), and 23% ($E3$), they are imprecisely estimated and none of the estimates are significant at conventional levels. In column 5, we remove the amount of subsidy and har-

[39] Enumerators from each of the seven teams lived less than a thirty minute drive from their assigned study plots. Plots were visited several times by the team during the year. We note, however, that unpaid labor is however not taken into account in our calculations because of the difficulty in imputing a shadow wage.

[40] Only about 70% of farmers sold maize, and we imputed the price of maize for the remaining farmers using the median price in their cluster.

[41] Table OA1 disaggregates expenditures into different categories.

vesting costs paid by the program from the costs to consider only the out-of-pocket investment made by each farmer. We find, unsurprisingly, an increase in profits in the range of 1,300 pesos/ha among farmers with the grant (*E*1 and *E*2) relative to control farmers as well as farmers in *E*3.

Table OA1: Cost disaggregation 2015

	(1)	(2)	(3)	(4)	(5)	(6)
	Labor costs		Capital costs		Input costs	
	Mex$	% total	Mex$	% total	Mex$	% total
Recommendation of any type (1=Yes)	-49.95	-0.01	35.11	0.00	39.43	0.02
	(215.59)	(0.02)	(82.23)	(0.02)	(128.93)	(0.02)
Grant (1=Yes)	-111.07	-0.08***	546.73***	0.08***	233.31**	-0.00
	(224.56)	(0.02)	(79.35)	(0.02)	(115.39)	(0.02)
Flexible (1=Yes)	317.13	0.03	-141.70*	-0.04**	138.40	0.01
	(224.25)	(0.02)	(72.81)	(0.01)	(94.86)	(0.01)
Observations	540	540	540	540	540	540
R-squared	0.11	0.11	0.27	0.14	0.15	0.08
Mean dep. var. control	2458.88	0.44	903.86	0.18	1917.28	0.37
SD dep. var. control	1788.69	0.19	713.63	0.15	1070.96	0.16
T1: $\beta_R + \beta_G = 0$	0.45	0.00	0.00	0.00	0.01	0.46
T2: $\beta_R + \beta_G + \beta_F = 0$	0.48	0.00	0.00	0.00	0.00	0.19

Note: This table reported results on profits earned by farmers in the 2015 season, breaking them down by cost and revenue components. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_R Recomm_i + \beta_G Grant_i + \beta_F Flexible_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Commercialization survey conducted in June 2016. In Column 1, the dependent variable is the sum of all labor expenses incurred by farmers in the 2015 season. In Column 2, the dependent variable reports the labor costs as a share of the total cost paid by farmers in the 2015 season. In Columns 3 and 4, we report analogous dependent variables for capital costs. In Columns 5 and 6, the dependent variables are the input costs, such as, but not restricted to, expenses on fertilizers, herbicides, and seeds. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Online Appendix B Soil Analyses and Recommendations

Soil samples were collected from the designated sub-plot during February and March 2015. Surveyors divided up the sub-plot into (up to) 6 relatively homogeneous regions and took 15 soil samples (from a depth of 30 cm). These 15 samples were then mixed and collected in bags following standard soil analysis protocols. These bags were then sent to Fertilab for analysis.[42] Based on focus group discussions conducted in December 2014 we developed a template for reporting the soil analysis and recommendations divided into three parts:

[42] Fertilab is one of the best known laboratories in Mexico and is accredited by the North American Proficiency Testing Program (run by the Soil Sciences Society of America) that certifies laboratory operations in the United States and elsewhere.

OA B.1 Soil Analysis

The soil analysis provided the main soil characteristics in a relatively easy to read format for farmers. The soil analysis measured a range of factors that measured the soil texture (percentage of sand, silt and clay) its ability of retain and transfer nutrients (pH levels, sand and lime concentrations, saturation points and cationic exchange capacity) as well as the levels of 13 key nutrients – the primary macro-nutrients (N, P, K), the secondary macro-nutrients (Ca, Mg, S) and selected micronutrients (Na, Fe, Zn, Mn, Cu, B, Al) – and the level of organic matter in the soil.

Nitrogen (N) affects plant growth. Many spoil microorganisms found in the soil are able to convert organic N found in plant residue, soil organic matter, or bacteria into inorganic N forms that can be taken up by plans. plant available inorganic Ammonium (NH_4^+) and nitrate (NO_3^-) are such forms of mineral or inorganic N. Nitrate NO_3^- is water soluble and does not remain in the soil.

Phosphorous (P) is critical in root development, crop maturity and seed production. P deficiency is a common problem causing crop stunting or discoloration in the field. One of the major contributing sources of P for crops comes from soil organic matter.

Potassium (K) is required for the activation of enzymes throughout. It is critical for the crop's ability to withstand extreme cold and hot temperatures, drought and pests. Potassium increases water use efficiency and transforms sugars to starch in the grain-filling process.

Calcium (Ca), magnesium (Mg), and sulfur (S), are considered secondary macronutrients, because they are required in amounts smaller than those typically needed for N, P, or K. These elements, however, are equally important for plant growth and nutrition.

Micronutrients are essential nutrients for plant growth that are used in relatively small amounts by crops. Boron (B), zinc (Zn), manganese (Mn), iron (Fe) and copper (Cu) will only make up a small proportion of a plant; however, a deficiency in any of these elements has the potential to cause a decrease in crop quality or yield.

OA B.2 Heterogeneity

We assess the heterogeneity in soil characteristics and input recommendations (described below) by running a standard analysis of variance (ANOVA) in Appendix Table A3. In particular, for registered subplot i in cluster c: $Y_{ic} = \mu + \alpha_c + \epsilon_{ic}$ and we report estimates of variation within (σ_ϵ) and across clusters (σ_α) and the share of the total variation arising from between cluster variation $\frac{\sigma_\alpha^2}{\sigma_\alpha^2+\sigma_\epsilon^2}$. We find substantial variation in the soil characteristics (panel A) and nutrient recommendations (panel B) both within and across clusters although most of the variation appears to be within clusters.[43]

These results are consistent with Figure OA1 which displays the level of N, P and K in the registered plots for the four different agro-climatic areas of the study along with the target level of nutrients required to achieve 4.5 mt/ha according to the Fertilab model. The figure shows that even across different agro-climatic zones, the variation in nutrient content within each zone is much higher than across zones. In addition, Panel (a) of Figure OA1 shows a deficit of N relative to the target level of N (red line) which is unsurprising because N is either absorbed by the plant, is lost to the atmosphere or lost via leaching or de-nitrification. Since soil analyses were taken right before sowing for the 2015 season, the N content in the soil should be relatively low. Panel (b) shows a soil level of P that is close to the target level and even higher in some plots, and therefore the recommendations call for relatively low amounts of the P rich fertilizer DAP. Finally, Panel (c) shows a significant deficit of K in the soil and thus the recommendations call for an increase of K fertilizer KCl.

In the following subsection we discuss the stability over time of the soil analyses.

OA B.3 Stability of soil characteristics

In February, 2017 we visited a randomly chosen set of 99 control plots and re-did the soil analysis to measure the stability of the nutrient content in the soil. Table OA2 in this online appendix shows that there are large and precise correlations across years, particularly for

[43] Heterogeneity in soil quality has received considerable attention. See, for example, Goyal and Nash, 2017; Jayne and Rashid, 2013.

macronutrient, so that the information from the 2015 soil analysis remained relevant in 2017.[44]

Table OA2: Soil Analysis comparison 2017 vs. 2015

$Y_{2017} = \alpha + \beta Y_{2015} + \epsilon$			
Soil characteristic	α	β	R^2
pH	2.71***	0.63***	0.51
	0.41	0.07	
Organic Matter (OM)	0.10	0.89***	0.60
	0.06	0.08	
Nitrogen (N)	3.49**	0.31**	0.22
	1.59	0.12	
Phosphorus (P)	6.84***	0.70***	0.82
	1.48	0.04	
Potassium (K)	64.99**	0.76***	0.52
	30.15	0.19	
Calcium (Ca)	1,447.66***	0.10	0.01
	155.75	0.09	
Magnesium (Mg)	37.84**	0.97***	0.36
	17.65	0.13	
Sodium (Na)	8.90***	0.44***	0.27
	1.94	0.12	
Iron (Fe)	7.27***	0.52***	0.64
	1.39	0.05	
Zinc (Zn)	0.10	0.64***	0.90
	0.06	0.11	
Manganese (Mn)	3.09**	0.26***	0.18
	1.13	0.07	
Copper (Cu)	0.17***	0.62***	0.93
	0.02	0.01	
Boron (B)	1.06***	0.19**	0.09
	0.01	0.07	

n = 99.
do-file: APPENDIX_SA_2015vs2017.do. Datasets: Soil analysis (2015 and 2017).

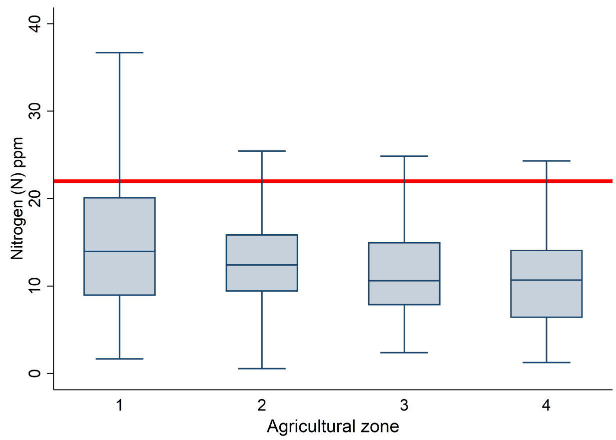
OA B.4 Recommendations

Figures OA3–OA7 provide a sample of the report. The first page explained the program and required a signature from the farmer for consent. The second page provided basic information about the plot's physical characteristics (e.g. texture, saturation, organic matter, pH level and bulk density). It also provided the nutrient levels in the plot (e.g. N, P, K and secondary macronutrients and micronutrients) as well as the required levels of nutrients for a maize yield of 4.5 mt/ha under normal weather conditions. Recommendations were based on a proprietary

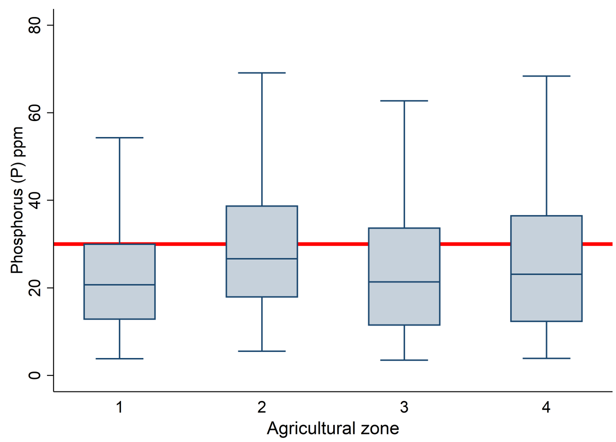
[44] Due to this persistence in the characteristics of the soil content, the USDA recommends that soil tests be carried out every 3-5 years (see e.g. `https://perma.cc/E8GN-GWGM`).

model that assumed that a certain quantity of N, P, K and micronutrients were needed to reach a target yield per hectare. The model is grounded in the Law of the Minimum formulated by J.V. Liebig in the 1850s which suggests that to reach a target yield, a certain quantity of each nutrient is needed (similar to a Leontief production function). The Fertilab model used this as well as a cost minimization approach given the price of available fertilizers. For example, for N one can use urea, DAP or ammonium sulfate. Taking into account the cost of the different fertilizers and the soil absorption capacity, the model selected the cheapest fertilizer package that met the nutrient requirements. For instance, if the soil were pH negative (alkaline), then ammonium sulfate was preferred to urea, but if the soil were pH positive (acidic) then urea was preferred. There are other maize yield models such as CERES and NLEAP but many of the variables and parameters required by these models are unknown for Tlaxcala (and Mexico in general). Empirical tests of the appropriateness of the Von-Leibig type production function in agriculture typically reject it (see e.g. Berck et al., 2000).

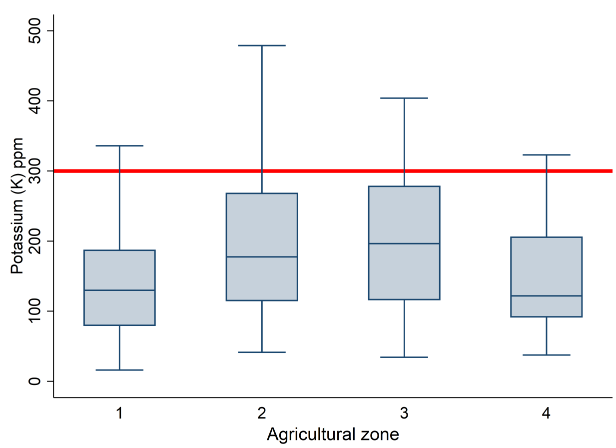
The third page provided a "shopping list", that is, the list of recommended fertilizer amounts (DAP, urea, KCl and micronutrients) and its cost at our partner agro-dealer. Costs were divided into the portion paid by the research team and the remainder which the farmer was expected to provide. The fourth and fifth pages compared the farmer's own 2014 input use and costs (from the baseline survey) to the recommended input mix and costs. They also provided sub-plot yields and prices from 2014. These 2014 costs and revenues were compared with the expected yields, revenues (using 2014 prices) and costs of inputs if the recommendations were followed and Fertilab's assumptions (about weather and temperature) proved accurate – the research teams were careful to explain the assumptions underlying the yield predictions.



(a) Nitrogen (N)



(b) Phosphorus (P)



(c) Potassium (K)

Figure OA1: Soil nutrients and target amounts

Note: this figures displays boxplots with distributions of different soil macronutrients across the 4 agricultural zones of Tlaxcala in our study. We use data from the soil analysis of farmers in our study sample. Sub-figures (a), (b) and (c) report data on Nitrogen, Phosphorus and Potassium. In each of the subfigures, we also report the average amounts of nutrients that farmers needed in their plots to reach the 4.5 ton/ha goal associated with our fertilizer recommendations. All values are reported in part-per-million (ppm) units.

Fertilab®
Fertilidad de Suelos S. de R.L.

Análisis que **Rinden Frutos**

DIAGNOSTICO DE LA FERTILIDAD DEL SUELO

INFORMACIÓN GENERAL

Cliente	Ismael Zacamolpa Cerbani		
No. de Registro	SU-35440	Cultivo Anterior	Ninguno
Fecha de Recepción	09/03/2015	Cultivo a Establecer	Maiz
Fecha de Entrega	11/03/2015	Tipo de Abono Organico	N/A
Rancho o Empresa	Cuaxomulco	Tipo de Agricultura	Temporal
Municipio	Cuaxomulco	Manejo de Residuos	Retirados
Estado	Tlaxcala	Meta de Rendimiento	5 Ton/Ha Ton/Ha
Identificación	.23.01.10.01	Prof. Muestra	0-30 cm

Propiedades Físicas del Suelo

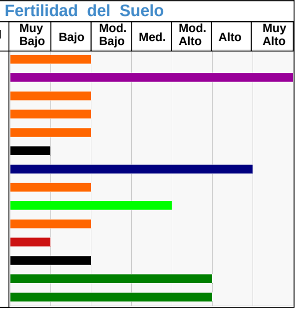
Clase Textural	Franco Arcillo Arenoso		
Punto de Saturación	31.6	%	Mediano
Capacidad de Campo	16.7	%	Mediano
Punto March. Perm.	9.94	%	Mediano
Cond. Hidráulica	6.00	cm/hr	Mod. Alto
Dens. Aparente	1.35	g/cm3	

Reacción del Suelo Necesidades de Yeso y Cal Agrícola

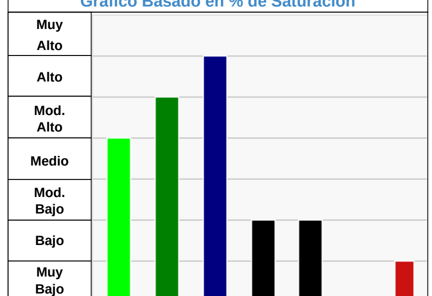
pH (1.2 agua)	5.12		Acido
pH Buffer	6.90		
Carbonatos Totales (%)	0.01	%	Libre
Salinidad (CE Extracto)	0.30	ds/m	Muy Bajo
Requerimientos de Yeso	No Requiere		
Requerimientos de Cal	0.00		

Fertilidad del Suelo

Det	Result	Unid
MO	1.11	%
P-Bray	61.2	ppm
K	121	ppm
Ca	633	ppm
Mg	90.0	ppm
Na *	19.5	ppm
Fe	34.3	ppm
Zn	0.42	ppm
Mn	7.70	ppm
Cu	0.45	ppm
B	0.13	ppm
Al *	12.2	ppm
S	13.8	ppm
N-NO3	22.7	ppm



Cationes Intercambiables
Gráfico Basado en % de Saturación



% Sat	71.3	16.7	7.00	1.81	3.16	ND	—
meq/100g	3.16	0.74	0.31	0.08	0.14	0.00	4.43
Catión	Ca	Mg	K	Na*	Al*	H*	CIC

Relacion Entre Cationes (Basadas en me/100g)

Relación	Ca/K	Mg/K	Ca+Mg/K	Ca/Mg
Resultados	10.2	2.39	12.6	4.27
Interpretación	Mediano	Mediano	Bajo	Mediano

* Es deseable que estos elementos tengan un bajo contenido

Interpretación Resumida del Diagnostico de la Fertilidad del Suelo

Suelo con pH acido. Suelo de textura media. Libre de carbonatos. Libre de sales. Bajo nivel de materia organica, es recomendable su aportacion. Bajo nivel de calcio. Muy alto suministro de fosforo disponible.Contenido bajo de potasio. Bajo nivel de magnesio. Suministro moderado en nitratos.

En cuanto a la disponibilidad de micronutrientes: Pobre en zinc. Bajo contenido de cobre. Muy pobre en boro.

Poniente 6. No. 200 Ciudad industrial
Celaya, Gto. C.P. 38010
Tel. (461) 614 5238, 614 7951
www.fertilab.com.mx

Supervisor de Análisis de Suelos
Ing. José Trinidad Guzmán M.

Figure OA2: Fertilab Original Soil Analysis

ID. .XX.XX.XX.

Estimado/a Señor/a **[NAME OF THE FARMER]**, de **[NAME OF THE LOCALITY]**

La Asociación Civil Qué Funciona para el Desarrollo (QFD) le informa de que usted ha salido beneficiado con el siguiente apoyo para utilizar en la hectárea delimitada en su parcela **[NAME OF THE PLOT]**

- **Vale de $ 1200 pesos para la compra de fertilizante formulado de acuerdo al estado nutricional de su parcela y requerimientos de su cultivo**
- **Ayuda para la renta de maquinaria de precisión para fertilizar a la siembra por valor $ 800 pesos**
- **Asistencia técnica por parte de un ingeniero agrónomo**

El día **[date]** a las **[time]** en **[place]** tendrá lugar la reunión en la que:

- Usted conocerá al ingeniero agrónomo que le dará asistencia técnica: **ING. [NAME OF THE ENGINEER]** cuyo número de teléfono es **[PHONE NUMBER]**. Si no puede acudir a la reunión por favor póngase en contacto con él/ella para re-agendar.
- Se le entregará el vale por valor de $1,200 pesos
- Se le indicará la fecha en la que usted tiene que recoger su paquete de fertilización en la dirección indicada más abajo
- Se le explicará cómo funciona la maquinaria de precisión y cómo se calibra la maquinaria
- Se le indicará **cuál será su fecha de siembra en la hectárea delimitada usando la maquinaria de precisión**

La dirección a la que tiene usted que pasar a recoger su fertilizante es: **[ADDRESS]** (VER MAPA IMPRESO EN EL REVERSO DE ESTA HOJA) RECUERDE: Tiene que presentar su vale y su IFE para que puedan entregarle sus paquetes.

Además, es MUY IMPORTANTE que usted:

a. **Siembre en la fecha que ingeniero agrónomo le indique ya que iremos con maquinaria para que le ayude a sembrar mejor. RECUERDE:** ***Las recomendaciones que le hicimos no son válidas si no se siembra con maquinaria de precisión.***

b. **Use los fertilizantes adquiridos con nuestro vale únicamente en la hectárea delimitada por nuestro equipo.**

Si tiene usted dudas no dude en contactarnos en nuestras oficinas del centro de Tlaxcala:

[CONTACT INFORMATION]

Conforme usted entiende y acepta lo expuesto en la presente carta le pedimos que la firme en el lugar indicado.

Atte el equipo de Qué Funciona para el Desarrollo A. C.

Firma del productor ____________________ Nombre ______________________Fecha____/____/____

Firma ingeniero QFD____________________ Nombre _______________________ Fecha____/____/___

Figure OA3: Recommendation letters (page 1)

ID. .23.01.09.

RECOMENDACIÓN PARA FEDERICO SERRANO HERNANDEZ

CUAXOMULCO, CUAXOMULCO

Municipio:	CUAXOMULCO
Localidad:	CUAXOMULCO
Parcela:	CUAXILCA
Análisis de suelo:	35455

1. *Diagnóstico de su PARCELA* CUAXILCA

El laboratorio Fertilab, especialista en suelos analizó la muestra de su parcela y encontró que existen los siguientes niveles de nutrientes:

Propiedades Físicas del Suelo		Reacción del Suelo		
Clase Textural:	Franco Arcillo Arenoso	pH (1:2 agua):	6,69	Neutro
Densidad Aparente	1,1 g/cm3	Materia Orgánica:	0,56	
Punto de Saturación:	30 %	Carbonatos Totales	0,01%	
Cond. Hidráulica:	6,7 cm/hr			

Elementos en el suelo	Ideal para 4.5ton/ha	Cantidad en su parcela (ppm)	
Nitrógeno	**71**	5,44	✗
Fósforo	**30**	4,86	✗
Potasio	**300**	246	✗
Magnesio	**200**	423	✓
Hierro	**9**	10,2	✓
Zinc	**1.2**	0,46	✗
Manganeso	**4**	10,2	✓
Cobre	**.5**	0,99	✓
Boro	**.8**	0,02	✗

ppm = partes por millón

Figure OA4: Recommendation letters (page 2)

ID. .XX.XX.XX.

HOJA DE PEDIDO

Dado que le vamos a subsidiar con $ 1200 pesos para la compra de fertilizantes para la siembra **usted sólo tendrá que pagar la diferencia en caso de que el paquete de fertilización sea más costoso de $1200 pesos. Si su paquete fuese más barato de $1200 pesos usaremos la diferencia del dinero para pagar parte de su paquete para fertilizar a los 30-35 días (primera fertilización) hasta completar los 1200 pesos entre los dos paquetes.**

¿Renta de maquinaria para la siembra? ☐ SÍ ☐ NO

PAQUETE SIEMBRA

	Dosis de fertilizantes en kg/ha				
Fertilizante	Marca Producto	**Total solicitado**	**Costo unitario**	**Costo total**	**A pagar por QFD**
Sembradora de precisión	YARA	X	X pesos	**X**	**X**
Urea (Blanco)	YARA	X	X pesos	**X**	**X**
DAP (Negro)	YARA	X	X pesos	**X**	**X**
Cloruro de Potasio (Rojo)	YARA	X	X pesos	**X**	**X**
Microelementos	AGROQUÍMICA	X	X pesos	**X**	**X**
Gastos total en fertilizantes por hectárea (aproximado)			**X pesos**		
Gastos total por hectárea Siembra (siembra aprox SUMANDO LOS HERBIDAS SELLADORES Y MAQUINARIA)			**X pesos**		

Remanente **A LA SIEMBRA de los 2000 pesos**: **X** pesos, si es negativo lo tienen que pagar el día que van a buscar el paquete SIEMBRA a YARA HUAMANTLA.

PAQUETE PRIMERA FERTILIZACIÓN DESPUÉS DE LA SIEMBRA (30-35 días)

	Dosis de fertilizantes en kg/ha				
Fertilizante	Marca Producto	**Total solicitado**	**Costo unitario (por kg)**	**Costo total**	**A pagar por QFD**
Urea (Blanco)	YARA	**X**	X pesos	**X pesos**	
Cloruro de Potasio (Rojo)	YARA	X	X pesos	**X pesos**	
Gastos total en fertilizantes por hectárea (aproximado)			**X pesos**		

Remanente a pagar por el productor **A LA PRIMERA FERTILIZACIÓN X** pesos, si es negativo lo tienen que pagar el día que van a buscar el paquete FERTILIZACIÓN 30 DÍAS a YARA HUAMANTLA.

Figure OA5: Recommendation letters (page 3)

ID. .XX.XX.XX.

2. Estimación de su Producción, Ingreso, y Costos del año pasado

De acuerdo a los datos que nos dio hace unas semanas, hicimos las cuentas y estimamos que usted produjo aproximadamente **X** pesos en maíz por hectárea (con un precio de **X** pesos por tonelada), y tuvo un gasto aproximado de **X** $/ha en fertilizantes y otros insumos, por lo que le quedaron **X** $/ha después de pagar por todos los insumos que utilizó.

Valor de Producción por hectárea

Producción 2014	X tn por ha
Precio de Venta promedio	X$ por tn
Valor total de la producción = 4 **x 2762,45**$	**X $ por ha**

Costos de Producción por hectárea

1. Gastos en fertilizantes Químicos	**X$ por ha**
2. Gastos en otros insumos y actividades	**X$ por ha**
Semillas	X$ por ha
Sembradora	X$ por ha
Costo de la producción (sin contar mano de obra)	**X$ por ha**

Esta tabla contiene información sobre el dinero que gastó, así como las cantidades de cada uno de los fertilizantes que utilizó en ciclo P-V 2014.

Dosis de fertilizantes en kg/ha:	MOMENTO DE APLICACIÓN				
	Siembra Kg aplicados por ha	**1ª fertilización** Kg aplicados por ha	**2ª fertilización** Kg aplicados por ha	**3ª fertilización** Kg aplicados por ha	**Total** Kg aplicados por ha
Urea (Blanco)	***X***	***X***	***X***	***X***	***X***
DAP (Negro)	***150***	***X***	***X***	***X***	***X***
Cloruro de Potasio	***X***	***X***	***X***	***X***	***X***
Sulfato de amonio	***X***	***X***	***X***	***X***	***X***
Microelementos	***X***	***X***	***X***	***X***	***X***
Costo por aplicación	***X***	***X***	***X***	***X***	***X***

[1]

[1] Los costos totales fueron calculados en base a los precios que nos proporcionó cuando realizamos las muestras de análisis de suelo

Figure OA6: Recommendation letters (page 4)

ID. .XX.XX.XX.

3. Paquete de fertilización con productividad mayor según los análisis de suelo de su parcela

Según el análisis de suelo de su parcela, Ud. podría alcanzar una productividad de **4.5 toneladas** en su parcela de prueba si en 2015 sigue los siguientes pasos:

1. Fertilizar a la siembra y a los 30 días después de la siembra con un paquete de fertilizantes diversificado.
2. Sembrar 20 kilogramos de semillas criollas o 60,000 de semillas híbridas por hectárea, utilizando una sembradora de precisión para asegurar que las semillas no compiten entre ellas por nutrientes, y que los fertilizantes no quemen sus semillas.
3. Aplicar un herbicida sellador a los 2 días de la siembra y volver a aplicar un herbicida a los 40 días de siembra para que sus plantas no compitan por nutrientes con malezas.

Le proponemos **diversificar el uso de fertilizantes** como se explica abajo para llegar a una productividad de hasta 4.5 toneladas por un costo total de **$X**

Dosis de fertilizantes en kg/ha [2]	MOMENTO DE APLICACIÓN		
	Siembra Kg aplicados por ha	**1era fertilización** Kg aplicados por ha	**Kg totales**
Urea (Blanco)	X	X	X
DAP (Negro)	X	X	X
Cloruro de Potasio	X	X	X
Minab R	X	X	X
Costo por aplicación	**$X**	**$X**	**$X**

PRODUCCION MAXIMA ESPERADA[3]	**4.5 tn por ha**
Precio de Venta promedio	X$ por ton
Valor de la producción	**X$ por ha**
1. Gastos en fertilizantes	**X$ por ha**
2. Gastos en otros insumos y actividades	**X $ por ha****
Semillas (20 kg por ha)	0 $ por ha
Sembradora	X $ por ha
Herbicida sellador (2 días después de la siembra)	X $ por ha
Herbicidas	X $ por ha
Costo de la producción	**X$ por ha**

[2] Los precios son establecidos según la casa de fertilizantes YARA HUAMANTLA al 31/3 por kg de producto: Urea Yara: $X, DAP Yara $X, Cloruro de Potasio YARA: $X; Agroquímica Minab-R $X

[3] Las metas de producción están basadas en la calidad de su terreno son **aproximadas** y pueden variar dependiendo de factores externos como la cantidad de lluvia y la ocurrencia de eventos adversos como heladas o plagas. Los actividades agrícolas incluyen: sembradora de precisión (1200 pesos), 2 aplicaciones de herbicidas (400 pesos) y 5 jornales de mano de obra para herbicidas, fertilización y otras labores y cosecha (2000 pesos)

Figure OA7: Recommendation letters (page 5)

jose luis castillo montes

ignacio allende

cuapiaxtla

Vale por 2000 pesos para fertilizante y/o maquinaria para la siembra*

Lugar para pasar a recoger los fertilizantes: Fertilizantes YARA Carretera Mexico-Veracruz Km 145.5, Huamantla, Tlaxcala en la fecha que se lo indique su ingeniero agrónomo

Número de FOLIO: 842 ID: .22.03.02.

Si tiene dudas contacte a los teléfonos: (246) 4626577 o (247) 4720603

*El costo de la maquinaria es de $800 pesos si decide rentarla con nosotros; sólo la cantidad de dinero restante podrá ser usada para la compra de fertilizante

Figure OA8: Cupon

Online Appendix C Fertilizer Quality

The research team tested samples for each of the three main fertilizers —urea, DAP and KCl— in the laboratory Laboratorios A-L de México, in Guadalajara, México. Samples came from five different locations – Altlzayanca, Apizaco, Calpulalpan, Cuapiaxtla and Muñoz – from YARA and the most popular manufacturer who provides government subsidized fertilizer.

Appendix Table A5 presents the results from our fertilizer testing exercise. The label of a bag of urea (Panel A) shows an NPK content of 46-0-0, so that 46% of the contents should be N. According to the laboratory tests, the commonly used bag had a content of 46.7% while the YARA bag had a content of 47%. Panel A also reports the total cost per bag which allows us to compute the cost per kilogram of nutrient at 13 pesos for the government subsidized bag compared to 13.6 pesos per kg of N in the YARA bag. We conclude that both urea bags have similar content and price per unit of nutrient. The results are similar for KCl (Panel C) although both bags have lower content of K than advertised. The YARA bag is a bit more expensive and thus its cost per kg of K is slightly higher. In Panel B however, we see that the subsidized DAP bag has much lower content of N and P than advertised. The label for DAP is 18-46-0, indicating that there should be 18% N and 46% P. According to the laboratory test, however, the government bag only had 10.4% of N and 14% of P. In contrast, the YARA bag had 16.7% of N and 36.2% of P. Therefore, even though the YARA bag was more expensive, its cost per kg of nutrient was in fact lower. We conclude that the YARA bag of DAP was of higher quality than the government subsidized one (and was in fact cheaper after adjusting for quality).

Online Appendix D Yield measurement protocol

The harvesting and weighing of yields followed different protocols depending on whether farmers had already harvested the crop by the time of the team visit or whether the harvester/thresher could reach the program plot.

OA D.1 Harvest by QFD

For the 376 farmers that had not yet harvested the crop and with a program plot that could be reached by the mechanized harvester/thresher, the size of the plot was verified with the pre-registered GPS coordinates and the maize production on the registered plot was harvested and threshed. The grain was then collected and loaded onto a truck and weighed in the nearest weighing station.

OA D.2 Harvest by farmer

For the remaining farmers that had harvested by the time the team visited the registered plot or for those farmers that had not yet harvested but whose plot could not be reached by the harvester/thresher, the following procedure was used during the QFD team visit (the QFD comprised of an agronomist, a supervisor and 2 field assistants).

If the harvested cobs were in the field, all the cobs were packed in burlap sacks provided by QFD. Each sack was sealed and stitched with raffia ribbon provided by QFD and properly identified with a label including the producer's ID, the plot's name, locality and number of harvested sack. Once all the cobs were collected, the producer moved the bags to their q home, where they were placed in a ventilated and moisture-free room for drying.

If the harvested cobs were already at the farmer's home, the QFD supervisor had to verify that the cobs from the registered plot could be identified. This was the case when the cobs were stored in a separate location from other maize production or the program plot had produced maize that could be distinguished due to color or maize variety (hybrid or creole). If identification was not possible, then the team was instructed not to proceed with the yield measurement protocol (and for these farmers we only have self-reported yields).

A day before the shelling of maize, a QFD team visited the farmer to verify that moisture content (ideally less than 16%) for the shelling.[45] The team also verified that all the bags were still sealed and unaltered. For the shelling visit, the team arrived with a freight truck to transport the grain to the weighing station after shelling.

The shelling was done with a mechanical sheller in an open space, placing a a blanket below the machine to avoid loss of grain, and placing a container to collect the grain and a sack to collect maize stalks. Cobs were fed slowly to the sheller and impurities of the threshed grain (such as maize stalk, leaves, etc) were removed.

[45]To test moisture, five cobs from different parts of a burlap were collected and a few grains from each cob were collected at random. Grain moisture was then measured with a portable grain moisture tester MT- 16.

Online Appendix E E1-E3 Specifications

Table OA3: Take up (E1-E3 specification)

	(1) Precision drill (1=Yes)	(2) 1^{st} Package (1=Yes)	(3) 2^{nd} Package (1=Yes)	(4) Out-of-pocket (Mex$/ha)	(5) # training sessions (0-3)	(6) # AEW visits (0-3)	(7) Total (0-9)	(8) Total (Std. Index)
E1	0.78***	0.83***	0.75***	319.59***	1.28***	1.25***	4.89***	3.73***
	(0.04)	(0.03)	(0.04)	(22.13)	(0.11)	(0.13)	(0.26)	(0.16)
E2	0.65***	0.89***	0.72***	212.38***	1.47***	1.24***	4.97***	3.67***
	(0.04)	(0.03)	(0.04)	(20.10)	(0.10)	(0.12)	(0.23)	(0.13)
Observations	410	410	410	410	410	410	410	410
R-squared	0.50	0.75	0.54	0.41	0.44	0.40	0.62	0.69
Mean dep. var. E3	0.08	0.07	0.04	0.00	0.76	1.40	2.34	0.00
SD dep. var. E3	0.27	0.25	0.19	0.00	0.95	1.28	2.11	1.00

Note: this table reports results on the take-up of our proposed treatment by farmers in our sample. Using only the set of 410 treated farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome variable for the group of farmers who did not receive the grant (E3), the omitted category in our regression. In column 1, the dependent variable is a dummy that takes value 1 if the farmer used the precision machinery provided by our team to fertilize at sowing. In column 2, the dependent variable is a dummy that takes value 1 if the farmer took up the first package of YARA fertilizers, that should be applied at sowing using the precision machinery. Farmers who did not use the sowing machinery were advised to use this package 30-60 days after sowing depending on how their crop grew. In column 3, the dependent variable is a dummy that takes value 1 if the farmer took up the second package of YARA fertilizers, that should be applied 45 days after sowing. In column 4, the dependent variable is the amount that each farmer had to pay for the packages of fertilizers, on top of the QFD subsidies, if they received them. In column 5, the dependent variable counts the number of training sessions each farmer attended, out of 3 our team organized. The first training session introduced farmers on how to fertilize at sowing. The second one aimed at on harvesting and preparations for yield measurement, as well as soil preparation for the following season. The third training session covered the importance of using quality fertilizers and herbicides, as well as on the right timing to fertilize during plant development. In column 6, the dependent variable counts how many times the farmer was visited by the our team to be provided with technical assistance (out of 3 scheduled visits). In column 7, the dependent variable is the sum of columns 1, 2, 3, 5 and 6, varying from 0 to 9. In column 8, the dependent variable is a standardized index of the outcome in column 8, computed by standardizing each variable individually, adding them all and standardizing the sum. We use the mean and standard deviation of E3 as reference for the standardized index. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table OA4: Practices 2015 (E1-E3 specification)

	(1)	(2)	(3)	(4)
	Existing practices		All new practices	
	Total practices applied	Standardized Index	Total practices applied	Standardized Index
E1	0.09	0.18*	2.57***	1.98***
	(0.07)	(0.11)	(0.11)	(0.14)
E2	0.07	0.17*	2.49***	1.90***
	(0.07)	(0.10)	(0.11)	(0.16)
E3	0.04	0.06	0.34**	0.32**
	(0.08)	(0.13)	(0.11)	(0.14)
Observations	540	540	540	540
R-squared	0.07	0.07	0.60	0.38
Mean dep. var. control	2.38	0.00	0.32	0.00
SD dep. var. control	0.61	1.00	0.69	1.00

Note: this table reports results on the agricultural practices performed by the farmers in our study in the 2015 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \beta_3 E3_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We use data from the Follow-up survey conducted in August 2015. The dependent variable in column 1 is a sum of individual dummies. Each dummy takes value of 1 if the farmer performed one of the so-called existing agricultural practices. In column 2, the dependent variable is the standardized index of the outcome in column 1, computed by standardizing each dummy individually, adding them all and standardizing the sum. We use the mean and standard deviation of the control group as reference for the standardized index. In columns 3 and 4, the dependent variables are analogous to the outcomes in columns 1 and 2, computed for the so-called new practices. The existing practices are: (a) ploughing, (b) using inorganic fertilizer and (c) covering the fertilizer. The new practices are: (a) deep tilling (ripping), (b) using hybrid seeds, (c) fertilizing at sowing, (d) sowing with precision machinery, (e) using pre-emergent herbicide and (f) using high-quality fertilizers. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table OA5: Fertilizer usage in 2015: applied vs. recommended (E1-E3 specification)

	(1)	(2)	(3)	(4)	(5)	(6)
	Absolute difference, applied vs. recommended					
	At sowing			Total		
	Urea (kg/ha)	DAP (kg/ha)	KCL (kg/ha)	Urea (kg/ha)	DAP (kg/ha)	KCL (kg/ha)
E1	-32.42***	-16.29***	-15.09***	-81.85***	-30.21***	-28.78***
	(1.76)	(1.76)	(1.22)	(8.97)	(4.98)	(3.08)
E2	-28.69***	-13.59***	-11.51***	-79.10***	-31.76***	-23.63***
	(1.78)	(1.81)	(1.42)	(9.21)	(4.53)	(3.49)
E3	-1.83	0.52	-1.47	-4.83	1.77	-0.93
	(1.97)	(2.37)	(1.28)	(10.87)	(5.73)	(3.79)
Observations	532	532	532	532	532	532
R-squared	0.52	0.39	0.44	0.25	0.21	0.28
Mean dep. var. control	38.69	19.40	16.44	114.90	37.83	32.66
SD dep. var. control	14.64	21.36	14.42	82.62	47.92	33.98

Note: This table reports results on the usage of fertilizers by the farmers in our study in the 2015 season, compared to the recommended dosages. Using the sample for the full sample of 540 farmers, except for 13 farmers for which we do not have data on usage of fertilizers, we run the following regression: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \beta_3 E3_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We use data from the Commercialization survey conducted in June 2016. In columns 1-3, the dependent variables are the absolute differences between the amount applied by farmers at sowing and the recommended dosages of Urea, DAP and KCl, respectively. In columns 4-6, we report analogous outcomes for the total amount of fertilizers applied in the full season. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table OA6: Yields and profits 2015 (E1-E3 specification)

	(1) Self-reported yields (t/ha)	(2) Revenue (Mex$/ha)	(3) Costs (Mex$/ha)	(4) Profits (Mex$/ha)	(5) Profits (no subsidy) (Mex$/ha)
E1	0.29*	1001.58*	686.70**	314.88	2389.30***
	(0.15)	(517.66)	(239.87)	(522.47)	(522.66)
E2	0.36**	1278.53**	1005.40***	273.13	2357.86***
	(0.15)	(523.15)	(260.94)	(503.28)	(509.91)
E3	0.22	744.96	48.19	696.77	705.94
	(0.16)	(528.22)	(276.10)	(517.75)	(518.38)
Observations	540	540	540	540	540
R-squared	0.27	0.30	0.20	0.22	0.25
Mean dep. var. control	2.36	7919.22	5280.02	2639.20	2639.20
SD dep. var. control	1.33	4397.72	2351.52	4024.33	4024.33

Note: this table reports results on yields and profits earned by farmers in the 2015 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \beta_3 E3 + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We use data from the Commercialization survey conducted in June 2016. In column 1, we use as the dependent variable the maize yields (tons/ha) self-reported by farmers in the 2015 season. In column 2, the dependent variable contains the value of farmers' maize production (per hectare) in the 2015 season. The value of the production (per hectare) is computed by multiplying the total amount of maize harvested by the farmer in the 2015 season by the price the maize could be sold in the market. We take the median price faced by farmers who sold at least a fraction of their production in the market as the price for all farmers when computing the value of the maize production. In column 3, the dependent variable is the total cost of production cost self-reported by each farmer. Total costs include the total investment in soil preparation activities, fertilizers (chemical and organic), herbicides, pesticides, and labor. We also include the cost of renting the sowing and harvest machines paid by QFD (when that was the case), as well as the subsidy for fertilizer packages, also paid by QFD. In column 4, the dependent variable is the difference between the dependent variable in columns 2 and 3. In column 5, the dependent variable is the cost of production, not including the subsidies paid by QFD. We use median market prices at the locality level to calculate revenues and profits. In localities where no farmer sold maize, we use median prices at the municipality level. To account for this imputation of prices (for 20 farmers in our sample), we include an dummy that takes value of one if prices were measured at the municipality level on the RHS of columns 2-5. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table OA7: Practices 2017 (E1-E3 specification)

	(1)	(2)	(3)	(4)
	Existing practices 2017		All new practices 2017	
	Total practices applied	Standardized Index	Total practices applied	Standardized Index
E1	-0.10	-0.08	0.32**	0.51**
	(0.11)	(0.12)	(0.11)	(0.16)
E2	-0.05	-0.03	0.77***	1.06***
	(0.10)	(0.12)	(0.13)	(0.17)
E3	0.11	0.12	0.24**	0.40**
	(0.11)	(0.12)	(0.11)	(0.16)
Observations	540	540	540	540
R-squared	0.09	0.08	0.22	0.18
Mean dep. var. control	2.31	0.00	0.42	0.00
SD dep. var. control	0.89	1.00	0.79	1.00

Note: this table reports results on the agricultural practices performed by the farmers in our study in the 2017 season. Using the full sample of 540 farmers, we run the following regression: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \beta_3 E3_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We use data from the Final survey conducted in May 2017. The dependent variable in column 1 is a sum of individual dummies. Each dummy takes value of 1 if the farmer performed one of the so-called existing agricultural practices. In column 2, the dependent variable is the standardized index of the outcome in column 1, computed by standardizing each dummy individually, adding them all and standardizing the sum. We use the mean and standard deviation of the control group as reference for the standardized index. In columns 3 and 4, the dependent variables are analogous to the outcomes in columns 1 and 2, computed for the so-called new practices. The existing practices are: (a) ploughing, (b) using inorganic fertilizer and (c) covering the fertilizer. The new practices are: (a) deep tilling (ripping), (b) using hybrid seeds, (c) fertilizing at sowing, (d) sowing with precision machinery, (e) using pre-emergent herbicide and (f) using high-quality fertilizers. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table OA8: Grant flexibility (E1-E3 specification)

	(1)	(2)	(3)	(4)	(5)	(6)
	Knowledge of recommendations					
	Remembers sowing recomm. (1=Yes)	Famers kept soil analysis (1=Yes)	Would follow the recomm. in the following year (1=Yes)	Trust in the recomm. from input supplying institutions: standardized index	Number of workers in 2015 (exc. harvest)	Attitudes towards change: standardized index
Year of data collection	*2015*	*2016*	*2016*	*2015*	*2015*	*2017*
E1	-0.01	0.36***	-0.10	0.98***	-1.24**	0.05
	(0.02)	(0.05)	(0.06)	(0.13)	(0.48)	(0.12)
E2	0.04	0.34***	0.04	1.33***	-0.53	0.32**
	(0.03)	(0.05)	(0.06)	(0.13)	(0.50)	(0.12)
E3		0.29***	-0.04	0.61***	-1.43**	-0.10
		(0.06)	(0.06)	(0.14)	(0.51)	(0.13)
Observations	395	510	540	508	540	540
R-squared	0.09	0.19	0.06	0.29	0.16	0.14
Mean dep. var. control (or E3)	0.03	0.58	0.39	-0.00	11.55	-0.03
SD dep. var. control (or E3)	0.18	0.50	0.49	1.00	4.74	1.12

Note: this table reports results on the effect of the grant flexibility on a variety of outcomes. Using the 410 treated farmers, in Column 1 report the estimates from the following regression: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \alpha_c \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. In Columns 2-6, we report the point estimates of the following specification: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \beta_3 E3_i + \alpha_c + \epsilon_{it}$, We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the omitted group of farmers, which in Column 1 corresponds to those who did not the grant (E3). In Columns 2-7, the omitted category is the control group of farmers. In Column 1, the dependent variable is a dummy that takes value 1 if the farmer reported remembering the sowing recommendations were given ti him or her as part of our intervention. This question was asked in August 2015 during our Follow-up survey. In Column 2, the dependent variable is a dummy that takes value 1 if the farmer kept record of the soil analysis given to him or her as part of our intervention. 33 farmers did not answer this question. In Column 3, the dependent variable is a dummy that takes value 1 if the farmer reported that he or she would probably follow the recommendations in the following season. Data for Columns 2 and 3 were collected as part of the Commercialization survey, conducted in June 2016. In Column 4, the dependent variable is a standardized index of two individual dummies that take value 1 if the farmers reported trusting the recommendations given by their input suppliers and IPAMPA, a local AES company. To compute the index, we standardize each dummy individually, add them all and standardize the sum. We use the mean and standard deviation of the control group as reference for the standardized index. The questions in the index in Column 4 were asked as part of our Follow-up survey conducted in August 2015. 40 farmers did not answer these questions. The dependent variable in Column 5 is the number of people each farmer reported to have worked in the plot registered to be part of our study, excluding harvesting activities. The data for Column 5 were collected as part of our Follow-up survey conducted in August 2015. In Column 6, the dependent variable is a standardized index of 5 questions from the Final Follow-up survey conducted in May 2017 that measured farmers' attitudes towards change. See Appendix Section 7 for the definition of variables. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table OA9: WTP for fertilizers (E1-E3 specification)

	(1) Reported WTP for YARA fertilizers (1=Yes)	(2)	(3)	(4)
		WTP for a bag of YARA fertilizer in 2017 (Mex$)		
		Urea	DAP	KCl
E1	0.57***	181.50***	203.21***	163.28***
	(0.05)	(16.51)	(20.93)	(18.56)
E2	0.61***	195.68***	228.24***	209.42***
	(0.04)	(15.96)	(20.86)	(17.95)
E3	0.20***	70.43***	64.68**	53.28**
	(0.06)	(19.57)	(24.69)	(20.63)
Observations	540	540	540	540
R-squared	0.36	0.31	0.27	0.29
Mean dep. var. control (or E3)	0.33	100.38	121.73	98.46
SD dep. var. control (or E3)	0.47	151.12	185.92	157.18

Note: this table reports results willingness to pay for YARA fertilizers. Using the full sample of 540 farmers in our study, we report the point estimates of the following specification: $Y_{it} = \beta_0 + \beta_1 E1_i + \beta_2 E2_i + \beta_3 E3_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We also report p-values of linear combinations of the estimates coefficients that map into the original study design. We use data from the Final survey conducted in May 2017. In Column 1, the dependent variable is a dummy that takes value 1 if the farmer reported his or her willingnes to pay for any of the 3 YARA fertilizers (Urea, DAP and KCl). In Columns 2-4, the dependent variables are the self-reported willingness to pay for a bag of each of the 3 YARA fertilizers. We imput WTP equal to zero for those who did not report their WTPs. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

OA E.1 Fertilizer Use: Heterogeneity Analysis

In this section, we examine whether treatment effects in fertilizer use varied by the baseline gap between fertilizer use in 2014 and the recommendations based on the soil analyses. In particular, we explore whether farmers with a larger gap at baseline were more responsive to the treatments.

Table OA10 reports the results. We focus on total urea as the results for DAP and KCl are qualitatively similar. First, as expected given our previous results, the point-estimates for the treatment indicators are negative for all arms $E1 - E3$ (though the effect for E3 is not statistically distinguishable from zero, all relative to the control arm). Second, a larger fertilizer gap in 2014 was not predictive of the 2015 fertilizer gap and finally, the interaction effects for all three arms are close to zero and not statistically significant.

Table OA10: Fertilizer usage in 2015: applied vs. recommended (E1-E3 specification)

	(1)	(2)	(3)	(4)	(5)	(6)
	Absolute difference, applied vs. recommended					
	At sowing			Total		
	Urea (kg/ha)	DAP (kg/ha)	KCL (kg/ha)	Urea (kg/ha)	DAP (kg/ha)	KCL (kg/ha)
E1	-15.74	-2.23	-17.39***	-30.53***	-5.09	-9.82***
	(21.56)	(11.01)	(5.12)	(3.73)	(5.79)	(2.18)
E2	-42.45*	-5.05	-14.69**	-32.81***	-9.82	-11.96***
	(22.23)	(10.93)	(6.19)	(3.96)	(6.01)	(2.84)
E3	55.20**	26.95**	-2.08	-3.36	0.81	0.58
	(23.69)	(13.01)	(7.69)	(3.53)	(7.96)	(2.53)
Fertilizer gap in 2014 (kg/ha)	0.21**	0.10**	0.03**	0.00	0.03	0.01**
	(0.07)	(0.04)	(0.01)	(0.01)	(0.02)	(0.01)
E1 x Fertilizer Gap	-0.20**	-0.09**	-0.02	0.00	-0.03	-0.01*
	(0.07)	(0.04)	(0.02)	(0.01)	(0.02)	(0.01)
E2 x Fertilizer Gap	-0.12*	-0.09**	-0.03	0.01	-0.01	0.00
	(0.07)	(0.04)	(0.02)	(0.01)	(0.02)	(0.01)
E3 x Fertilizer Gap	-0.20**	-0.08*	0.00	0.01	-0.00	-0.01
	(0.07)	(0.05)	(0.03)	(0.01)	(0.03)	(0.01)
Observations	529	529	529	529	529	529
R-squared	0.25	0.23	0.28	0.47	0.34	0.43
Mean dep. var. control	114.90	37.83	32.66	38.69	19.40	16.44
SD dep. var. control	82.62	47.92	33.98	14.64	21.36	14.42

Note: This table reports results on the usage of fertilizers by the farmers in our study in the 2015 season, compared to the recommended dosages. Using the sample for the full sample of 540 farmers, except for 11 farmers for which we do not have data on usage of fertilizers, we run the following regression: $Y_{it} = \beta_0 + \beta_1 T1_i + \beta_2 T2_i + \beta_3 T3_i + \beta_G FertGap + \beta_G 1 FertGap * T1_i + \beta_G 2 FertGap * T2_i + \beta_G 3 FertGap * T3_i + \alpha_c + \epsilon_{it}$, where i corresponds to a farmer, Y is the outcome of interest and t is the time period. We include randomization strata fixed effects and compute robust standard errors. At the bottom of the table, we report the mean and the standard deviation of the outcome for the control group, the omitted category in our regression. We use data from the Commercialization survey conducted in June 2016. In columns 1-3, the dependent variables are the absolute differences between the amount applied by farmers at sowing and the recommended dosages of Urea, DAP and KCl, respectively. In columns 4-6, we report analogous outcomes for the total amount of fertilizers applied in the full season. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.