Technology Adoption When Risk Attitudes Matter: Evidence from Incentivized Field Experiments in Niger

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ABSTRACT

Fertilizer micro-dosing is a precision fertilizer application technique with the potential to improve agricultural productivity and livelihoods in the semi- arid-tropics. Despite more than two decades of disseminating the technology in Niger, micro-dosing adoption rates remain low with evidence of dis-adoption. Since fertilizer is a risk increasing technology, this paper estimates the effects of risk attitudes on fertilizer use and the practice of micro-dosing. We use different methods to elicit measures of risk aversion and supplement those with measures of aversion to ambiguity and loss. We find that incentivized measures of risk attitudes have better predictive power than general measures based on hypothetical survey questions. Among the risk attitudes explored, risk aversion tends to matter in the decision to use fertilizer and in the choice of an application technique when fertilizer is used. This indicates that ex post programs like insurance could promote the use of fertilizer and fertilizer micro-dosing among risk averse farmers.

1. Introduction

Background and motivation

Inorganic fertilizer use across sub-Saharan Africa (SSA) is generally considered to be low. However, in Niger and other countries in the drier regions of the continent, inorganic fertilizer use is even lower (Morris, Kelly, Kopicki, & Byerlee, 2007). Compared to Tanzania and Uganda where about 16.9% and 3.2% of households use fertilizer at a rate of 95.6 and 37.5 kilograms (Kg) per hectares (ha) Sheahan & Barrett, (2014) show that 17% of farming households in Niger use inorganic fertilizer at a rate of only 26.3 Kg/ha. Traditionally in Niger, increases in agricultural production have been achieved through the cultivation of new land rather than increased yields. With increasing population density alongside limited supply of high quality land, the importance of agricultural intensification (including fertilizer use) is eminent. It is imperative for Niger and its farmers to focus on yield increasing intensive technologies like fertilizer micro-dosing.[1] Fertilizer micro-dosing is a precision farming technique, where a small amount of fertilizer (2-6 g) is placed with the seed (separated by a thin layer of soil) (ICRISAT, 2012). This amounts to about a third to a fourth of the usual fertilizer recommended by research or advisory services (Camara, Camara, Berthe, & Oswald, 2013). Thus, compared to traditional inorganic fertilizer application techniques such as line spreading and broadcasting, fertilizer micro-dosing is cost effective. Micro-dosing also enables efficient nutrient absorption and reduced soil degradation via soil nutrients replenishment, reduced soil erosion and enhanced use of water (Abdoulaye & Sanders, 2005; Pender, Abdoulaye, Ndjeunga, Gerard, & Kato, 2008; Tabo, Bationo, Maimouna, Hassane, & Koala, 2006).

[1] Fertilizer micro-dosing was developed by scientists at the International Crop Research Institute for the Semi-Arid tropics (ICRISAT) and partner organizations to address the cost constraints associated with fertilizer use in the Sahel

After over 20 years of micro-dosing promotion by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partner institutions, the use of the technology remains persistently low with some evidence of dis-adoption in Niger.[2] This is puzzling given the technology's potential to increase production thereby improve livelihoods for cash strapped smallholder farmers. Therefore, it is important to understand under which conditions farmers are willing to practice micro-dosing on scarce arable land for agricultural production. Anecdotal evidence and information from key informants indicate that a vast majority of farmers who apply some fertilizer mix the fertilizer with seeds at planting.[3] While mixing seeds with fertilizer is frequently interpreted as micro-dosing by some (Abdoulaye & Sanders, 2005; Pender et al., 2008; Tabo et al., 2006) we consider these application techniques to be different. Farmers mixing seed with fertilizer typically apply 2 to 8kg/ha of fertilizer (Abdoulaye & Sanders, 2005) compared to the 20kg/ha-60kg/ha recommended for micro-dosing. This large difference in the quantity of fertilizer used is thus likely to have very different implications for profitability and production risk.

Inorganic fertilization strategies are risk increasing (since they introduce a higher variance in yield) and risk associated with innovative technologies can be a barrier to their adoption (Bocqueho, Jacquet, & Reynaud, 2014; Ghadim, Pannell, & Burton, 2005; Marra, Pannell, & Abadi Ghadim, 2003). Furthermore studies have shown the importance of farmers' risk preferences on the adoption of new farming technologies (Feder, Just, & Zilberman, 1985; Feder & Umali, 1993; Knight, Weir, & Woldehanna, 2003). However, there are limited empirical studies which actually elicit risk attitudes and integrate them in the technology adoption process. No study

[2] Niger is a big land locked country in West Africa. Though agriculture employs more than 80% of working age adults, agricultural productivity under mainly rain fed conditions is low.

[3] Liverpool-Tasie, Sanou, & Mazvimavi, (2015)show that the use rate of mixing seeds with fertilizer is much higher than micro-dosing among fertilizer users in Niger.

of micro-dosing was found that considered the effect of risk attitudes on adoption. Consequently this paper explores the role of risk attitudes in the adoption of fertilizer micro-dosing in Niger.

We elicit various types of risk attitudes using different elicitation methods. We supplement a traditional survey question on risk attitudes with incentivized experiments designed to elicit risk preferences. There is an ongoing debate in the literature regarding the appropriateness of general survey questions versus incentivized/hypothetical experiments. While a few studies have used different elicitation methods to compare hypothetical and incentivized risk elicitation methods, this is the first study (we are aware of) that actually uses the exact same question for the hypothetical and incentivized elicitation methods in the field in a developing country. Using the same question in both a hypothetical survey and an incentivized experiment allows us to contribute to this debate by truly isolating the effect of incentives.

In addition to attitudes towards risk over gains, we also collect information on farmers' attitudes towards ambiguity and loss.[4] By collecting multiple measures we are able to test which risk attitudes (risk aversion, ambiguity aversion and loss aversion) most closely explains farmers' behavior in our sample. This is important since different risk attitudes may call for different policy interventions. If risk aversion is key in farmers' decisions to practice micro-dosing, then ex post risk-coping mechanisms such as crop insurance might be an appropriate policy response. On the other hand if ambiguity aversion matters more, then ex ante strategies such as farm extension services and demonstration trials may help increase familiarity with the technology and boost farmers' confidence about the new technique.

[4] Ambiguity aversion is putting higher values on events with known probability than those with unknown probability

This study makes several contributions to the existing literature. First, it leverages a unique data structure and simple framed field experiment to demonstrate the importance of taking risk preferences into account in the design and evaluation of programs promoting new technologies. The framed field experiment is easy to implement in a rural context when one wants to ensure that participants understand the task. It has the advantage of eliciting attitudes toward risk, ambiguity and losses without using lotteries with varying probabilities as in previous studies (Liu, 2013). Instead, each experiment involved choices between changing certain payments and an invariant risky prospect. Charness & Viceisza (2012) tested respondents' understanding of and the level of meaningful responses to three distinct risk elicitation mechanisms in rural Senegal. Their findings suggest that individuals may have a much more difficult time with varying probabilities than with varying payoffs.

Second, we provide empirical evidence that incentives matter and risk attitudes elicited with incentives predict behavior better. The study also contributes to the limited empirical evidence regarding farmers' understanding and consequent experience with the practice of fertilizer micro-dosing in Niger.

Finally, collecting farmers' risk attitudes using both incentivized and hypothetical context-specific experiments to frame a familiar decision terrain for farmers is the first of its kind in the literature to our knowledge. While previous studies have been concerned with comparing distinct risk elicitation mechanisms or using student populations in lab experiments, we compare the same risk elicitation mechanism without monetary stakes and with monetary stakes in the field in a developing country.[5] We will thus be able to more accurately identify if incentivization matters

[5] This refers to the elicitation method using fertilizer without payoff and with payoff

and the potential consequent effects this has on being able to identify the effect of risk attitudes on fertilizer micro-dosing adoption.

The paper is organized as follows: Section 2 presents our conceptual framework while section 3 describes our data and study sample. Our evaluation of measures of risk attitudes and how they relate to adoption decisions are discussed in section 4. Section 5 concludes.

2. Conceptual framework

In order to model the adoption of micro-dosing among Nigerien farmers, we consider a standard household utility maximization problem subject to cash/credit and labor constraints. In rural Niger, like elsewhere in developing countries, farmers face multiple imperfect or missing markets including land, labor and credit[6]. Consequently, it is appropriate to use a non-separable agricultural household model where household production decisions (including the adoption decision of a new technology) are simultaneously made with consumption and household labor supply decisions (Singh, Squire, & Strauss, 1986). The non-separable household model enables us to account for individuals' characteristics such as risk attitudes, our variables of interest, which might influence production decisions.

The use of fertilizer exposes a farmer to a higher yield variance compared to a farmer's traditional practice. This is largely due to uncertainty associated with rainfall and other agro ecological factors beyond the farmer's control. This study assumes that farmers' risk attitudes influence their decisions on fertilizer allocation to crop production. We incorporate measures of risk aversion, ambiguity aversion and loss aversion. Risk aversion is the aversion to a set of outcomes with a known probability distribution whilst ambiguity or uncertainty aversion is the

[6] Using nationally representative data, Dillon & Barrett (2014) find evidence of market failure in rural Parts of Niger and other countries in SSA.

additional aversion to being unsure about the probabilities of outcomes. Farmers' experience in seeing the results of fertilization in the field has been shown to be a determinant of micro-fertilization (Abdoulaye & Sanders, 2005). If we assume that the dissemination of micro-dosing was effective and allowed the farmer to learn about the probability distribution of the yields associated with its use, then the low adoption rate can most certainly be explained by risk aversion. However, we cannot rule out ambiguity aversion because the farmer may not know the probability of high and low yields associated with the technology (Engle-Warnick, Escobal, & Laszlo, 2007). Although this is a plausible proposition in the Nigerien context with regard to the adoption of micro-dosing, the opposite can also be true because the technology has been rolled out to farmers for over two decades now. Nevertheless, we account for ambiguity aversion to test whether some farmers are still learning about the technology. Farmers' decisions can further be explained by the endowment effect which indicates an individual's aversion to changing from an established behavior (Liu, 2013). Since there are potential monetary losses connected to the use of micro-dosing when growing conditions are not optimal, we also elicit a measure of loss aversion as part of our measures of risk attitudes.

We assume that at the beginning of each planting season, the farmer decides whether to use fertilizer or not then decides which fertilizer application method to use. The rainy season can be characterized by good or bad growing conditions. If growing conditions are good, the resulting yield with fertilizer is greater compared to no use of fertilizer. If growing conditions are bad, yields might be worse than under the status-quo of not using fertilizer and the farmer incurs a loss. If both the labor and cash/credit constraints are binding, which we expect in Niger, then the household's optimal choice of fertilizer level depends on a number of variables including the plot manager's attitude towards risk. We expect that farmers with higher tolerance toward risk, ambiguity and losses will be more likely to use fertilizer because they are less sensitive to the variability in yield introduced through the use of the risk increasing technology.

Consequently, the farmer's input demand for fertilizer takes into account risk attitudes along with other factors that affect the profitability of fertilizer use. These include manure use (desirable because it retains available water better), the price of fertilizer, the price of the crops on which fertilizer is applied, the availability and cost of both family and hired labor for the application of the input, as well as the size and agronomic characteristics of the plot allocated to the crop's cultivation, wealth (captured by value of assets), access to extension services, the level of education and the experience in farming contribute to the farmer's ability to use the technology well. Location specific factors that determine farmers access to infrastructure and capture variations in administration and agro-ecological conditions are also likely to affect a farmer's input use decision. Conditional on these expected factors, we can empirically test for the significance of our variable of interest; risk attitudes and which attitudes, in particular affect the farmer's decision to use fertilizer? We can also explore the effect that risk attitudes play on farmer's adoption of particular fertilizer application techniques, once the decision to use fertilizer has been made.

3. Data and study sample

The analysis in this study relies on two main datasets namely an agricultural household survey and data from risk attitude elicitation experiments administered in four regions of Niger – Dosso, Maradi, Tillabéri and Zinder. These four regions are mainly in the southern Sahelian, Sahelo-Sudanian and Sudanian agro-ecological zones, where crop production is most feasible. Although this is not a nationally representative sample, this group of regions capture the variation across important dimensions relevant to the adoption of a technology like micro-dosing such as rainfall, soils, population density, and access to markets, services, and assets.

The household survey captures detailed information on agricultural practices at the plot level. These include crop choice and detailed input (such as inorganic fertilizer, labor, manure) allocation across crops. It also includes household socio economic characteristics such as landholdings, livestock, experience using modern and traditional inputs and non-agricultural income sources. Information was also collected on risk attitudes using a general survey instrument and hypothetical experiments (i.e. without payout). Using the same respondents as in the household survey, framed field experiments (to elicit risk attitudes) were conducted with a randomly selected subset with monetary payoffs.

The sampling strategy and village selection for our primary data collection builds on the one adopted by a previous study conducted by the International Food Policy Research Institute in Niger between 2004 and 2005. The sample selection used in that study was both purposive and random. Of the 40 villages selected 10 were purposely selected because they had well-functioning input supply shops. In each of the selected villages, a random sample of 10 households was drawn from a listing of households in the village. In all 397 households were interviewed during the first round in 2004-2005. A follow up round administered by ICRISAT between April and May in 2014 collected data on about 800 households comprised of the same 400 households interviewed in 2005 and 400 new households. The new households were randomly selected from 40 villages (different from the ones included in the earlier survey) randomly selected in the four regions using the Repertoire National des Communes (RENACOM) database.[7]

The framed field experiments were conducted from June 25, 2014 to July 3, 2014 at the onset of the raining season in the four regions to avoid the possibility that respondents' answer

[7] National database of all the communes (3rd level of administrative division) in Niger

might be influenced by their expectation of the outcome of the 2014 agricultural season. The subsample chosen for the incentivized field experiments is a randomly selected group of 20 villages from the larger sample of 80 villages included in the agricultural household survey. Combining the two sources of data, the plot level analysis in this paper will involve 237 plot managers responsible for a total of 640 plots. Figure A- 2 shows the households' location.

Empirical analysis

The decision to use fertilizer and to practice a particular application method depends on an unobservable latent variable (here the farmer's utility) that is determined by one or more explanatory variables such as the larger the farmer's utility, the greater the probability of a farmer adopting fertilizer. We do not observe the latent variable but we can measure the ultimate decision in terms of the farmer being a fertilizer user or not a fertilizer user.[8] Consequently, we adopt a binary response model to estimate the response probability of using fertilizer conditional on the set of explanatory variables described above i.e. $P(\boldsymbol{Y} = \mathbf{1}|\boldsymbol{X})$ (Wooldridge, 2010). We opt for a probit model where the response probability depends on a set of parameters which are function of the standard normal cumulative distribution function. This ensures that the estimated response probabilities are strictly between zero and one. Since the data contains one plot manager for several plots in some instances, to obtain robust standard errors for accurate statistical inference, we cluster at the household level to allow for intragroup correlation.[9]

Given our focus on the practice of micro-dosing against mixing seeds with fertilizer it is important to assess the heterogeneous factors associated with the decision to practice each

[8] We focus on this binary decision first because all farmers mentally go through this process before choosing their preferred application method

[9] We opt to cluster at the household level because we are interested in differences in behavior across household. We also cluster at the village level for robustness since a significant proportion of production shocks are likely correlated at that level. However we only have 20 villages and that maybe too few for accurate statistical inference.

technique. This heterogeneity may be driven by labor and non-labor input costs at the time of planting. Abdoulaye & Sanders, (2005) demonstrate that fertilization is a stepwise decision in Niger. Once the traditional soil-fertility maintenance system breaks down due to population pressure, falling yields forces farmers to increase their consumption of organic fertilizer. Secondly, they move on to mixing small quantities of inorganic fertilizer with the seed in the seed pocket at planting (mixing fertilizer with seeds) and finally adopt a fertilizer application method that allows for the use of greater quantities of fertilizer applied to the plant outside of the seed pocket during side dressing (micro-dosing). This might mean that by the time the farmer starts practicing micro-dosing (and mixing to some extent) the learning and experimentation period is over. Thus we assume that fertilizer is not a new technology in Niger.[10]

Descriptive statistics from the data show that compared to mixing seeds with fertilizer, micro-dosing requires greater quantities of fertilizer and consequently greater monetary investment per hectare at planting. From anecdotal evidence, the general belief is that micro-dosing is more labor intensive than mixing fertilizer with seeds. Thus, it is surprising that the total man-days per hectare for fertilizer application is greater under mixing seeds with fertilizer in our study sample. These differences imply potentially different returns on investment and associated risk between micro-dosing and mixing fertilizer with seeds and the necessity of differentiating between them.

Conditional on using fertilizer, the decision to use either micro-dosing or mixing could be made separately or jointly by farmers. If jointly made, a seemingly unrelated bivariate probit model would be the appropriate estimation technique to explore the effects of risk attitudes on the

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[10] Given that fertilizer is not a new technology in Niger, ambiguity aversion should not matter for the vast majority of farmers in the sample.

probability of using a particular technique. However if separately made, the conditional probit regression is more suitable. With a rho of -1 and p-value of 0.8 we failed to reject the null hypothesis that the decision to use micro-dosing and mixing are made separately. Thus a conditional probit regression is used to identify the effect of risk attitudes on which fertilizer application technique to use conditional on fertilizer use. Here we assume that the decision to use fertilizer is a two stage decision process. First, the farmer decides whether to use fertilizer or not on the plot. In the second stage, the farmer decides which fertilizer application technique to use. The empirical specification for the binary decision is:

$$\boldsymbol{Y_{hij} = \beta X_{hi} + \gamma Z_{hij} + V + \varepsilon_{hij}} \tag{1}$$

where $\boldsymbol{Y_{hij}}$ is the probability of adoption taking the value of 1 if a farmer $\boldsymbol{i}$ in household $\boldsymbol{h}$ uses fertilizer on plot $\boldsymbol{j}$. $\boldsymbol{X_{hi}}$ is a vector of characteristics of farmer $\boldsymbol{i}$ in household $\boldsymbol{h}$. It includes age, gender, formal education, household size, measures of risk attitude and the number of years in farming. The risk attitude variables are continuous with higher values denoting lower degrees of risk aversion, ambiguity aversion or loss aversion. $\boldsymbol{Z_{hij}}$ is a vector of control variables that affect the decision to use inorganic fertilizer on a particular plot. They include the area allocated to crop production, use of organic fertilizer, soil fertility, wealth, indicators of climatic growing conditions, knowledge of inorganic fertilizer, distance to market, price of input, and regional characteristics. $\boldsymbol{V}$ is village fixed effects to control for village characteristics like infrastructure and administrative factors or production shocks that affect production decisions and input demand. We use village controls and the household's distance to the local market as proxies for unobserved factors like wage rates and output price data which are also likely to be endogenous at the household level[11].

The empirical model for the conditional probit is the same as above except that now the outcome variable $\boldsymbol{Y_{hij}}$ takes the value of 0 if a farmer $\boldsymbol{i}$ in household $\boldsymbol{h}$ mixes seeds with fertilizer on plot $\boldsymbol{j}$, and the value of 1 if the farmer practices micro-dosing on plot $\boldsymbol{j}$.

Eliciting risk attitudes

Risk elicitation methods can be broadly divided into hypothetical (non-incentivized) and incentivized methods. In this study, the hypothetical methods include a general risk assessment question and a hypothetical question with context-specific details relevant to farming that are designed to improve the farmer's understanding of the question and thus allow them to more readily place themselves on the risk scale. In effect, the hypothetical context-specific question attempts to simulate a real life agricultural decision related to the use of inorganic fertilizer. The literature also suggests that if measures of risk preferences are to be associated with actual risk-taking behavior, their elicitation should be incentivized in order to ensure that choices more accurately reflect true underlying attitudes toward risk (Charness, Gneezy, & Imas, 2013; Holt & Laury, 2002). Consequently, the second elicitation approach we use includes an incentivized contextualized framed field experiment (with fertilizer). By including both hypothetical and incentivized fertilizer context specific assessment experiments we are able to explore whether contextualized questions and/or incentives matter when eliciting risk preferences in rural agricultural settings. More specifically, comparing the hypothetical and incentivized versions of

[11] Separate identification of the effects of factors like wage rate and output prices when aggregated at the village level is not possible with a village level fixed effects. Since these variables are not our key variables of interest we decided to use the village level fixed effects to capture additional unobserved village characteristics that could be correlated with our variable of interest and decisions on fertilizer use.

the fertilizer question provides a unique opportunity for a true comparison of the effect of incentives when eliciting risk attitudes without confounding factors from changing contexts associated with previous comparisons observed in the literature (Charness & Viceisza, 2012; Dohmen et al., 2011; Hardeweg, Menkhoff, & Waibel, 2013). In addition to the incentivized fertilizer question, we also conduct incentivized experiments to elicit risk over gains, risk over ambiguity and risk over losses using non-contextualized HL-like choice experiments. These elicited measures of loss aversion and ambiguity aversion enable us to better understand how each type of aversion influences (or does not influence) the farmer's behavior and the subsequent adoption decision.

All of the experiments were implemented in a one-on-one interview with extensive explanations provided by enumerators in the relevant local language: Haoussa, Zarma or Fulani. Each interview lasted between thirty to forty minutes. The enumerators were trained beforehand in French then in the local language and proceeded to a testing of the instrument to ensure they would communicate the tasks appropriately and uniformly to each participant. Each enumerator used visual aids to depict possible choices in an effort to improve participant understanding of the games.

The general hypothetical risk question is inspired by Dohmen et al. (2011) which requested that respondents give an assessment of their general willingness to take risks on a 0-10 scale. In this study, we simply ask that participants give an assessment of their general willingness to take risks on a 4-point Likert scale where the value 1 means "avoids risk most of the time" and the value 4 means "take risk most of the time". This approach has two main features: (1) there are no financial incentives provided, and (2) this question is not specific to any context.

The production specific questions implemented without monetary stakes (hypothetical) and with monetary rewards (incentivized), are modeled after the experiments in Gneezy & Potters, (1997). Using real monetary payoffs, Gneezy & Potters, (1997) give respondents a simple choice of how much to invest in a risky asset with a positive expected profit from investing. For example each person is endowed with 100 cents. Any part of this amount could be invested in a risky asset and the rest is kept by the participant. The risky asset returns 2.5 times the amount invested with a probability of one-third and nothing with a probability of two-third.[12] The Gneezy and Potters experiment has the advantage of being easy to understand and has been previously implemented in a developing country setting (see Charness & Viceisza, 2012). We frame the experiments in this study in terms of "fertilizers" and "yields".

In our task, we presented farmers with a scenario where they have to choose 10 sachets of fertilizer and we framed the decision in terms of how many of those 10 sachets will they choose to be of "risky fertilizer". As shown in Figure A- 1 farmers are told that the plot yields 500 kg (5 bags of 100 kg each) of millet without the use of fertilizer. Each 100 kg of millet bag pays FCFA 25.[13] The traditional non-risky fertilizer (2) available in 2 kg sachets has a certain yield distribution. Specifically, it increases the yield of the plot by 100 kg (1 bag) for every sachet of fertilizer regardless of the growing conditions (temperatures). The new type of risky fertilizer (1) - also available in 2 kg sachets - generates higher yields than the traditional fertilizer under good conditions but significantly lower yields in bad conditions. Specifically, it increases the yield of the plot by 300 kg (3 bags) per sachet of fertilizer in good weather but increases the yield by only

[12] The expected value of investing is higher than the expected value of not investing. A risk-neutral (or risk seeking) individual should invest the entire starting endowment.
[13] At the time of the experiment US$ 1 was equivalent to 470 CFA

10kg per sachet of fertilizer in bad weather. We simulate random growing conditions by flipping a coin. If the coin came up heads then conditions were good and bad otherwise (tails).

As shown in Figure A- 1, farmers were presented with a table including all possible combinations associated with the number of sachets of risky fertilizer and non-risky fertilizer that one might choose. The incremental yield observed from the use of fertilizer is added to crop production without fertilizer i.e. 5 bags of millet. The resulting table comprises 11 options. Suppose the farmer opts for 7 sachets of the new risky fertilizer and 3 sachets of the non-risky traditional fertilizer (which corresponds to option H in the table). If conditions are good, the field would yield 29 bags and pay FCFA 725. On the other hand, if conditions are bad, the field would yield only 8.7 bags and pay FCFA 217.5.[14] Clearly, a preference for more sachets of the risky new fertilizer indicates lower degrees of risk aversion. The use of monetary incentives in the incentivized fertilizer experiment aimed to encourage participants to reveal their true preferences (Andersen, Harrison, Lau, & Rutström, 2006).

The final set of experiments were designed to elicited individuals' preferences toward (i) risk , (ii) ambiguity, (iii) and losses using a lottery choice mechanism similar to Holt & Laury (2002). In the typical Holt & Laury experiment, the participant is presented with a list of 10 to 20 decisions between paired gambles with changing probability distributions. For every decision row, the participant chooses which gamble she prefers to play from each pair. In contrast to Holt & Laury (2002), the experimental design used here asked participants to choose between a fixed

[14] During the experiments the monetary payoffs were rounded up to the nearest FCFA 5 the smallest coin available.

lottery and a changing safe payoff. The lottery was presented to participants as colored balls in a bag to facilitate a clearer sense of the gamble.

A growing body of research cautions against imposing restrictive assumptions (i.e. using expected utility theory) on behavioral parameters in describing individuals' decision making process (de Brauw & Eozenou, 2014; Liu, 2013; Tanaka, Camerer, & Nguyen, 2010; Ward & Singh, 2014). In standard expected utility theory, risk aversion is the only parameter that determines the curvature of the utility function. In prospect theory (Kahneman & Tversky, 1979)[15] the curvature of the utility function is jointly determined by parameters of risk aversion, loss aversion, and nonlinear probability weighting (the individual tendency of overweighing small probabilities and underweighting large probabilities) (Liu, 2013). Our experimental design does not make any assumptions about the underlying decision process (whether preferences conform to expected utility theory or cumulative prospect utility theory). For each experiment, we treat the elicited risk attitudes for each respondent relative to the responses provided by the other participants in our sample. This means that we do not calculate any coefficients of risk aversion but instead evaluate degrees/levels of relative risk attitudes. Nevertheless, the combination of three elicitation methods enables us to identify three different non-parametric measures of attitudes towards risk (degrees of risk, ambiguity and loss aversion) over a series of experiments.

Consequently, the final set of experiments were designed to elicit individuals' preferences toward (i) risk over gains , (ii) ambiguity, (iii) and losses using a lottery choice mechanism similar to Holt & Laury (2002). In the typical Holt & Laury experiment, the participant is presented with a list of 10 to 20 decisions between paired gambles with changing probability distributions. For

[15] Individuals' valuation of a particular prospect/lottery is conditioned by the asset position of the individual (personal reference point) and the change in the asset position from that reference point represented by the prospect.

every decision row, the participant chooses which gamble she prefers to play from each pair. In contrast to Holt & Laury (2002), the experimental design used here asked participants to choose between a fixed lottery and a changing safe payoff. The lottery was presented to participants as colored balls in a bag to facilitate a clearer sense of the gamble. The tables used for the elicitation of the HL-like measures of risk attitudes are provided in Table A- 1 and Table A- 2.

In the risk over gains experiment, participants were presented with a list of 20 choices between a varying safe payoff (Option B) and a fixed lottery (Option A). For every decision choice or row, the participant chooses which option (A or B) she prefers. To minimize potential inconsistencies in choices that could be linked to a lack of comprehension, we enforced monotonic switching. This is known in the risk preference literature as monotonic switching and it is a common practice to ensure that results are not altered by a lack of understanding of the experiment (Liu, 2013; Tanaka et al., 2010). Specifically, respondents were asked to move down the list and once they switched from the risky option to the safe option they were not allowed to switch back. This is not to say that they were not allowed to change where they wanted to switch, but they were prevented from switching multiple times[16]. This is important since the "switching row" allows us to determine the respondent's relative risk attitude. While each of the 20 rows in the table constituted a choice, the participant was informed in advance that one pair of decisions would be randomly selected and played out for payment using a 20-sided die.

As the respondent moves down the table (see Table A- 1), the value of the safe payoff increases by an amount equal to FCFA 60 while the values for the fixed lottery could be either FCFA 0 or FCFA 1,200. The value of FCFA 0 corresponds to drawing a white ball and FCFA

[16] The options of never switching (always choosing A) or switching at row 1 (always choosing B) were available

1200 to an orange ball. As shown in the expected value of the safe payoff becomes greater than the expected value of the lottery. In all cases except risk over ambiguity, participants were allowed to check that the bag contained five white balls and five orange balls. That is the probability of choosing a white ball or an orange ball is 50% chance. As shown in Table A- 1 the first 9 rows offer the choice of a higher expected payoff in the gamble relative to the certain payoff, while the final 10 choices offer an expected payoff lower in the gamble. In row 10, the expected value of the gamble is CFA 600 – the same as the 'safe' choice. The individual exhibiting lower degrees of risk aversion switches from choosing the lottery option (Option A) to choosing the safe payoff (Option B) further down the table (higher row numbers).The only difference between the risk over gains and risk over ambiguity experiment is the unknown probabilities in the gamble (i.e. the number of white versus orange balls in the bag).

In the risk over losses experiment, the gamble is not fixed while the safe payoff is For this choice experiment, the lottery choice involves 50 % chance of winning FCFA 1,200 versus 50% chance of losing an amount that increases as one moves down the rows. The safe option (Option B) is a zero payoff. As shown in Table A- 2, the first 9 rows offer the choice of a positive excepted payoff in the gamble relative to the zero payoff, while the final 10 choices offer a negative expected value in the gamble. In row 10 the expected value of the gamble is zero – the same as the 'safe' choice. Clearly, then switching from the lottery to the safe amount further down the table indicates a lower degree of loss aversion.

Note that it is possible to lose up to FCFA 2400 in the risk over loss experiment. As such, participants were endowed with 2400 FCFA (about $5USD) to ensure that they could not end up owing the experimenters money. In order to avoid ordering or endowment effects due to earnings in previous rounds, the outcomes not determined until after all decisions had been made. The average payout was 4,159 FCFA for the 396 participants.[17] This average represents approximately four times the median daily wage of an agricultural laborer in rural Niger.[18] This average amount should thus be large enough to generate a less noisy risk attitude measure relative to a hypothetical payoff (Camerer & Hogarth, 1999; Holt & Laury, 2002).

4. Results

Pairwise correlation across the measures of risk attitudes

In order to get a sense of how different measures of risk attitudes are related to each other, we perform a spearman's rank order correlation analysis. The spearman's correlation coefficient denoted by $\boldsymbol{r_s}$ measures the strength of the association between two ranked variables for the same individual (Gujarati, 2003). It is defined as follows:

$$\boldsymbol{r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}} \tag{2}$$

where $\boldsymbol{d}$ = difference in the ranks assigned to the same individual and $\boldsymbol{n}$= number of individuals. A positive correlation means that individuals are ranked similarly in terms of the pair of elicitation methods being compared.

Table 1 shows the spearman's correlation coefficients between pairwise measures of risk attitudes. Among the measures of risk aversion, the general risk question is not correlated with any of the other measures. Thus compared to incentivized and context specific questions, the general risk question rank individuals differently. Also, the incentivized and hypothetical fertilizer

[17] 4,207 FCFA for 207 respondents and 4,176 FCFA for the 189 male respondents.
[18] The median daily wage of an agricultural laborer is about 1094 FCFA (Dillon & Barrett, 2014)

measure are not correlated – implying that these two measures elicit different metrics of attitudes toward risk attributed to the use of incentives.

The incentivized fertilizer measure is positively and significantly correlated with the HL-like risk measures. This is not surprising since both elicit risk aversion under the use of incentives. Perhaps somewhat surprising is the correlation between the incentivized fertilizer measure and the ambiguity measure, but this along with the correlation between HL-like risk measure and the HL-like ambiguity measure implies that preferences toward risk are correlated with preferences regarding ambiguity.

Table 1: Spearman correlation coefficients across measures of risk attitudes

	Incentivized fertilizer	Hypothetical fertilizer	General risk	Risk over gains	Ambiguity over gains	Loss over gains
Incentivized fertilizer	1					
Hypothetical fertilizer	0.051	1				
General risk	0.0403	0.0781	1			
Risk over gains	0.1425**	0.0517	-0.0303	1		
Ambiguity over gains	0.1620**	-0.0369	0.1221*	0.4685***	1	
Loss over gains	0.0479	0.0598	0.0312	0.2613***	0.2943***	1

Note: **, ** and *** represent significance at 10,5 and 1 percent level respectively*

Predictive power of the general risk question for other measures of risk aversion

Some studies (see Dohmen et al., 2011; Hardeweg et al., 2013) suggest that a general risk question such as that used here is a good predictor of risky behavior and as such can be used for the elicitation of risk attitudes in the field instead of more complex incentivized and contextual mechanisms.[19] We follow their test of the predictive power of the general risk question (used as

[19] Although we used a 4-point Likert scale instead of an 11-point Likert scale as in Dohmen et al.(2011) and (Hardeweg, Menkhoff, & Waibel, 2013), the general risk question in this study is comparable to previous ones. See Table A- 3.

an explanatory variable) in explaining the more complex mechanisms in our study (i.e., the contextual questions and the HL-like risk experiments).[20]

The results are summarized in Table 2. The coefficient on the general risk question is not statistically significant for any of the regressions. In addition, the sign is not stable across regressions as would be expected given the spearman correlation coefficient results above. In all, the general risk question does not appear to be a good predictor of the hypothetical fertilizer, incentivized fertilizer or HL-like risk over gains experiments. These results indicate that the use of context specific questions and/or incentives lead to the elicited of measures of risk attitudes that are not always compatible with those generated by the general risk question. This is contrary to the strand of the literature spearheaded by Dohmen et al., (2011) who found that the general risk question is a valid substitute for an experimental H&L type elicitation. Despite, the general risk question's appealing ease of elicitation and low implementation costs, its ability to accurately capture the subject's true risk attitude is questionable. Our results resonate with conclusions gathered from field experiments in Senegal (see Charness & Viceisza,(2012)).

[20] We also used the ordered probit estimator as well as different specifications but the coefficients on the variables of interest don't change.

Table 2: OLS regressions of measures of risk attitudes with the general risk question as the predictor variable

	(1) Hypothetical fertilizer		(2) Incentivized fertilizer		(3) Risk over gains	
Variables	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
General risk question	0.2114	0.4250	0.0757	0.6962	-0.4693	0.4110
Age (years)	0.0020	0.9240	-0.0147	0.3509	-0.0366	0.4120
Female (0/1)	0.5346	0.5920	0.3380	0.6744	-2.9917	0.2200
Value of livestock (in 10000 FCFA)	-0.0220	0.2210	-0.0045	0.7412	-0.0132	0.7860
Formal education (0/1)	-1.24912*	0.0930	-0.1720	0.7252	-1.1755	0.4770
Married	-1.1727	0.5340	-1.0560	0.3909	-4.3595	0.3970
Household size	0.0479	0.1400	0.0280	0.3426	-0.0251	0.8030
Number of years farming	-0.0173	0.3990	0.0069	0.6607	0.0734	0.1290
Leader in community (0/1)	-0.0025	0.9970	0.981*	0.0503	2.7972	0.1010
Farmer organization member(1/0)	-0.7864	0.1810	-0.1480	0.7454	-0.8177	0.5670
Constant	8.4803***	0.0000	8.352***	0.0000	11.7768**	0.0380
Number of observations	181		184		184	
R-squared	0.052		0.046		0.039	

Note: **, ** and *** represent significance at 10,5 and 1 percent level respectively.*

Given our interest in the effect of incentives on risk attitudes, we include an experiment framed around the adoption of an agricultural technology, namely fertilizer. Using OLS regressions, we find that the hypothetical fertilizer measure is not any better than the general risk question at capturing risk aversion elicited using incentives. The coefficients on the hypothetical fertilizer variable are largely insignificant when the response variables are the HL-like risk over gains and incentivized fertilizer measures. This implies that the addition of context to a hypothetical elicitation technique does not necessarily strengthen the predictive power of that instrument. This result is further supported by the histogram (see

Figure A- 3) illustrating the distribution of responses for the incentivized fertilizer and the hypothetical fertilizer experiments. Given that there were no shocks between the two experiments, it seems that respondents behave differently due to the use of monetary stakes.

Technology adoption

Fertilizer use

As described earlier, a probit regression model is used to estimate the binary adoption decision to use fertilizer. We estimate different models in which the response variable is an indicator variable taking the value of one (1) if the farmer uses fertilizer on the plot and zero (0) otherwise. In each model specification, the main explanatory variables is a measure of risk attitudes with additional controls variables for individual, household and plot level characteristics that may influence the adoption decision. A complete list and description of the variables used in the regression analyses is provided in Table A- 4.

In Table 3, we present marginal effects from probit models where the dependent variable is fertilizer use.[21] The magnitude of these estimates are similar to those reported in studies which tested the predictive power of measures of risk attitudes on real world behavior (Dohmen et al., 2011; Hardeweg et al., 2013). In column 1, we present results without the variables of risk attitudes to assess the effect of the observable characteristics on the use of fertilizer as is commonly done in the technology adoption literature. The prevailing temperature during the wettest quarter is negative and significantly correlated with the use of fertilizer. Optimal growing temperatures are indeed an important complementary factors for the use of fertilizer in a Sahelian country like Niger.

[21] Results with standard errors clustered at the village level remain qualitatively unchanged.

The availability of manure and interaction with extension agents do not appear to influence the use of fertilizer. As expected, the higher the price of fertilizer the less likely is the use of fertilizer.

Although columns 2 through 3 show that the measures of risk aversion elicited using the general risk question and the hypothetical fertilizer experiment have the expected sign, they are not statistically significant. Thus these variables cannot be used to explain the revealed behavior of using or not using fertilizer.

However, measures of risk aversion elicited using the incentivized framed field experiments are statistically significant. Farmers' level of risk aversion appears to be a barrier to the widespread adoption of fertilizer in our sample. The incentivized fertilizer variable in column 4 indicates that less risk averse farmers are more likely to use fertilizer at 15%. This is confirmed by the significance of the coefficient on the HL-Like risk over gains variable in column 5 which is significant at 1%. These results are comparable to the behavior of Malagasy farmers whose risk aversion significantly reduces their likelihood of using the System of Rice Intensification (SRI) practices (Takahashi, 2013). Table 3 indicates that the HL-Like measure is a better predictor of the decision to use fertilizer relative to the incentivized fertilizer question. This might be due to the larger variation in this variable which goes from 1-20 compared to 11 for the incentivized fertilizer question. It also distinguishes between risk-seeking and risk-neutral preferences unlike the latter.

Taking advantage of the fact that both incentivized elicitation methods of risk aversion correctly predict behavior, we use the HL-like risk over gain variable as an instrumental variable for the incentivized fertilizer variable. This aims to correct for possible measurement errors that might explain the weak statistical significance observed above for the incentivized fertilizer variable. We find that the coefficient of the incentivized fertilizer variable is larger in magnitude, positive and statistically significant at 1%. This lends credence to our results and suggests that there might be value in eliciting risk aversion using more than one type of incentivized elicitation method to reduce potential measurement errors.

Column 6 indicates that ambiguity aversion is not an important parameter in the decision to use fertilizer. This result is similar to Ward & Singh, (2014) whose study among Indian farmers found that ambiguity aversion does not have any significant impact on the likelihood of choosing a new technology over the current one.[22] Considering that close to 50 percent of farmers in our sample have used fertilizer over the last ten years, the lack of explanatory power of the ambiguity aversion variable is not surprising. As discussed earlier, dissemination efforts in the regions of the study might have enabled farmers to learn about the probability distribution of the yields associated with the use of fertilizer.

Finally, column 7 indicates that loss aversion is not statistically significant and is not a good predictor of fertilizer use in our data. Other empirical studies however, have found loss aversion to be statistically significant for the adoption of new technologies. Liu (2012) found that if farmers perceive *Bt cotton* as ineffective at eliminating pests (as advertised by scientist), then more loss averse farmers tended to adopt the technology later. Hence, this result is not surprising because fertilizer is not a new technology.

As mentioned earlier, the initial sample used for the household survey was not completely random but partly purposive. In 2014, 400 more households were randomly selected and added to the initial sample. To confirm that our results are not driven by the non- random nature of the initial sample, we estimated the probit model using only the portion of the sample that was selected randomly.

[22] The discrete choice experiment for the adoption of new rice seeds in Ward and Singh (2014) was hypothetical.

The main study results for measures related to risk over gains are maintained. However, for this sub-sample, ambiguity aversion is positively and significantly correlated with the decision to use fertilizer at 5% level. This difference between the subsample and the larger sample is likely due to the fact that the initial sample (from 2004) was not random and those households have had more exposure to fertilizer than the rest of rural Niger Thus, these results confirms the role that knowledge and experience with the technology plays on farmers knowledge about the distribution of outcomes under the technology. It indicates that ex ante strategies such as farm extension services and demonstration trials could potentially help increase the take up rate of the technology.

Table 3: Probit regression results of the determinants of fertilizer use (use fertilizer=1)

Variables	(1) No measure of risk attitudes	(2) General risk question	(3) Hypothetical fertilizer	(4) Incentivized fertilizer	(5) HL-like risk over gains	(6) HL-like risk over ambiguity	(7) HL-like risk over losses
	Marginal coefficient						
Incentivized fertilizer				0.01486+			
HL-like risk over gains					0.01135***		
HL-like risk over ambiguity						0.00279	
HL-like risk over losses							0.00165
Hypothetical fertilizer			0.01185				
General risk question		0.00873					
Age	-0.02185*	-0.0201	-0.01733	-0.02128*	-0.02510**	-0.02180*	-0.02062
Age squared	0.00014	0.00013	0.0001	0.00014	0.00017	0.00014	0.00013
Formal education (1/0)	0.09849	0.13711	0.13623	0.10635	0.10472	0.10439	0.0997
Active farming (years)	-0.00171	-0.00201	-0.00144	-0.00169	-0.00255	-0.0017	-0.00177
Household size	0.00011	0.00192	0.00047	-0.00061	0.00228	0.00027	0.00005
Area allocated to crop (hectares)	0.00239	0.00405	0.00608	0.00192	0.00627	0.00335	0.00238
Distance to market (Kilometers)	0.00784	0.00802	0.00807	0.00754	0.00839	0.00727	0.00803
Value of livestock (in 10000 FCFA)	0.00092	0.00114	0.00055	0.00142	0.00039	0.00071	0.00072
Farmer organization member(1/0)	0.10638	0.08916	0.07725	0.11306	0.11052	0.10689	0.11021
Temperature (10*C)	-0.06117**	-0.05697**	-0.05264**	-0.06676**	-0.06168***	-0.06345**	-0.06146**
Annual precipitation (millimeters)	-0.00237	-0.00212	-0.00166	-0.00282	-0.00228	-0.00256	-0.00235

Organic fertilizer (1/0)	0.05693	0.04281	0.06936	0.03932	0.01205	0.04139	0.05711
Fertilizer price (in 10000 FCFA)	-12.84499*	-12.13103*	-10.6452	-14.13439*	-11.72172*	-13.24527*	-12.61335*
Fertile soil (1/0)	-0.05467	-0.05264	-0.02584	-0.06404	-0.0792	-0.06163	-0.05334
Extension (1/0)	0.10414	0.07017	0.052	0.11884*	0.12819**	0.10966*	0.10374
Number of observations	445	415	409	445	445	445	445

Note: +, *, ** *and *** represent significance at 15, 10, 5 and 1 percent level respectively*. *All regressions include village fixed effects.*

Choice of the fertilizer application technique conditional on fertilizer use

Table 4 presents the results from the conditional probit regression. It reveals that risk attitudes significantly affect farmers' decisions on which fertilizer application technique to use. We restrict our analysis here to the incentivized fertilizer and incentivized HL-like measures of risk attitudes given that they were the measures with explanatory power in the fertilizer probit regressions. We investigate two model specifications – one that includes the three HL-like measures of risk attitudes (column 1) and another that replaces the HL-like measure of *risk over gains* with the *incentivized fertilizer measure* but keeps the HL-like measures of ambiguity and loss aversion (column 2). The reported results in columns 1 suggest that less risk averse farmers tend to practice micro-dosing over mixing seeds with fertilizer. Loss aversion is not statistically significant. The results for the second specification are not statistically significant implying that HL-like risk over gains maybe a better predictor of behavior. This is consistent with our proposition stemming from the probit regressions whereby the HL-like risk over gains variable has a higher predictive power than the incentivized fertilizer variable.

Table 4 also indicates that higher temperature reduces the likelihood of mixing seeds with fertilizer compared to micro-dosing. This might be driven by a fear of seed burning. With mixing, the quantity of inorganic fertilizer combined with the seed has to be kept low in the seed pocket to avoid seed burning (Abdoulaye & Sanders, 2005). Lastly, the high cost of fertilizer encourages farmers to practice mixing and discourages the practice of micro-dosing. Since micro-dosing requires higher quantities of fertilizer compared to mixing, these results support that high fertilizer costs appear to be a barrier to the practice of micro-dosing.

Since we excluded plots with both micro-dosing and mixing for the analysis above, there might be concerns that our results are biased. Those concerns hold if we excluded plots with vastly different characteristics or if the plot managers behaved differently from the rest of the sample. Thus as a robustness check, we first re-categorize plots with both application methods using the main application method used on the plot. Second, we re-categorize plots with both methods as using micro-dosing and mixing. For both re-categorization, the main study results in Table 4 are maintained.

Table 4: Probit regression results of the determinants of fertilizer application technique conditional on fertilizer use (use micro-dosing=1)

	(1) *HL-like measures of risk attitudes*		*(2)* *Incentivized fertilizer, HL-like risk over ambiguity and losses*	
Variables	Marginal coefficients	P-value	Marginal coefficients	P-value
HL-like risk over gains	0.01686**	0.025		
HL-like risk over ambiguity	-0.00792	0.253		
HL-like risk over losses	-0.00865	0.126		
Incentivized fertilizer			**-0.01556**	**0.472**
HL-like risk over ambiguity			**-0.00092**	**0.883**
HL-like risk over losses			**-0.00526**	**0.358**
Age	0.02314	0.186	0.02524	0.194
Age squared	-0.00018	0.189	-0.00020	0.173
Formal education (1/0)	0.04088	0.665	0.01340	0.889
Active farming (years)	-0.01350***	0.001	-0.00974**	0.019
Household size	-0.00229	0.797	0.00110	0.907
Area allocated to crop (hectares)	0.00468	0.795	-0.00135	0.944
Distance to market (Kilometers)	0.00306	0.741	0.00296	0.777
Value of livestock (in 10000 FCFA)	-0.00254	0.569	-0.00125	0.773
Farmer organization member(1/0)	0.08580	0.552	0.09409	0.499
Temperature (10*C)	0.19978*	0.056	0.12795	0.109
Annual precipitation (millimeters)	-0.00109	0.604	-0.00123	0.560
Organic fertilizer (1/0)	0.26363***	0.004	0.28455***	0.003
Fertilizer price (in 10000 FCFA)	-98.19181***	0.001	-67.21660***	0.003
Fertile soil (1/0)	-0.08706	0.346	-0.07416	0.454
Extension (1/0)	0.05561	0.613	-0.00413	0.970
Number of observations	142		142	

Note: **, ** and *** represent significance at 10, 5 and 1 percent level respectively. All regressions include village fixed effects.*

5. Conclusion and policy implications

This paper explored the effect of risk attitudes on fertilizer use decisions in Niger. We find that a general risk question included in a household survey is not sufficient to capture risk attitudes and to explain adoption behavior. Our results indicate that context alone is not enough to overcome the lack of incentives. The measure of risk attitude elicited with a non-incentivized question framed in the context farmers are familiar with (fertilizer use) is not correlated with other measures of risk aversion and does not predict the adoption decision. However, our findings suggest that the use of incentives is important for eliciting risk attitudes in rural Niger and risk attitudes elicited with incentives are more likely to result in choices that more accurately reflect true underlying attitudes toward risk.

Our analysis of the effect of risk attitudes on technology adoption confirms that in general, risk aversion undermines the use of fertilizer. Using the measure elicited with the incentivized context specific question (which was the better predictor), we find that farmers who are more risk averse have a lower likelihood of using fertilizer and are also less likely to practice micro-dosing. While ambiguity aversion does not appear to matter in the decision process leading to the practice of micro-dosing or mixing seeds with fertilizer, our results indicate that it is likely to be important in areas where farmers have less experience using fertilizer. The analysis further demonstrates that high fertilizer costs tend to dissuade farmers from using fertilizer in general and from practicing micro-dosing in particular.

These findings have important policy implications. First, we have shown that risk aversion matters among Nigerien farmers. Consequently, it is important to consider ex-post policies like crop insurance programs, to increase their likelihood of using fertilizer and promote the practice of fertilizer micro-dosing. Credit facilities and measures to solve the liquidity problem at planting could increase fertilizer use and enable farmers to take advantage of the higher yields resulting from the practice of micro-dosing. Nigerien policy makers could develop or revive credit systems such as the *warrantage or inventory credit system*. The warrantage system provides credit to farmers at harvest time, using part of their production pledged as collateral (Pender et al., 2008).

Further research on the profitability of micro-dosing compared to mixing fertilizer with seeds is necessary. This would provide additional insights into the low adoption rates of micro-dosing. At the least, it might enable us to understand whether most Nigerien farmers are not adopting micro-dosing because it is not an optimal investment decision given the profitability of its used within existing safety nets.

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Appendices

Figure A- 1: Incentivized and hypothetical fertilizer elicitation table

			Many days of **good** growing temperature 50% likely 				Many days of temperatures **too hot** for growing 50% likely 			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Option	Fertilizer 1 (New) (2kg **sachets**)	Fertilizer 2 (traditional) (2kg **sachets**)	Plot yield with no fertilizer (**100 kg bags**)	Yield Increase from Fertilizer 1	Yield Increase from Fertilizer 2	Total Plot Yield (**100 kg bags**)	Plot yield with no fertilizer (**100 kg bags**)	Yield Increase from Fertilizer 1	Yield Increase from Fertilizer 2	Total Plot Yield (**100 kg bags**)
A	0	10	5	0	10	15	5	0	10	15
B	1	9	5	3	9	17	5	0.10	9	14.1
C	2	8	5	6	8	19	5	0.2	8	13.2
D	3	7	5	9	7	21	5	0.3	7	12.3
E	4	6	5	12	6	23	5	0.4	6	11.4
F	5	5	5	15	5	25	5	0.5	5	10.5
G	6	4	5	18	4	27	5	0.6	4	9.6
H	7	3	5	21	3	29	5	0.7	3	8.7
I	8	2	5	24	2	31	5	0.8	2	7.8
J	9	1	5	27	1	33	5	0.9	1	6.9
K	10	0	5	30	0	35	5	1	0	6

Figure A- 2: Map of households in the sample

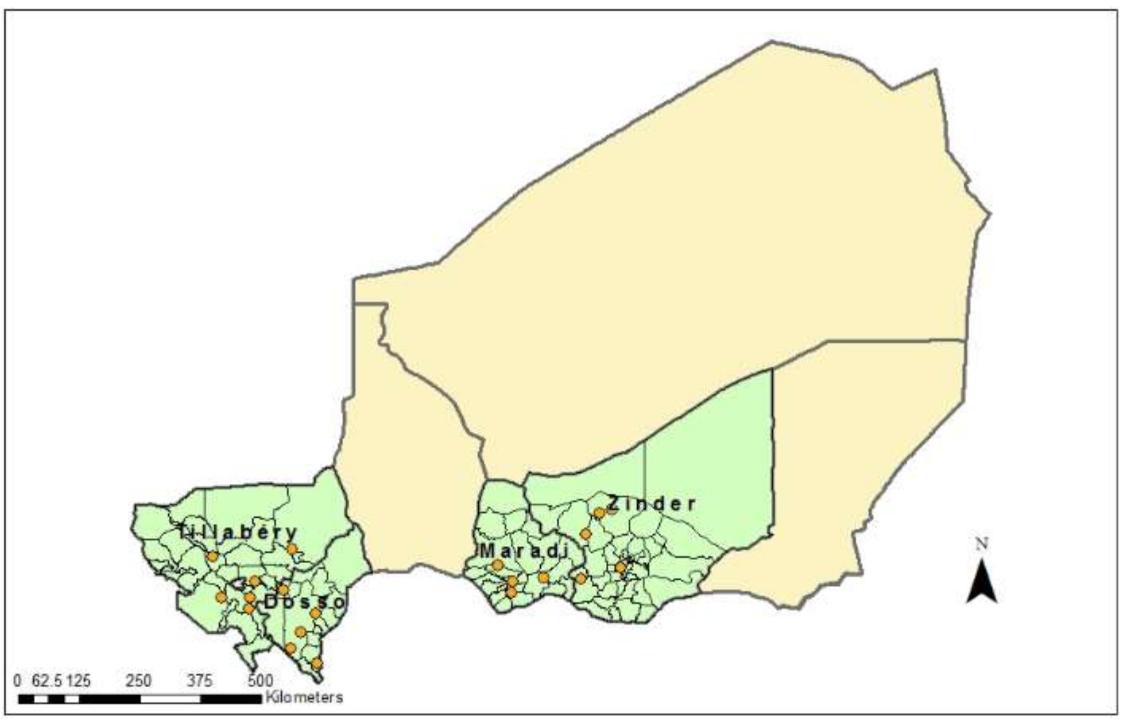

Figure A- 3: Distribution of responses for the hypothetical and incentivized fertilizer experiments

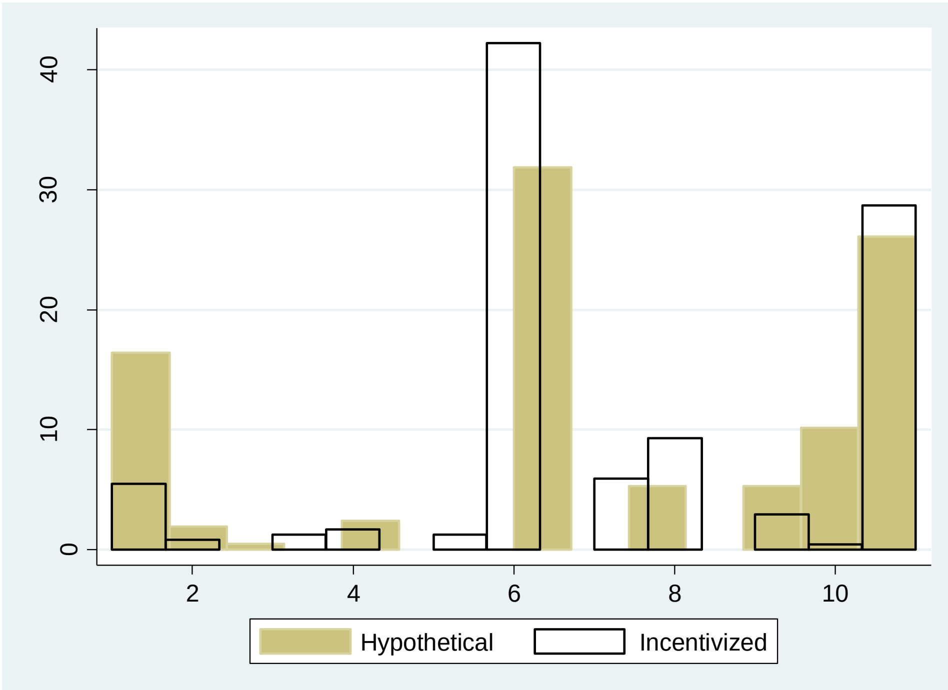

Table A- 1: Elicitation of risk over gains and risk over ambiguity

Decision Number	Option A – Chance to draw a ball		Option B
	If Orange ball	If White ball	
1	CFA 1200	CFA 0	CFA 60 for sure
2	CFA 1200	CFA 0	CFA 120 for sure
3	CFA 1200	CFA 0	CFA 180 for sure
4	CFA 1200	CFA 0	CFA 240 for sure
5	CFA 1200	CFA 0	CFA 300 for sure
6	CFA 1200	CFA 0	CFA 360 for sure
7	CFA 1200	CFA 0	CFA 420 for sure
8	CFA 1200	CFA 0	CFA 480 for sure
9	CFA 1200	CFA 0	CFA 540 for sure
10	CFA 1200	CFA 0	CFA 600 for sure
11	CFA 1200	CFA 0	CFA 660 for sure
12	CFA 1200	CFA 0	CFA 720 for sure
13	CFA 1200	CFA 0	CFA 780 for sure
14	CFA 1200	CFA 0	CFA 840 for sure
15	CFA 1200	CFA 0	CFA 900 for sure
16	CFA 1200	CFA 0	CFA 960 for sure
17	CFA 1200	CFA 0	CFA 1020 for sure
18	CFA 1200	CFA 0	CFA 1080 for sure
19	CFA 1200	CFA 0	CFA 1140 for sure
20	CFA 1200	CFA 0	CFA 1200 for sure

Note: HL-like risk over gains - subjects choose between a risky Option A (CFA 0.00 or CFA 1,200 with 50% chance) or a safe Option B (a certain amount for sure) . HL-like risk over ambiguity- subjects choose between an ambiguous Option A (CFA0 0 or CFA 1,200 with unknown chance) or a safe Option B (a certain amount for sure)

Table A- 2: Elicitation of risk over losses

Decision Number	Option A – Chance to draw a ball		Option B
	If Orange ball	If White ball	
1	LOSE CFA 120	CFA 1200	CFA 0 for sure
2	LOSE CFA 240	CFA 1200	CFA 0 for sure
3	LOSE CFA 360	CFA 1200	CFA 0 for sure
4	LOSE CFA 480	CFA 1200	CFA 0 for sure
5	LOSE CFA 600	CFA 1200	CFA 0 for sure
6	LOSE CFA 720	CFA 1200	CFA 0 for sure
7	LOSE CFA 840	CFA 1200	CFA 0 for sure
8	LOSE CFA 960	CFA 1200	CFA 0 for sure
9	LOSE CFA 1080	CFA 1200	CFA 0 for sure
10	LOSE CFA 1200	CFA 1200	CFA 0 for sure
11	LOSE CFA 1320	CFA 1200	CFA 0 for sure
12	LOSE CFA 1440	CFA 1200	CFA 0 for sure
13	LOSE CFA 1560	CFA 1200	CFA 0 for sure
14	LOSE CFA 1680	CFA 1200	CFA 0 for sure
15	LOSE CFA 1800	CFA 1200	CFA 0 for sure
16	LOSE CFA 1920	CFA 1200	CFA 0 for sure
17	LOSE CFA 2040	CFA 1200	CFA 0 for sure
18	LOSE CFA 2160	CFA 1200	CFA 0 for sure
19	LOSE CFA 2280	CFA 1200	CFA 0 for sure
20	LOSE CFA 2400	CFA 1200	CFA 0 for sure

Note: Subject choose between a risky Option A (which has 50% chance of losing a certain amount CFA 1,200) or a safe Option B (CFA 0 for sure)

Table A- 3: Spearman's rank correlation between socio-demographic characteristics and general risk question

Variables	(1) General risk question in this study	(5) General risk question in Hardeweg et al (2013)
Age (years)	-0.0837	-0.171***
Female (0/1)	-0.1463**	-0.010
Formal education (0/1)	0.0895	0.146***
Value of livestock (in 10000 FCFA)	0.0482	0.029
Married	0.0227	0.041
Leader in community (0/1)	0.1136*	
Household size	0.0633	0.022
Number of years farming	-0.0806	
Farmer organization member(1/0)	0.1873*	

Note: **, ** and *** represent significance at 10,5 and 1 percent level respectively. The reader should note that although some of the variables are not measured in the same way they still capture similar socio-demographic characteristics. The general risk question in this study correlates well with socio-demographic characteristics and is mostly aligned with findings from the literature.*

Table A- 4: Definition of variables used in the analyses

	Definition
Dependent variables	
General risk question	Equal to the number the respondent chooses on the 4-point Likert scale (no monetary payoffs)
Hypothetical fertilzer	Equal to the number of bags of risky fertilizer chosen by the respondent for a total of 10 bags (no monetary payoffs)
Incentivized fertilizer	Equal to the number of bags of risky fertilizer chosen by the respondent for a total of 10 bags (no monetary payoffs)
HL-like risk over gains	Switching row in the experiment from 0 to 20, where 0 is choosing the safe payoff for all decisions and 20 the risky option for all decisions
HL-like risk over ambiguity	Switching row in the experiment from 0 to 20, where 0 is choosing the safe payoff for all decisions and 20 the risky option for all decisions
HL-like risk over losses	Switching row in the experiment from 0 to 20, where 0 is choosing the safe payoff for all decisions and 20 the risky option for all decisions
Independent variables	
Age	Age of plot manager
Formal education (1/0)	Equal 1 if household head received primary, secondary or university education
Active farming (years)	Number of years the farmer practiced farming
Household size	Number of people in household
Farmer organization member (1/0)	Equal 1 if the farmer belongs to a farmer organization
Area allocated to crop (hectares)	Plot area allocated to crops cultivation in hectares
Distance to market (Kilometers)	Distance from plot to nearest principal market (kilometers)
Value of livestock (‘000 FCFA)	Average current market value of livestock owned by the household in ‘000 of FCFA
Organic fertilizer (1/0)	Equal 1 if the farmer applies manure on the plot
Temperature (10*C)	Mean temperature of wettest quarter (10*C)
Annual precipitation (millimeters)	Annual Precipitation in millimeters
Fertilizer price (10,000 FCFA)	Price of fertilizer at the village level in 10,000 FCFA
Fertile soil (1/0)	Equal 1 if the farmer qualifies the soil as medium of good quality
Extension (1/0)	Equal 1 if the main source of information about fertilizer is from government extension agent or development projects