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Adoption of an improved bean seed variety and consumption of beans in rural Madagascar: Evidence from a randomised control trial

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Abstract

This paper studies access to, and adoption of improved seed, as well as the diffusion of improved seed information in a remote area of central Madagascar. The analysis is based on panel data gathered from 2012 to 2014 from 390 households in three villages. In 2013, a randomised control trial was applied. Half of the 390 households were randomly assigned to receive improved lima bean seed (*Phaseolus lunatus*), which were specifically bred for dry regions. Of the seed-receiving households, 50 % were randomly assigned to receive information on how to store, plant, and cultivate the improved seed, as the variety was unfamiliar in the region. The control group and the two treatment groups are compared with respect to baseline characteristics, bean cultivation, information exchange with other farmers, legume consumption, and willingness to pay (WTP) for improved bean seed. To account for non-compliance, contamination and spillover effects, local average treatment effects (LATE) are estimated. Of the seed-receiving households, 54 % cultivated the seed, reaping an average yield of 6.3 kg per kg of seed obtained. Seed information did not lead to higher yields. A small significant positive impact of seed distribution on legume consumption is found. WTP is 171 % of the local market price for bean seed, free provision of seed and information did not result in a higher WTP.

Keywords: information dissemination, legumes, local average treatment effects, technology adoption, willingness to pay

1 Introduction

Agricultural productivity in Madagascar is low due to climate hazards and limited adoption of improved agricultural technologies. This limited adoption is attributed to: labour and liquidity constraints at planting time (Moser & Barrett, 2003, 2006); increased prices and high transaction costs for inputs due to remoteness and poor transport infrastructure (Stifel & Minten, 2008; Minten *et al.*, 2013); and risk aversion, social conformity, and customs (Moser & Barrett, 2003; Barrett *et al.*, 2004; Barrett, 2008; Stifel *et al.*, 2011). In addition to the low demand from farmers, low supply and the resulting limited access to agricultural inputs are constraints to adoption (Minten *et al.*, 2013).

This low supply and uptake of technologies has also been studied in the seed market and through the lens of seed aid as a disaster response (Sperling *et al.*, 2008). Several authors (Alemayehu, 2009; Sperling & McGuire, 2010; Katungi *et al.*, 2011b) argue that informal seed markets, while not fully understood, present a potential for more, higher quality, and more diversified seed. Establishing links between variety innovators and those who can multiply and distribute seed at affordable prices, is suggested. Newly created seed material could be delivered directly to important community-

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based nodes, instead of solely to parastatal and commercial entities (Sperling *et al.*, 2008; Gibson, 2013).

Randomised control trials to study adoption and diffusion of improved agricultural technologies are increasingly popular (Banerjee & Duflo, 2008; Duflo *et al.*, 2008; Barrett & Carter, 2010). Some of the experiments showed that rates of return of improved agricultural technologies, like improved seed or fertiliser, are not as positive in real world situations as they are in demonstration plots or controlled conditions (Vandercasteelen *et al.*, 2013; Bulte *et al.*, 2014). One study found positive impacts on yields, but not on profits (Beaman *et al.*, 2013). Fixed costs, including the psychological costs of changing habits, might be substantial (Duflo *et al.*, 2011). A growing number of studies is testing how information can best be disseminated among farmers (Hotz *et al.*, 2012; Vasilaky, 2013; Culbertson *et al.*, 2014).

Under- and malnutrition is prevalent in Madagascar, where 33 % of the population is undernourished (FAOSTAT, 2015). Calories are mainly obtained from staple foods, such as rice and cassava. Given the poor diets, hidden hunger is widespread. The share of cereals, roots and tubers in Madagascar's dietary energy supply was 79 % in 2011, which is by far the highest value globally. At 48 g per capita per day, protein intake is very low and is less than the average of all least developed countries (FAOSTAT, 2011). Higher dietary diversity among Malagasy children is highly correlated with micronutrient intake (Moursi *et al.*, 2008). Legumes improve diets by adding essential vitamins and minerals, especially iron, and are high in protein and dietary fibre (Aykroyd & Doughty, 1982).

The lima bean (*Phaseolus lunatus* / *kabaro* in Malagasy) is a perennial plant that achieves highest yields in the hot and humid tropics. Lima beans are tolerant to mild drought, high temperatures, and poor soils. In Madagascar, mean yield is one ton per hectare (Ministry of Agriculture, 2004). To raise yield and quality, a research station of FOFIFA (National Centre of Applied Research and Rural Development) in Toliara, southwestern Madagascar, is developing an improved variety (personal interview with FOFIFA representative, 2014).

Willingness to pay (WTP) can be defined as the amount of money an individual assigns to the benefits or costs of a particular product or service. WTP surveys have often been used to assess social benefits of environmental policies or projects. The application to private goods, like agricultural products, is rather uncommon, as these goods are traded in markets and have observable prices. However, when it comes to the assessment of non-traded goods or value components that are not (yet) reflected by real market data, WTP surveys are a useful tool. Recent studies assess WTP for improved or certified seed (Dalton *et al.*, 2011; Kaguongo *et al.*, 2014; Kassie *et al.*, 2014), traditional and locally produced foods (Chelang'a *et al.*, 2013), fertiliser (Minten *et al.*, 2007), and extension services (Ulimwengu & Sanyal, 2011).

This paper explores the impact of seed and seed information distribution on yield, willingness to pay and consumption, for the case of lima beans. The following research questions are addressed: (1) If seed is distributed for free, do households plant or consume it? (2) Does the inclusion of agronomic information with the distributed seed increase seed utilisation and bean yield? (3) How much are farmers willing to pay for improved seed? (4) Does the inclusion of agronomic information with the distributed seed increase the willingness to pay for improved seed? (5) Does seed receipt and bean cultivation increase legume consumption?

2 Materials and methods

2.1 Randomised control trial: sampling strategy and study design

The study was carried out within the framework of a household panel that ran from 2009 to 2014 in three villages in the community of Fenoarivo, which belongs to the district of Ambalavao in the Haute Matsiatra region (Fig. 1). Fenoarivo is the local centre of administration, is connected with transport, and hosts a weekly market. The other two villages in the sample, Maroilo and Sakafia, are eight and twelve kilometres away from Fenoarivo, respectively.

Baseline characteristics originate from a household survey that took place between December 2012 and February 2013. Bean seed was obtained from the research station of FOFIFA in Toliara and distributed during a second survey from September to November 2013. Of the 390 eligible households in the panel, 196 (50 %) were randomly assigned to receive 0.6 kg of bean seed [1]. Of those, 84 (43 %) were randomly assigned to receive detailed information on how to store and cultivate the seed, following recommendations by the Ministry of

[1] Households received 1.5 *kapoaka* of beans. *Kapoaka* is a common expression for milk tins used to measure amounts of various items. For beans, 1 *kapoaka* is equivalent to approximately 390 g.

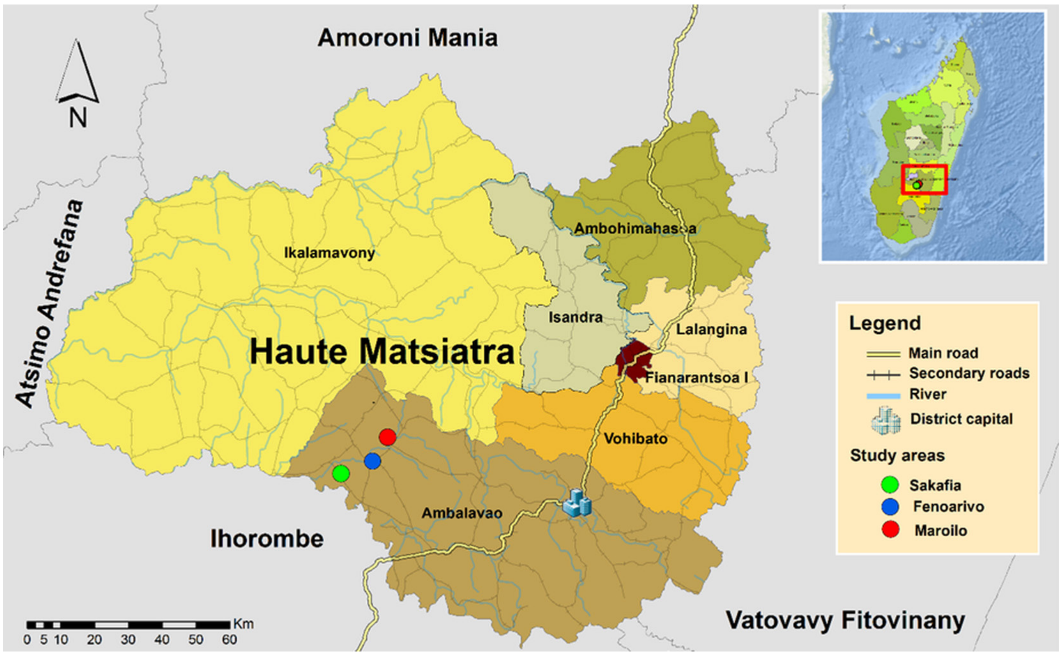

Fig. 1: *Map of the study area.*

Agriculture (2013). It was recommended to plant the seed in April 2014 and to harvest in September/October 2014.

From November to December 2014, after the harvest of the beans, a follow-up survey and additional focus group discussions were carried out. Net-maps, a participatory, interview-based mapping technique developed by Schiffer & Hauck (2010), were used to enable participants to visualize and discuss the bean seed market, the actors involved, their linkages, their importance and influence, and their individual objectives, as well as existing knowledge about and attitudes towards improved seed. Because of the remoteness of the research area, not all actors involved could be present. Representatives of the agricultural extension service and the research station of FOFIFA in Toliara were interviewed separately.

2.2 *Descriptive statistics*

The baseline characteristics used in this study are variables that are expected to influence the adoption of lima bean seed and related production and consumption outcomes. In addition to demographic and agricultural characteristics, this includes information on innovations and social capital of the households. Innovations were elicited for five years prior to the interview and include dummies for five categories, namely crop diversification, technology adoption, access to new markets and traders, as well as innovations in work organisation, resulting in a score ranging from 0 to 5 innovations (Hartmann & Arata, 2011). The index on social capital comprises seven questions on trust, honesty, and willingness to help in the villages. Answers range from full agreement (1) to no agreement at all (5) on a Likert scale. The index is the mean of the seven answers. Attitudes towards work are elicited using the question “Can hard work improve your living standard?”.

Some villagers have cultural taboos (*fady* in Malagasy) concerning certain bean types that prohibit consumption, cultivation, or talking about the beans, since they are believed to inhibit rainfall or successful prevention of cattle rustling. Common beans (*Phaseolus vulgaris* / *tsaramaso* in Malagasy) are widely cultivated in the area and not considered as taboo for the village fields. Apart from a climbing variety grown in home gardens, lima beans were an unknown bean species in the villages and it was unknown whether they are assigned with a taboo when grown in fields. Therefore, as a proxy, we use taboos for bambara groundnut (*Vigna subterranea* / *voanjobory* in Malagasy), a legume introduced from West Africa and widely believed to inhibit rainfall if cultivated in village fields.

In the follow-up survey, the following issues were examined in the control and the two treatment groups (seed-only and seed-and-information-receiving households): seed utilisation, problems during cultivation, the importance and diffusion of information, potential spillover effects regarding this information, evaluation of and WTP for improved seed, and bean consumption. For yield the seed multiplication rate is used as an operational proxy variable, given in kg per kg of seed. Lima bean and legume consumption data were elicited for different recall periods. Ravallion (2008) and Deaton (2010) recommend the use of intermediate indicators, in addition to outcome indicators, to understand the processes determining impacts. Descriptive statistics are based on the initial assignment of the households to the three groups. Statistical differences for categorical variables were determined with the help of chi-square tests, and for ordinal and interval variables with Kruskal-Wallis tests. The Wilcoxon rank-sum test served as the post-hoc test. All tests were done with STATA.

The contingent valuation method (CVM) is a survey-based method to elicit WTP which does not rely on experimental or real purchase decisions (Whittington, 1998; Bateman *et al.*, 2002). Potential buyers are asked how much they would be willing to pay for the product contingent on a description of an alternative or a hypothetical scenario. Following Haab & McConnell (2002), enumerators described the benefits of improved bean seed (yield roughly twice that of locally available beans, higher pest and disease resistance, and higher drought tolerance) and explained the need to pay. Due to the fact that lima beans were assigned with a taboo, households were given the choice between lima and common beans. Enumerators then showed the household a so-called payment card with a list of price ranges, ordered from lowest to highest. The lower bound was set roughly double the price of bean seed available at the local market. The household was asked to pick the range that included the maximum amount they were willing to pay. WTP is estimated by taking the mean value of these price ranges. Compared with open questions, the payment card has the advantage that it offers respondents a visual aid for the choice.

To check for the reliability of stated WTP, additional questions were included: “Do you think the seed would be available at the market?”, “What amount of seed would you buy for the indicated price?”, and “Would you be able to afford the seed at the indicated price?”.

2.3 *Empirical strategy*

Impact evaluation generally aims to assess a program’s effect against a counterfactual, showing the situation in the absence of the program (Rubin, 1974; Ravallion, 2008). Random assignment of households to a treatment group seeks to ensure that the control group is a valid counterfactual and allows simple comparisons of outcomes. If there are no differences in household characteristics between the control and treatment groups at baseline, any changes of outcomes can be attributed solely to the program. Significant differences in baseline characteristics could indicate a problem in the random assignment of treatment.

The average treatment effect (ATT) is the average gain of households from having received the seed, whether they received them from an enumerator or from another household, ignoring random assignment to treatment groups. By adding control variables, heterogeneity of impacts for observed control variables can be estimated as:

$$y_i = \beta_0 + \beta_1 treated_1 + \beta_2 treated_2 + \beta_i x_i + \varepsilon_i \,,$$

where y_i are the outcome indicators (lima bean yield, consumption, and WTP) $treated_1$ and $treated_2$ are dummy variables for seed and information received, β_1 and β_2 are the respective treatment effects, x_i are household characteristics at baseline, β_i the respective coefficients, and ε_i the error term (Ravallion, 2008). Ceteris paribus, the regression model predicts how a unit change in an explaining variable would increase (or decrease) the outcome variable. ATT is likely to be overestimated as it is subject to self-selection. Control households that received seed might differ from the average household, for example in bean production experience. The intention-to-treat estimate (ITT) approximates the average treatment effect on those intended to treat with random assignment:

$$y_i = \beta_0 + \beta_1 treat\_intended_1 + \beta_2 treat\_intended_2 + \beta_i x_i + \varepsilon_i \,,$$

where $treat\_intended_1$ and $treat\_intended_2$ are dummy variables for the assignment to seed and information receipt. ITT is likely to be underestimated, as not all households intended to treat actually received, kept, and cultivated the seed. In the latter case, outcomes do not just depend on random assignment, but also on purposive assignment of others. Selective compliance and contamination into the control group can lead to biased estimates of the impacts of treatment. Imbens & Angrist (1994) showed that an average treatment effect under mild restrictions (local average treatment effect – LATE) can still be identified, even when there is no subpopulation for whom the probability of treatment is zero. Using assignment to treatment in a randomised trial as an instrument variable, LATE requires three conditions to be held: (1) eligibility for the treatment group has to be exogenous that is held under random assignment by the design of the study, (2) the use of an instrument requires an exclusion restriction, meaning that random assignment to treatment only affects outcomes through ac-

Table 1: *Household characteristics at baseline in 2012/2013.*

	Seed-and-information (*n* = 112)	*Seed-only* (*n* = 84)	*Control group* (*n* = 194)	*Total* (*n* = 390)
Age of household head (years)	44.3 (12.5)	47.1 (15.4)	46.6 (14.0)	46.0 (14.0)
Education of household head (years)	4.5 (3.2)	4.1 (3.3)	4.2 (3.1)	4.3 (3.2)
Maximum education among household members (years)	6.3 (3.3)	6.1 (3.1)	6.8 (3.3)	6.5 (3.3)
Household size (n)	6.0 (2.4)	6.0 (2.5)	6.3 (2.8)	6.1 (2.6)
Household members in working age (n)	4.0 (1.8)	3.8 (2.0)	4.4 (2.4)	4.1 (2.1)
Dependents in household (n)	2.2 (1.4)	2.3 (1.3)	2.3 (1.4)	2.3 (1.4)
Legume consumption (number of days, past 7 days)	1.9 (1.7)	2.0 (2.0)	2.0 (2.0)	1.9 (1.9)
Dietary diversity (7 days)	43.1 (13.4)	44.7 (13.4)	44.0 (14.0)	43.9 (13.4)
Cultivated land per capita (ha)	0.4 (0.5)	0.3 (0.4)	0.3 (0.4)	0.4 (0.4)
Seasonally flooded land (dummy)	0.5 (0.5)	0.6 (0.5)	0.6 (0.5)	0.6 (0.5)
Wealth self-assessment (1–10)	4.0 (1.7)**	3.5 (1.4)	3.7 (1.7)	3.7 (1.6)
Cattle per capita (n)	1.3 (2.7)*	0.8 (1.3)	1.0 (2.2)	1.0 (2.2)
Agricultural equipment (dummy)	0.7 (0.5)	0.6 (0.5)	0.6 (0.5)	0.6 (0.5)
Bean production (kg per household)	27.6 (67.0)	29.0 (75.7)	28.3 (54.8)	28.2 (63.4)
Legume types cultivated (n)	1.5 (1.0)	1.5 (1.1)	1.5 (1.0)	1.5 (1.0)
Selling crops to trader (dummy)	0.9 (0.3)	0.9 (0.4)	0.9 (0.4)	0.9 (0.3)
Legume sales revenue (year, in EUR)	11.2 (37.1)	8.4 (17.7)	9.4 (34.6)	9.7 (32.3)
Innovations (number, last 5 years)	1.9 (1.0)	1.7 (1.1)	1.8 (1.1)	1.8 (1.1)
Taboo for at least one bean species (dummy)	0.5 (0.5)	0.5 (0.5)	0.4 (0.5)	0.4 (0.5)
Cultivation of bambara groundnut until 2013 (dummy)	0.4 (0.5)	0.3 (0.5)	0.4 (0.5)	0.4 (0.5)
Attitude towards work (mean agreement, 1–5)	4.0 (1.0)	4.1 (0.8)	3.9 (1.0)	4.0 (1.0)
Social capital (mean agreement, 1–5)	2.8 (0.5)	2.8 (0.5)	2.7 (0.5)	2.8 (0.5)

Numbers in parenthesis indicate standard deviations. ** (*) indicates differences at the 5 % (10 %) significance level.

tual participation in the program, (3) anyone who would take the treatment if assigned to the control group would also take treatment if assigned to the treatment group. If these conditions are met, LATE is the average treatment effect for those households that always comply with their assignment and for those whose treatment status is changed by the instrument (Angrist *et al.*, 1996; Ravallion, 2008). Instrumental-variable regressions are estimated with the help of the ivreg2 command in Stata (Baum *et al.*, 2007).

3 Results

3.1 Baseline characteristics

Table 1 compares household characteristics at baseline between the two treatments (seed-only and seed-and-information-receiving households) and the control group. Because of randomization, we expect that there are no significant differences between the groups. This holds true for all variables, except for subjective wealth and the possession of cattle. Wealth is significantly correlated with cattle, an important status symbol in the region. The significant difference is based on two verified outliers with 20 cattle per capita that were assigned to control and seed-and-information-receiving group, respectively. In the 2012/2013 season, 83 % of households planted one or more types of legume, and for the 34 % that sold legumes in 2013, average sales amounted to 10.2 EUR[2]. Legumes are also important for consumption: in September 2013, they were consumed two days per week on average. The households that bought legumes at the market (27 %) spent an average of 0.4 EUR per week. Almost half of the households reported a taboo for bambara groundnut. However, by 2013, 38 % of households were growing it.

3.2 Utilisation and cultivation of bean seed

Of the 390 panel households, 354 were revisited to evaluate the seed distribution. The remaining 36 households had moved away, or were not available in the survey period (Table 2).

[2] Euro (EUR) values in this paper are converted from Malagasy Ariary (MGA) using official yearly averages: 1 EUR = 2,945 MGA (2013) and 3,273 MGA (2014).

Table 2: *Household attrition after baseline survey and seed distribution.*

	Seed-and-information	*Seed-only*	*Control group*	*Total*
Households in baseline survey (2013)	112	84	194	390
Households dropping out	6	12	18	36
Households in follow-up survey (2014)	106	72	176	354

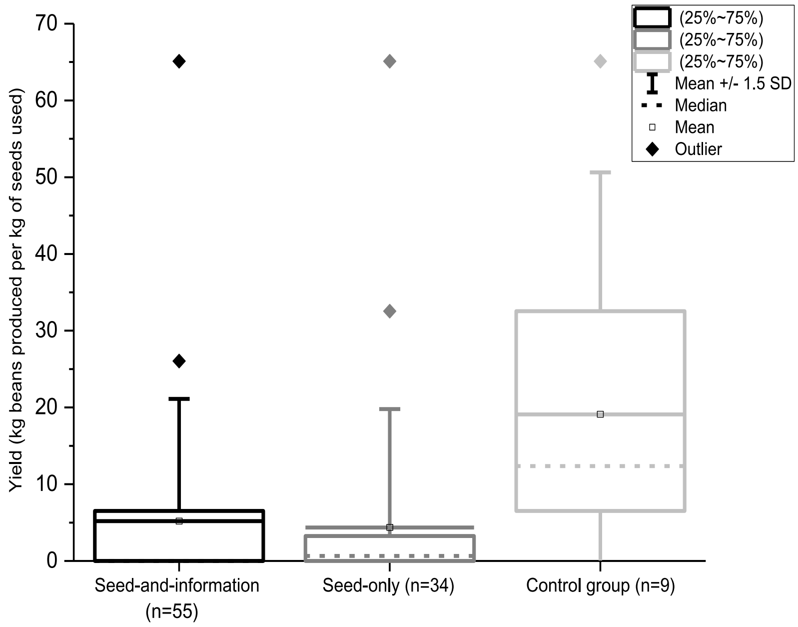

Fig. 2: *Yield of lima beans, 2014.*

At baseline in 2013, 88 % of the 390 households stated planting the seed, if given, 1.2 % would give the seed to another person, and 1.8 % rejected the seed due to taboos or would cook them. In 2014, 98 out of the 354 revisited households reported having cultivated the received seed, mostly out of curiosity and with the objective of home consumption or as food for agricultural labourers. Seed-and-information-receiving households (n = 55, 52 %) were not significantly more likely to cultivate the seed than seed-only-receiving households (n = 34, 45 %). Nine control households (5 %) reported having received lima bean seed from other sources (neighbours, family, friends) and cultivated these. Insect damage (50 %), consumption of seed (41 %), or taboos were reported as main reasons for not planting, with no significant differences between the groups. Three households reported having replaced other legumes, the remaining households said they cultivated the seed in addition to existing legumes. Women were more involved in bean cultivation than man, with no significant differences between the groups.

Seed quality, seeding, cultivation, and yield of lima beans were evaluated as better than average and better than other legumes. Control households planting lima beans perceived cultivation compared with other legumes to be significantly easier than treatment households. The average yield was 6.3 kg beans per kg of seed used. Taking out those households that did not achieve any yield (48 %), gives an average yield of 12.2 kg per kg of seed. Control households planting lima beans achieved a significantly higher yield, whereas information provision did not result in a higher yield (Fig. 2).

The most cited reasons for low yield were drought and destruction of the plants by cattle or insects, with no significant difference between the groups. Of the legume-cultivating households, 63 % rated climatic conditions for legumes in 2014 “much worse” or “worse” than in the past five years.

3.3 *Information dissemination*

Of the information-receiving households, 83 % rated the given information as useful. For 80 % of those households, the information was sufficient. Out of the seed-and-information-receiving group, significantly more households (20 %) also received information from others, compared with 12.5 % of the seed-only-

Table 3: *Local average treatment effect (LATE) of information provision on lima bean yield.*

	LATE	*LATE with controls*
Seed-only	3.87 (2.1)*	4.29 (2.0)**
Seed-and-information	−1.45 (2.1)	−1.18 (2.0)
Age of household head (years)		0.07 (0.05)
Maximum education among household members (years)		−0.07 (0.4)
Dependency ratio (dependent members/members in working age)		3.40 (1.0)***
Gender of household head (dummy)		−1.14 (1.7)
Willingness to take risks (self-assessment, 1–10)		0.36 (0.3)
Cultivated land per capita (ha)		−0.80 (1.5)
Legume types cultivated (*n*)		0.28 (0.6)
Selling crops to trader (dummy)		−4.15 (1.9)**
Innovations (number in the last 5 years)		1.29 (0.6)**
Adjusted R^2		0.12
N		354

Numbers in parenthesis indicate standard deviations. *** (**) (*) indicates significance at the 1 % (5 %) (10 %) level.

Table 4: *Consumption of lima beans and legumes, differentiated by recall period, 2014.*

	Seed-and-information (*n* = 106)	*Seed-only* (*n* = 76)	*Control group* (*n* = 172)	*Total* (*n* = 354)
Lima bean consumption (dummy, 12 months)	0.6 (0.5)***	0.6 (0.5)***	0.3 (0.4)	0.5 (0.5)
Legume consumption (dummy, 12 months)	0.9 (0.4)	0.8 (0.4)	0.8 (0.4)	0.8 (0.4)
Legume consumption (*n*, 7 days)	3.2 (2.4)	3.4 (2.5)	3.2 (2.5)	3.3 (2.4)
Legume consumption from own production (dummy, 7 days)	0.7 (0.5)	0.8 (0.4)	0.7 (0.5)	0.7 (0.5)
Expenditures for legumes (EUR, 7 days)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)

Numbers in parenthesis indicate standard deviations. *** indicates difference at the 1 % significance level.

receiving households. Households receiving additional information from sources other than the enumerators, achieved a significantly higher yield. Most reported information sources were family (49 %), neighbours (43 %), and friends (8 %). Only 7 % of the control households were informed about the new bean variety.

Significantly more seed-and-information-receiving households (74 %) planted the bean seed on seasonally flooded fields next to a river or rice fields, as advised in the included information. Seed-only-receiving households planted mostly on other fields (62 %), and the control households mostly next to the house (56 %). Yet the planting location had no significant impact on reported bean yield.

Table 3 shows the impact of seed and information distribution on lima bean yield. The regression models do not predict a significant impact of information on yield. Adding control variables shows that next to seed distribution, a household's willingness to take risks and innovations are positive and significant predictors of yield. Dependency ratio and access to traders are negative predictors of yield.

3.4 Consumption

Almost all households (98 %) reported consuming their harvested beans. Seven households saved seed for the next cultivation period and two households sold parts of their harvest. No significant differences with respect to the use of the harvested crop between the three groups could be detected.

Of the 354 households, 45 % stated having eaten lima beans in the past year. Control households were significantly less likely to consume lima beans than treatment households. No significant differences could be detected when looking at legume consumption in general in the week prior to the interview (Table 4).

Table 5: *Local average treatment effect (LATE) of seed distribution on legume consumption.*

	LATE	*LATE with controls*
Seed-only	0.63 (0.47)	0.89 (0.5)**
Seed-and-information	−0.49 (0.47)	−0.67 (0.5)
Education of household head (years)		0.03 (0.1)
Dependency ratio (dependent members/members in working age)		−0.28 (0.2)
Gender of household head (dummy)		−1.04 (0.4)***
Agricultural equipment (dummy)		−0.57 (0.3)*
Crop diversity (number of different crops)		0.11 (0.04)***
Selling crops to trader (dummy)		−0.47 (0.4)
Livestock sales (dummy)		0.48 (0.3)*
Income from own business (dummy)		−0.79 (0.3)***
Income from agricultural labour (dummy)		−0.85 (0.3)***
Access to mutual help (dummy)		0.50 (0.3)
Adjusted R^2		0.05
N		354

Numbers in parenthesis indicate standard deviations. *** (**) (*) indicates significance at the 1 % (5 %) (10 %) level.

Table 5 shows the impacts of seed distribution on the frequency of legume consumption in the past seven days before the interviews. When controlling for household characteristics, a significant positive impact of seed distribution on legume consumption is observed.

3.5 *Willingness to pay*

More than half (58 %) of the farmers stated they usually produce their own legume seed, 30 % of the farmers said they usually buy their seed at the market, 10 % buy them from other farmers, and the rest mostly receive seed from family members. In total, at least once in the last five years, 49 % of all households cultivating legumes bought seed at the market, 64 % used their own seed, and 21 % bought from other farmers in the village. The net-maps compiled during focus group discussions in 2014 (Fig. 3) show the most important seed and information sources.

The Malagasy agricultural extension service, Centre de Services Agricoles (CSA), an NGO funded by the European Union and managed by local officials, is distributing improved seed to farmers. It aims to increase agricultural productivity by linking service demands of farmers with appropriate service providers, operating in the rural districts, and training village representatives (Ministry of Agriculture, 2015).

In the district capital Ambalavao, CSA provides free samples of improved rice and bean seed, for which farmers can apply directly or indirectly through local administration with a written contract. In 2013, very few farmers knew about this possibility and none had received seed. There are also problems on the supply side: those who had applied for improved seed were told that reserves had already been exhausted. On the local market, there is no improved seed. Due to a breeding and dissemination project on improved common beans, a farmer who is being trained as village representative of CSA understood yield and quality advantages of improved bean seed.

When asked about the importance of seed traits, farmers listed yield and potential for sale, followed by taste and ease of cultivation as most important. Pest and disease resistance and drought tolerance were not highly ranked by most households. Results from focus groups showed that the majority of households were unaware of the possibility of breeding resistant and tolerant seed. It was stated that improved seed is properly sorted, thus the biggest and least damaged seed.

According to focus group discussions and information from traders at the local market, a reference value of 0.2 EUR was chosen, the average price for local bean seed. Mean WTP of all households amounts to 0.3 EUR/*kapoaka*, which is 171 % of the reference value (premium of 42 % compared with the average bean price). Interviewees stated a higher mean WTP for common bean seed than for lima bean seed, the differences between species and between treatment and control households were not significant.

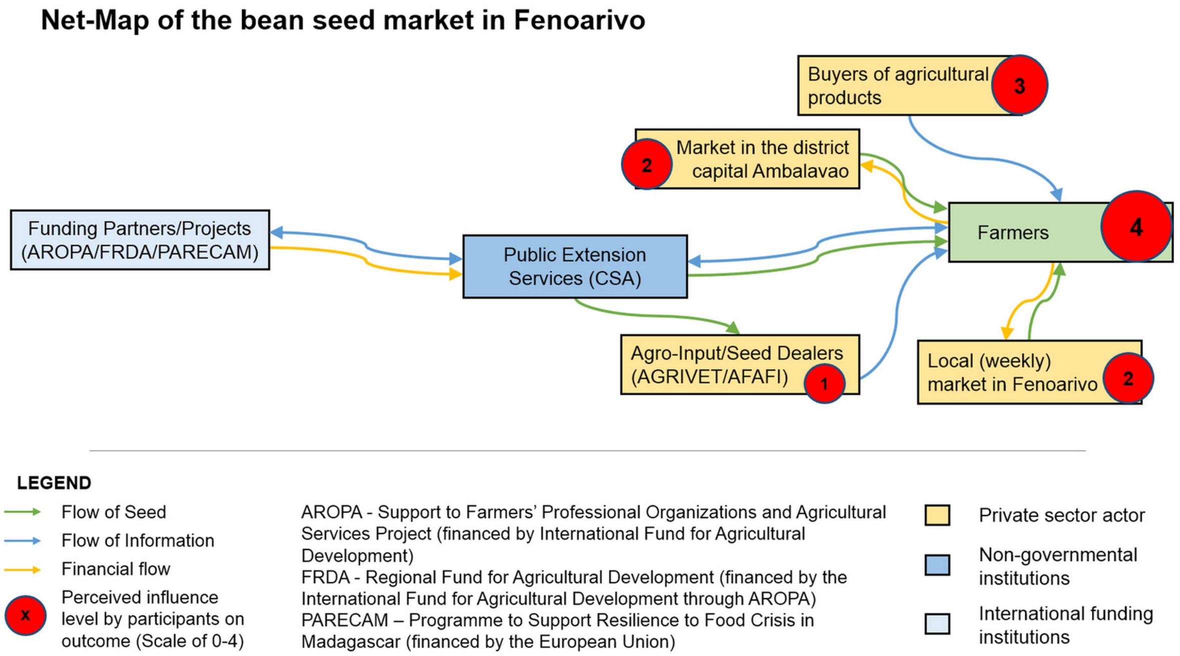

Fig. 3: *Exemplary net-map of the bean seed market in Fenoarivo.*

Almost two-thirds (63 %) of respondents thought it was likely that improved bean seed would be offered at the market in Fenoarivo, and 60 % that they could be offered at their stated WTP. The majority (86 %) of households thought it was likely that they could afford the bean seed at their stated WTP. No differences between treatment and control households could be detected.

No significant impact of either seed or information on WTP could be observed in the regression models (Table 6). Positive predictors of WTP were: additional information sources on improved seed, cultivated land area, social capital, willingness to take risks, and household wealth Legume consumption was a negative predictor.

Of all households, 40 % stated that they would purchase lima beans for consumption and 49 % said being interested in cultivating the beans. Seed-and-information-receiving households are significantly more likely to buy and cultivate lima beans in the future than the two other groups. The majority of households would prefer to buy improved seed in March (217), February (54), and April (31), and at the local market rather than from other farmers or the extension service.

4 Discussion

4.1 *Utilisation and cultivation of lima bean seed*

Although seed utilisation rates (55 %) seem low, they are comparable to other areas in Madagascar. Snoeck (2016) reported for the northeast of Madagascar that about one out of two freely distributed improved clove seed has been planted. Moser & Barrett (2003) reported an adoption rate of only 25 % for improved rice technology (SRI) over a period of five years for different sites in the island's central and southern highlands. Utilisation rates were affected negatively by limited storage possibilities and long storage time, as seed was distributed six months before sowing time. This might have led to the high number of households reporting that insects destroyed their seed. Taboos against beans were a significant hindrance to utilisation. Some households that were intended to receive seed rejected it, and were not willing to cultivate, eat, or talk about them, while others wanted to keep them for consumption. This confirms that social conformity in Madagascar limits adoption of new varieties and technologies (Moser & Barrett, 2003). The adoption process of bambara groundnut shows that it might take some years, but that if beliefs are updated, taboos can be overcome. After its introduction at a nearby large-scale *Jatropha* plantation and by some innovative farmers, villagers realised that rainfall had been unaffected and started planting the beans.

Table 6: *Local average treatment effect (LATE) of seed distribution on willingness-to-pay for improved seed.*

	LATE	*LATE with controls*
Seed-only	−62.25 (42.8)	−48.40 (38.0)
Seed-and-information	3.89 (42.9)	−32.73 (37.7)
Information from other sources		123.85 (34.4)***
Age of household head (years, squared)		0.01 (0.01)
Maximum education among household members (years)		−1.46 (7.1)
Gender of household head (dummy)		−41.4 (31.6)
Dependency ratio (dependent members/members in working age)		5.42 (18.5)
Willingness to take risk (self-assessment, 1–10)		35.29 (4.9)***
Subjective wealth assessment (1–10)		11.82 (7.1)*
Cultivated land per capita (ha)		59.91 (27.2)**
Mutual help (dummy)		49.70 (28.1)
Selling crops to trader (dummy)		48.41 (35.2)
Frequency of legume consumption (number of days, past 7 days)		−10.94 (5.8)*
Social capital (mean agreement)		24.92 (13.0)*
Positive attitude towards work (mean agreement)		4.09 (11.0)
Adjusted R^2		0.20
N		350

Numbers in parenthesis indicate standard deviations. *** (**) (*) indicates significance at the 1 % (5 %) (10 %) level.

Seed was planted mostly by older family members in home gardens with the objective of contributing to household consumption. The seed quantity distributed was low and unlike in the Toliara region, farmers do not have access to lima bean markets. According to focus group discussions, reliable access to markets would increase investments in agricultural production. The maximum production obtained was 65 kg, which is very close to the yield expectation of FOFIFA (43–69 kg of beans per kilogram of seed). Households with an above-average lima bean yield were more experienced in bean production at baseline and also cultivated bambara groundnut. Seed-receiving households unwilling to cultivate might have given their seed to people they knew were experienced in bean cultivation. Prior to the seed distribution a climbing lima bean variety was known in the villages and grown by some farmers in home gardens, and in home gardens people might spend more time weeding and watering and therefore achieve a higher yield.

4.2 Information dissemination

Information-receiving households did not have significantly higher cultivation rates or lima bean yields than their seed-only-receiving counterparts. Seed-only-receiving households, however, were more likely to consume the seed at the beginning of the lean season and not take the risk of keeping them until the planting season. Information-receiving households might have kept the seed with the intention to plant them, pointing to the importance of information dissemination.

As illiteracy is still widespread in the region, information was given verbally only, thus households were not able to look up information that they might not have remembered at sowing time. Lima beans had not been planted before in the villages, there was no local contact person to consult, and the nearest place to access information was in the district capital. Households with above-average yield recalled or knew more information concerning lima bean cultivation. One reason for the rather low information dissemination from information-receiving households to others might have been that lima beans were considered taboo by some households, and it is common to avoid talking about taboos. Furthermore, the distributed information did not target the most mentioned problems, drought and destruction of the plants by cattle or insects. Interestingly, out of the seed-and-information-receiving households, significantly more households also received information from others, thus were more likely to discuss and to be consulted by others. FOFIFA Toliara is training technicians from farmers' organisations in lima bean cultivation, who are then responsible for disseminating this expertise to farmers in their organisations. Hotz *et* *al.* (2012) found that group-level trainings in nutrition and cultivation of orange sweet potato had a significant impact on production and consumption of rural households in Mozambique. One-year and three-year interventions were found having the same significant impact on vitamin A intake, suggesting that group training could be limited to the first year of intervention.

4.3 Consumption

Bean seed distribution did lead to a small, but significantly higher legume consumption for the seed-only-receiving households. Additional information provision did not lead to higher legume consumption, which might be due to the lower achieved yield of this group, and due to the possibility that households had already consumed their supply by the time of the interview. A trader at the market confirmed that after the seed had been distributed, he sold lima beans originating from the region of Toliara. This might explain the high percentage of control households having consumed lima beans, also because only two households sold part of their harvest. Larochelle *et al.* (2015) found that adoption of improved bean seed in Uganda led to increased dietary diversity through the channel of home consumption, and indirectly through farm income, productivity, and empowerment of women. Because beans are mainly cultivated by women, the authors hypothesize a positive effect for dietary diversity as women might have control over bean sales and, therefore, might be in a better position influencing household nutrition outcomes. Similarly, Kabunga *et al.* (2014) showed that fruit and vegetable production led to significant improvements in household nutrition. Although many studies support the hypothesis that household agricultural production is correlated with household and individual consumption, the evidence for a pathway from agriculture to nutrition is mixed. Types of food (especially when comparing crops and dairy products), context, and location cause the effects to vary greatly in size (Carletto *et al.*, 2015). According to Sibhatu *et al.* (2015) the effect of crop and livestock diversification on dietary diversity diminishes with farm size, probably because of foregone benefits from specialisation for already diversified farms.

4.4 Willingness to pay

Mean WTP for improved bean seed was estimated at 171 % of the market price for traditional seed or at a premium of 42 % compared to traditional seed. This result is comparable to other studies. Kaguongo *et al.* (2014) valued certified potato seed in Kenya, where farmers on average are willing to pay 190 % of the price of farmer seed for certified seed, and 170 % for clean seed. Chelang'a *et al.* (2013) found that consumers prefer African leafy vegetables to exotic ones and are willing to pay an average premium of 79 %.

The FOFIFA research station sells its improved lima bean seed to farmers at a price of 1.2–1.5 EUR per kilogram (0.5–0.6 EUR/*kapoaka*). Seed originating from farmers' own seed production ranges from 0.5–0.6 EUR per kilogram (0.2 EUR/*kapoaka*) with regional and seasonal differences (personal interview with representative of FOFIFA, 2014). Comparing these prices with WTP from this study, farmers cannot or do not want to afford improved seed directly from research stations, but would be willing to pay a premium for farmer's own produced seed. FOFIFA had a similar experience in the Toliara region when marketing their improved bean seed to farmers' organisations (personal interview with representative of FOFIFA, 2014). As the case of AfricaRice in the Antsirabe region shows, bean seed could be marketed through participatory varietal selection (personal interview with representative of AfricaRice, 2015).

An interesting result is that 87 % of households answering the WTP question chose the familiar common bean over the lima bean, when asked which of the two they prefer to buy. An explanation for this can be that households selecting lima beans were significantly more willing to take risks, regardless of whether they were successful in cultivating the seed or might have been disappointed by their experience. Risk aversion was also associated with a significantly lower WTP for weather-index insurance (Hill *et al.*, 2013). Common beans are not taboo in the village fields, therefore taboos for lima beans and consequent social pressure might have played a role in this decision.

Households that received additional information on improved lima bean seed reported a significantly higher WTP. This aligns with the study of Kaguongo *et al.* (2014) where farmers' awareness of seed quality had a positive impact on WTP. Cultivated land per capita and subjective household wealth increase WTP significantly. Ulimwengu & Sanyal (2011) also indicated that the amount of land owned and the income level increased farmers' WTP for agricultural services. Legume consumption is a negative predictor, suggesting that households cultivating legumes mostly for home consumption are willing to invest less in inputs. Similarly to Kaguongo *et al.* (2014), remoteness to markets does not result in a lower WTP neither does proximity to markets increase WTP. Contrary to Chelang'a *et al.* (2013), gender, education, and dependency ratio have no significant influence on WTP.

Whittington (1998) summarizes potential biases of WTP studies. Both overstatements due to prestige effects and understatements due to consumers trying to influence the final price can occur. As in this study no data on the purchasing of improved beans is available, these biases cannot be ruled out. To minimize hypothetical bias, which is the difference between stated and revealed values, lower bounds were set for the payment card, but with an effort to keep a realistic range of prices from which households could choose (Murphy *et al.*, 2005).

Contrary to the results of Bates *et al.* (2012) that receiving a product for free increased peoples' WTP for it later, in this study neither seed distribution nor information provision increased WTP. Insect damage, low yield due to climatic conditions, and not following cultivation recommendations may be to blame. Households planting the bean seed might have had higher expectations or might have been disappointed by the performance of the seed. CRS *et al.* (2013) discuss the downside risk of free distribution of seed in Madagascar. Institutions are still buying the largest amount of seed, which is hindering the development of a sustainable private sector serving smallholder farmers.

5 Conclusions and recommendations

The amount of seed distributed to households was small and only 54 % of the seed-receiving households cultivated the lima bean seed. Of those, 48 % reported zero yield, mainly due to drought. Seed information did not increase cultivation. Taboos played a role, as did insect damage due to the long storage time. A timely distribution of packaged seed could avoid those problems. Local seed could be tested in comparison to improved seed on demonstration plots of farmer field schools, so that farmers could experience the differences. Similarly to FOFIFA Toliara, some farmers could be trained in the use of improved seed and other agricultural technologies and given incentives to disseminate this knowledge to farmers in their organisations and villages. CRS *et al.* (2013) suggest participatory varietal selection, decentralised seed production (by farmers or farmers' associations), low-cost delivery mechanisms (e.g. through village committees or with the help of radio programs), and technologies to minimize storage losses. These results also strengthen importance and need for public extension services in rural Madagascar. We recommend participatory community-level interventions that match farmers' needs and focus not only on technological issues in introducing new varieties, but also allow to consider social processes that hinder innovations. Net-maps compiled during the focus group discussions turned out to be a helpful and easy-to-implement tool, as participants learned about the breeding program of the Ministry of Agriculture and the possibility of obtaining improved seed from the extension service.

Seed information did not increase yield. Reasons for low yield are climatic conditions as well as crop losses due to insects and cattle. The explanatory power of the factors determining lima bean yield is low, suggesting that unobserved factors, like cow dung application, irrigation, plot-specific rainfall during critical times of bean growth, or time invested played a role. If cultivation is more closely monitored, inputs used or problems during cultivation could be used as intermediate indicators to better explain yield variances. Local representatives could be trained in storage and cultivation techniques and serve as contact persons for households in case they have questions or encounter problems. This would allow for information sharing on topics that initial information provision cannot address. Group training sessions or demonstration plots could give impetus to information dissemination. As mostly women are responsible for bean production, female contribution and knowledge sharing at the demonstration plot and effects on cultivation and decision making could be tested. Information diffusion via videos or visual aids containing pictures and short sentences could be tested. While targeting farmers, the extension service could cooperate with schools. Educating children in agricultural production processes and the agricultural market might lead to long-term benefits and to more participation of the rural population in development programs.

A small positive effect on legume consumption was found. As unobserved factors, like food or cooking preferences or taboos might have played a role, cooking and nutrition information should be included during the dissemination of new varieties (Katungi *et al.*, 2011a).

Neither seed distribution nor information provision increased WTP. The training of a local farmer in the commune has shown to be an effective means of disseminating knowledge about improved inputs from the extension service to the village; however, no improved seed has been supplied yet. Given the poor infrastructure and high poverty rates, as well as market failures in a remote and underdeveloped setting lacking cash crops, continued state and non-governmental organisations support might be justified.

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