Farmers' Valuation of Transgenic Biofortified Sorghum for Nutritional Improvement in Burkina Faso: A Latent Class Approach

Abstract

This study applied a choice experiment to analyse Burkina Faso farmers' valuation of different attributes of transgenic biofortified sorghum, also investigating the factors that influence their preferences. Data were collected from 150 farmers cultivating sorghum who were randomly selected from three districts in the country. A latent class model was used to investigate the heterogeneity in the preferences and to profile the characteristics of farmers' according to their preference structure. The results show that a majority of the farmers (67%) would likely adopt the new sorghum seed. Nevertheless, farmers have a preference for seeds with shorter maturation periods and higher yields that are available at a lower cost, produced and marketed through a governmental institution. We also found that farmers will be willing to pay more for seeds with higher micronutrient level. When looking at the heterogeneity in the preference structure for biofortified sorghum, three classes of farmers were identified. We labelled them as 1. Micronutrient preference group, 2. The small sorghum producers, and 3 The risk takers. Owing to this heterogeneity, we agreed that farmers should be offered different varieties of the new product based on a pooled combination of different attribute levels and prices. The study equally shows that the seed sector producing and marketing transgenic seeds are an important determinant of farmers buying decision. Hence, we recommend that for the crop to achieve its full potential, the government should partner with the private seed sector for proper awareness creation and seed distribution.

Keywords: Farmers, Transgenic biofortified Sorghum, Micronutrient malnutrition, Choice experiment, Latent Class Model

1. Introduction

Micronutrient malnutrition (MNM) is an important contributor to the global burden of diseases. It has been a challenge in Burkina Faso for many years. According to UNICEF data, MNM in form of vitamin, iron and zinc deficiencies affects every 1 in 4 children in the country. It has been found that the local sorghum cultivar which is the most important staple crop in the country is deficient in essential nutrients (da Silva et al., 2011; Traore and Stroosnijder, 2005). The effort to improve the nutritive content of the local sorghum cultivar through biotechnology was initiated by African Harvest International (AHI) in 2001. The project was funded under the Grand Challenges in Global Health initiative by the Bill and Melinda Gates Foundation. The resulting African Biofortified Sorghum (ABS) would contain increased levels of vitamin A, Iron, and Zinc.

However, there are many factors that could reduce the market potential of the ABS seeds in the country. Firstly, genetic modification (GM) programmes in general have attracted one of the highest controversies in the last two decades. Concerns over the impact on health and environment have been debated extensively (Brookes and Barfoot, 2014; Paarlberg, 2010). This debate can have an impact on the market for transgenic biofortified foods. Secondly, biofortification processes in general tend to alter the sensory attributes of crops such as taste, fragrance and colour (De Groote et al., 2014). These changes have been found to play an important role in the consumers acceptance (Banerji et al., 2016; De Steur et al., 2012). However, while the acceptance by consumers is crucial and might impact on the demand, the adoption by farmers is also important. This study therefore focusses on this supply side, with the aim to identify the preference of farmers taking into account the agronomic and economic perspective.

While the addition of extra micronutrients to the local cultivar can make the biofortified sorghum more attractive, other characteristics like time to maturity, yield, source and cost of the seeds could also influence the farmers' adoption, and by extension determining the potential of the proposed crop. In Burkina Faso, studies have shown that farmers prefer their local sorghum cultivar over conventionally improved (hybrid) varieties that are provided by collaboration of the National Agricultural Research System and International Crops Research Institute for Semi-Arid Tropics (Olembo et al., 2010; vom Brocke et al., 2010; Adesina and Baidu-Forson, 1995). Major causes for this are issues related to the perceived superiority of the local cultivars, penchant to seed saving culture, and transaction costs leading to inadequate demand and supply. Because there are multidimensional factors that might influence the farmers, a Discrete Choice Experiment is applied in this study to understand the values farmers attach to different attributes of the new variety, as well as identifying the factors that influence the farmers' preference.

The study is significant on two fronts. Firstly, the study is quite unique. Most ex-ante studies conducted on farmers' choice for transgenic crops use contingent valuation presenting a dichotomous choice between a transgenic variety and a non-transgenic variety (Krishna and Qaim, 2007; Qaim and de Janvry, 2003 and Hubbell et al, 2002). This method has been subjected to criticisms in terms of its ability to deliver reliable and accurate estimates (Mogas et al., 2006). For instance, Hanley et al. (2001) observed that the approach is not suitable to deal with cases where attributes valuations are multidimensional. In addition, compared to the few other studies that applied a DCE (Schreiner, 2014, Breustedt et al., 2008; Birol et al., 2007), our study is different because it accounts for farmers' preference heterogeneity. By using a Latent Class Model (LCM) we were able to segment the farmers and to integrate a wide spectrum of covariate parameters in our model including socioeconomic, farm and motivational variables.

Secondly, the addition of the seed source attribute to the DCE is unique. Arguments have been put forward on the influence of seed source on farmers' adoption of transgenic crops. According to Mabaya, et al., (2015), the potential of transgenic crops to improve nutritional security in Sub-Saharan Africa (SSA) depends to a large extent on the farmers access to the seed. Virgin et al. (2007) also stated that the informal seed saving culture in SSA might lead to low adoption of transgenic crop varieties. Likewise, the control and property right protection of seed by private seed companies are an important argument put against transgenic crops by the anti-GM groups. Nevertheless, the extend that seed source can influence farmer's choice for biofortified crops is yet to be explored.

The paper is structured as follow: in the next session the theoretical model is presented. This is followed by description of the choice experiment method. The results and discussion come afterwards, before conclusion and recommendations were made.

2. Theoretical Framework of the Latent Class Model

Latent Class models are based on the theory of individual choice behaviour which captures the farmers' preference for attributes that make up a product (Louviere et al., 2008). It has its theoretical origin in Lancasters' model of consumer choice (Lancaster, 1966), and the theory of Random Utility. Lancaster stated that satisfaction will be obtained from the attributes of a product rather from the product itself, while Random utility observed people to be rational and as such when presented with two or more options, they would likely make a decision in favour of the one providing them higher utility. To elucidate the preference of an individual in a set of alternatives, a DCE is often applied. As a stated preference elucidation method, DCE is appropriate when a product is new and/or not yet commercially available (Louviere et al., 2000; Lindsay et al., 2009). Unlike the revealed preference method, the stated preference gives the researcher the room to include hypothetical attributes which might not be available in alternative products that are already in the market.

A LCM can be used to simultaneously identify subgroup having homogenous preferences for an attribute and the characteristics they have in common. It assumes that individuals reside in 'latent' classes which are unknown to the analyst with each class having a homogenous preference structure. Classes are often determined by the socio-economic characteristics of the respondents and choice of product attribute. In related literature, LCM was applied by Birol et al. (2011), Kikulwe et al. (2011) and Birol et al. (2007). In the latter two studies, motivational questions concerning farmers' knowledge, perception and attitude towards GM food were included to class membership structure. It was observed in all the studies that a significant heterogeneity exists in respondents' preference of GM foods. The result is particularly important in market segregation and targeting. For instance, in Uganda, Kikulwe et al. (2011) observed that the biofortified banana should be a pro-poor programme targeting rural farmers. Therefore, by applying LCM in our study, we are expecting to provide information to policy makers and product developers that are relevant in product development and marketing.

2.1 Econometrical Model

Following the econometric model specification proposed by Greene and Hensher (2003), a Conditional Logit (CL) was first specified. While the CL presents a holistic preference of the whole sample, the LCM gives a segmented preference structure. The general econometric model consists of parameterized utility functions $U_{nij/s}$ in terms of observable independent variables $\beta_s X_{nij}$ and unknown parameters or Error components $\varepsilon_{nij/s}$ as shown below.

$$U_{nij/s} = \beta_s X_{nij} + \varepsilon_{nij/s} \quad (1)$$

Simply put, $U_{nij/s}$ is the utility that a farmer n, who belongs to a segment s derives from the selection of alternative i in the choice set j. The β is the segment-specific parameter vector which encompasses first, the choice parameter and second, socioeconomic and motivational parameter vectors, while X is the vector of attributes, and ε is the error component. The inclusion of the error component implies that researchers can only predict with some level of uncertainty the choice of the respondent; therefore, it is assumed that choices made among the alternatives will be a function of the probability that the satisfaction associated with the selected option is higher than that of the alternatives not selected. Nevertheless, for this probability function to be accurate, the error term must be identical, independently distributed and follow a Type 1 or Gumbel distribution (Rungie et al., 2011). If this is the case, the conditional probability that the farmer n, belonging to segment s, selects the alternative i in the choice set j is given as

$$P_{nit/s} = \frac{\exp(\beta_s X_{nij})}{\sum_{i=1}^{I} \exp(\beta_s X_{nij})} \quad (2)$$

And the probability that the farmer belongs to the segment is expressed as:

$$P_{ns} = \frac{\exp(\alpha_s \theta_n)}{\sum_{s=1}^{S} \exp(\alpha_s \theta_n)} \quad (3)$$

Where α_s is the segment-specific parameter vector to be estimated (i.e. the characteristics of the farmer that contributes to the membership of a particular segment) and θ_n is the individual specific variable (attributes of the product). Therefore, the probability that the farmer chooses an alternative is the conditional joint probability from equation (2) and (3), as specified below as

$$P_{ni} = \sum_{s=1}^{S} \left(\frac{\exp(\alpha_s \theta_n)}{\sum_{s=1}^{S} \exp(\alpha_s \theta_n)} \right) \prod_{j=1}^{J} \left(\frac{\exp(\beta_s X_{nij})}{\sum_{i=1}^{I} \exp(\beta_s X_{nij})} \right) \quad (4)$$

By including the seed cost attribute, it is possible to calculate the farmers' valuation or willingness to pay (WTP) for other attribute changes. This is done by dividing the non-price attribute with the seed price attribute, as specified below

$$\text{WTP} = \frac{\beta_k}{(-)\beta_c} \quad (5)$$

where β_k is the coefficient of a non-seed price attribute, and β_c is the coefficient of the seed price attribute. In determining the farmers' valuation or welfare measure, attributes presented in quantitative form are often compared with other quantitative attribute. This is also similar with qualitative attributes. In respect of this rule, the farmers' valuation for a change in an attribute can be compared among the classes observed in the LCM.

3. Choice Experiment Method

3.1 Identification of Attributes and Levels

The first stage of DCE is to select the relevant attributes and the possible levels of each attribute. Relevant attributes for transgenic biofortified sorghum were identified by combining literature review with experts' opinion. The engaged experts included researchers from the AHI consortium and stakeholders from the Ministry of Agriculture and Food Security in Burkina Faso. During the consultation, five attributes were selected reflecting important sorghum characteristics. The use of a reduced number of attributes is a fair standard assumption in DCE model as it helps to improves the respondent cognitive ability to complete the experiment (Lindsay et al., 2009).The second step is assigning attribute levels. There is no agreed optimal number of level but the levels assigned must reflect the range of situations that the respondents might expect to experience, and they should be feasible and realistic (Lindsay et al. 2009 and Hanley et al. 2001). Literature review, expert consultation, and market surveys were used in the selection. Where quantitative values were used for example in seed price, yield and maturity attributes, the status quo represents the base level. Additional levels were added to the base level as shown in Table 1.

Table 1: Attributes and levels of attribute for Choice experiment

Attributes	Definitions	Levels
Increased Micronutrients	Whether or not an additional micronutrient is present	Yes, No*
Seed price (CFA)	The amount paid for the purchase of seed per Kg	5000, 4000*, 3000
Seed source	The sector responsible for the production and marketing of seed	Private, public*, public-private partnership
Yield (Kg)	The expected yield per hectare (Kg)	650, 750*, 850, 1000
Days to Maturity (days)	Number of days taken for the crop to mature	70, 80*, 95, 110

*Represent the baseline level, $1 =592 CFA

The first attribute "increased micronutrients" refers to the higher amount of micronutrients in the local variety which can contribute to the reduction of MNM. This attribute was observed as the most important feature of the biofortified sorghum programme, and the major difference from the local sorghum variety. Two levels were suggested: Yes, indicating the presence or No indicating the absence of extra micronutrients. As the transgenic biofortified sorghum has not yet been commercialized, the exact type and amount of nutrients increased in the crop is not yet known, making qualitative levels the preferred option. More so, although Vitamin A is the target nutrient, the AHI experts consulted hinted that other micronutrients are being considered.

The "seed price" attribute is the price of sorghum seed per kg. It is a monetary variable that is relevant in the estimation of the utility derived from the attributes of the product. Three levels were proposed. The first level 4000 CFA is the current average price of one Kg of sorghum seed in the country. The other levels 5000 CFA and 3000 CFA are an estimate on the variation of seed cost from the market survey. The rational is that the accepted seed price might be higher because of the extra features or it might be lower because farmers are not used to buying seeds in the market.

The “Seed source” attribute describes the sector that manufactured and provides the seed to the farmers. This attribute is added from the backdrop of the information trailing the GM debate that farmers in SSA might be less willing to adopt transgenic crop seed from private organizations (Mabaya, et al., 2015). Three levels: private, public and public-private partnership were included. In the existing Bt Cotton production, the contract agreement entered by the farmers to acquire the seed empowers them to pay up through their harvest. In the ABS project, the channel of distributing, contract agreement and means of payment is yet to be determined. However, from expert consultation, it was found that for high seed viability, seed reuse might be discouraged and the best distribution channel that would make seed easily accessible to farmers will be considered.

The "Yield" attribute is the anticipated yield of the product per hectare. The baseline yield 750kg/ha was obtained through the consultation with experts in the Ministry of Agriculture and Food security. The study of Lacy et al. (2006) on farmer choice of sorghum varieties in southern Mali gave an insight on the other levels. The yield attribute is important to evaluate the findings of previous research by Adesina and Baidu-Forson (1995) who opined that the yield attribute of sorghum is "barely significant" in farmers adoption of modern sorghum varieties.

The final attribute "Days to Maturity" refers to the number of days taken for the crop to mature. This attribute is added due to the desire for drought resistant crops in the region. A crop with a shorter maturity period means a higher ability to resist the climatic variations, and it is often preferred. Again, the study of Lacy et al., (2006) was vital in the identification of levels. Four levels were specified with 80 days being the average of sorghum maturity date in the study area.

3.2 Design of Experiment

The second stage in the DCE is designing the choice set. A choice set is a group of hypothetical alternatives constructed through experimental design. Among available alternatives, a fractional factorial design was used for the study. The fractional factorial design generates a sample of the full design in such that the most important effects are estimated (Lindsay et al., 2009 and Alpizar et al., 2001). One pro of fractional factorial design is that the reduction in the number of choice sets does not lead to a concomitant loss in estimation power (Hanley et al., 2001). The D – efficiency approach of fractional factorial was used to design the experiment with the help of SAS software (Kuhfeld et al., 1994). The D-efficiency design tends to greatly reduce the predicted standard errors of the parameter estimate and produce even stronger statistical results (Hoyos, 2010; Rose et al., 2008). The alternatives were not labelled because it could make the respondents ignore the attribute and concentrate on the product alternatives (Saldias et al., 2016). This is particularly a problem in sensitive market research like GM food, where a strong attitude can exist due to controversies and external influences.

Therefore, for the choice set, two opt-out alternatives were included. One describing the desire to continue with current sorghum seed, and the other, the intention to abandon sorghum production if a GM variety is introduced. The addition of these opt-out alternatives is used to determine the farmers' penchant to the local sorghum cultivar and their attitude towards GM crops. The respondents were also asked during the interview about their current yield and their frequency of purchase of seeds, in a way that their current values for the status quo could be used in the analysis. To avoid that the survey would become too long, the design was blocked into 2 partitions. Blocking helps to promote response efficiency by reducing cognitive effort for each respondent (Johnson et al., 2013). Respondents were randomly assigned to one of the blocks, facing 6 choice sets or situations. A total of 5400 individual choices were obtained for the study (6 alternatives x 6 choice sets x 150 farmers). Figure 1 presents an example of one of the choice sets.

If the proposed transgenic biofortified sorghum produced by African Harvest International is released, which of the following alternatives would you most likely prefer?

	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Micronutrient	Yes	No	No	Yes	I prefer the local sorghum seed	I will totally abandon sorghum production
Seed cost	3000	5000	4000	4000		
Seed Provider	PP	Public	PP	Private		
Yield	650	850	1000	750		
Maturity date	110	80	70	95		
	☐	☐	☐	☐	☐	☐

Figure 1: Example of choice Set

3.3 Data

The study was conducted in Burkina Faso with respondents from three districts; Dedougou, Bobo, and Diebougou. The districts were purposely selected because they are among the main sorghum growing areas in Burkina Faso. Being located in the cotton zone, most of the farmers cultivate cotton but they also allocate some percentage of their land to sorghum production (Sanders, 2016). The respondents used for the study were drawn from a list of farmers belonging to a local cotton cooperative. These farmers are assumed to be aware of GM technology because of their production of Bt cotton.

A random sampling method was used to select 50 farm households from each of the 3 districts. Data was collected from the household head using a structured questionnaire by a trained survey team. The survey was conducted face to face. The individual assessment was adopted due to the sensitivity of the subject matter. The farmers were trained briefly on how to respond to questions, and were assured of the confidentiality of their response. The survey usually took 30 minutes, covering 3 parts, 1. information regarding their socioeconomic and farm characteristics, 2. A set of motivational questions to ascertain their nutritional knowledge and attitude towards GM crops, and 3. the application of the choice experiment.

The socio-economic and farm characteristics were evaluated using descriptive statistics like mean and Analysis of Variance (ANOVA). The 17 motivational questions were structured into 5 points Likert scale which ranged from Strongly disagree (1) to Strongly agree (5). To group farmers based on their response to the motivational questions, a principal component analysis (PCA) was conducted. The PCA was used to remove correlation, reduce complexities, and synthetize more relevant factors (or classify variables). The criteria for accepting factor solution (number of components) were set on a minimum eigenvalue of 1 and factor loadings above 0.30. However, other conditions such as the information on the scree plot, number of variables loaded in each factor, and the theoretical sense of the loadings were also considered. The factor score was used to assign individuals to different components. A positive coefficient indicates a likelihood of possessing the feature explained by the associated component. The coefficient of the factors was obtained using the factor score command in the STATA 13 software.

Finally, the factors obtained from PCA and the explanatory variables included in the socio-economic characteristics were used as class membership parameters in the LCM of the choice experiment.

4. Results and Discussion

4.1 Socioeconomic and Farm Characteristics

Table 2 presents the socioeconomic characteristics of the respondents. From the 150 farm household heads interviewed, 140 (93.3%) were males, and the average age was 44.6 years. The level of education was low among the respondents, with only 32% having any form of formal education. The mean farm size per household was 8.25 ha from which on average 1.57 ha (19%)

was allocated to sorghum production. The average sorghum produced by the respondents was 790 kg/ha. Sorghum was the most important food staple reported by 72.7% of the respondents, and a great majority of them (84.7%) cultivate it every season. Sorghum is cultivated mostly for household consumption (91.3%). The majority of farmers (92.7%) still practice seed saving culture, but about 60% indicated that the source of their seed did not matter. Although the practice of seed saving culture could hinder farmers' adoption, their indifference to seed source implies that it is possible to break this ancient culture. This result is somewhat good news for the transgenic biofortified sorghum project, as it shows that if all conditions are being met, the practice of seed saving would not prevent most farmers from adoption. Finally, the means of the 3 districts were compared using ANOVA. The result shows that there were no significant differences in any of the socio-economics characteristics of the farmers across the three districts.

Table 2: Socio-economic and Farm Characteristics of farmers

Parameters	Total Sample (150)	Bobo (N=50)	Dedougou (N=50)	Diebougou (N= 50)
Socioeconomic characteristics				
Gender (% of males)	93.3	94	92	94
Age (average years)	44.6	45.20	44.26	44.44
Education level (% literacy)	32	36	38	42
Sorghum acreage (hectare)	1.59	1.60	1.41	1.77
Total acreage (hectare)	8.25	9.88	8.81	6.07
Total annual yield (Kg/ha)	790	801	761	807
Farm Characteristics (% of yes)				
Importance of sorghum				
Sorghum as household staple	72.7	74	68	76
Grows sorghum every season	84.7	92	82	80
Purpose of sorghum production				
Consumption only	91.3	94	92	88
Sales only	8.7	6	8	12
Sorghum seed provision				
Save seed for next season	92.7	94	92	92
Sometimes purchase seed from market	6.7	6	10	4
Seed source does not matter	59.3	68	60	50

4.2 Motivational Factors

Three components were obtained from the PCA which satisfied the criteria set for selection. The first component was labelled 'Knowledgeable farmers'. These consist of the group of farmers (56%) that recorded a high score on questions relating to nutritional knowledge. They showed great understanding of the micronutrient deficiency in the local sorghum cultivars and were aware of the ABS project. The second component is labelled 'Risk-averse farmers'. They scored high on questions relating to the risk associated to adopting transgenic biofortified sorghum. They demand more information, affordable price and government approval before they would adopt the new product. About 63.3% of the farmers are risk averse. Finally, the third component is called 'Negative experience'. This factor has high loading on the questions regarding previous experience. The farmers in this group (about 36%) are regularly informed of research on improved sorghum varieties but due to previous bad experience with hybrid varieties introduced to them, are most likely to continue with their local cultivars.

Unlike the socio-economic characteristics, the motivational indices showed a significant difference in at least one district. Specifically, the farmers in the Dedougou district in average scored significantly higher on Risk averse and Negative experience than the other two districts. Generally, the risk averse farmers and those with negative experience are hypothesized to be less likely to accept the transgenic sorghum.

Table 3: Principal Component Analysis Result (N = 150)

	Motivational Statements	Rotated Factor Loading (Varimax)		
		Knowledgeable	Risk averse**	Negative Experience**
1	Do you know that the public health studies in Burkina revealed deficiencies in vitamin A, iron and zinc for children under 5 and women?	**0.36**	0.18	-0.06
2	Do you know that these deficiencies can be the cause of certain diseases?	**0.36**	0.18	-0.06
3	Have you (or your family members) already suffered from any deficiency due to a lack of these elements?	0.17	0.14	-0.01
4	Do you know that these nutrients can be enhanced in sorghum?	**0.56**	-0.01	0.03
5	Have you ever heard about bio-fortified sorghum?	**0.44**	-0.11	0.06
6	Do you know that Burkina Faso has subscribed to a local sorghum enrichment programme to fortify sorghum with vitamin A, zinc and iron?	**0.40**	-0.07	0.05
7	Do you think the bio-fortified sorghum programme is welcome?	-0.17	0.14	0.05
8	Do you think it's appropriate to improve the micronutrients in sorghum?		-no loadings	
9	Would you like to learn more about this bio-fortified sorghum programme?	-0.01	-0.26	0.01
10	I am regularly informed of the research on improved varieties	-0.05	0.26	**0.37**
11	I regularly participate in exhibition fairs of research findings	-0.07	0.07	**0.37**
12	I believe bio-fortified sorghum should be better explained to the producers by the relevant authorities	0.01	**0.49**	-0.11
13	The bio-fortified sorghum seed should be available at the same price as the local variety	-0.01	**0.50**	-0.14
14	I prefer to continue with the local variety	0.04	-0.10	**0.56**
15	I will produce bio-fortified sorghum provided the government agrees	-0.08	**0.33**	0.17
16	I have a bad experience with previously improved varieties of sorghum	0.05	-0.09	**0.53**
17	I will produce bio-fortified sorghum if the price is affordable	0.001	**0.35**	0.21
	Eigenvalues	2.92	2.75	2.20
	Accepted factor loadings	>0.3		
	Number of farmers (%)	56	63.3	36

Statements 1: Strongly disagree; 2 Disagree; 3 Neutral; 4 Agree; 5 Strongly agree.

***, **, * = significant at 1%, 5%, 10% level

4.3 Result of the Latent Class Model

The LCM was estimated using NLOGIT 5.0. We first specified the product attributes that influence the farmers' choice for transgenic sorghum. Secondly, we specified the socioeconomic characteristics and motivational factors that could determine the class membership.

In a first estimation, the CL model was used to assess the overall preference structure of the farmers without considering their personal characteristics. The result of the CL is presented in Table 4. It reveals that all the product attributes included in the model are significant utility parameters considered by the farmers in their choice decision. This, therefore, suggests that the farmers consider many attributes and often compare them before making decisions. For the attributes with dummies, compared to the seed source, the addition of micronutrients returns the highest absolute value, suggesting that it is a very important determinant of the transgenic sorghum seed choice. It has a positive and very high significant effect on farmers' utility. Preference for the seed providers shows that farmers have preference for public partnerships compared to public-private providers and a negative preference towards private providers when compared to public-private. That means that farmers will favour in the first instance, a public source for the seeds, before public-private partnerships. This is in line with earlier studies that the seed sector matters for GM crop adoption in SSA (Mabaya, et al., 2015)

For the quantitative attributes, farmers also show preference for the period of maturity, yield and seed cost. The expected days of maturity of sorghum have a negative and significant relationship with the farmers' choice. The negative coefficient is in line with the expectation that farmers would likely adopt a sorghum cultivar that is early maturing. Drought is arguable the major environmental challenge facing sorghum farmers in Burkina Faso, therefore, an early maturing attribute would be a high incentive to adopt the seeds.

The utility parameter of yield is positive and highly significant indicating that the farmers have a high preference for high yielding seeds. A positive but barely significant preference for yield has been reported for Burkina sorghum farmers by Adesina and Baidu-Forson (1995). Ascribing a higher utility for sorghum yield is expected. This is because the demand of food generally has increased, thanks to the high population growth rate (3%). While the poverty level is high with the poorest farmers not being able to purchase cereals, it is, therefore, plausible for farmers to have a preference for high yielding sorghum seed. The seed price attribute is negative and significant, indicating a preference for seed varieties with a lower cost. This is expected because a great majority of farmers in the study area save their sorghum seed for the next planting season. Therefore, having to purchase their seed yearly will conflict with their current practices.

The probabilities of selecting the opt-out alternatives were presented in the second part of the table. The result shows that on average, 27% of the farmers would prefer the local seed irrespective of the characteristics of the new sorghum variety. Although previous studies indicated that sorghum farmers in Burkina Faso have strong penchant for their local sorghum variety (Olembo, et al., 2010), the result suggested evidence of change. This improvement can be attributed to the participatory breeding approach adopted in the country. More so, with a 0% preference for alternative 6, we can assert that in average, at least 73% of the farmers sampled in our study may adopt a GM variety. Hence, our next concern is to identify these farmers and the socioeconomic and motivational characteristics that would their choice of the transgenic sorghum seeds.

Table 4: Conditional Logit Representing Utility Derived from Sorghum Attribute

Utility parameter	Coefficient	Standard Error
Increased Micronutrients	3.3835***	0.1685
Seed price	-0.0008***	0.0006
Public seed source[1]	0.7164***	0.1088
Private seed source[1]	-0.6964***	0.1419
Yield	0.0069***	0.0004
Days to maturity	-0.0333***	0.0032
Probability of selecting an opt out alternative		
Alt 5: Preference for local seed	27%	
Alt 6: Abandon (GM) sorghum	0%	

[1]Compared to public-private partnership,

***, **, * = significant at 1%, 5%, 10% level

4.4 Socioeconomic and Motivational Factors Influencing Farmers Preference

Although the result from the CL model is useful in determining the level of utility ascribed to the product attributes thereby helping to estimate the farmers' preference, it does not however reflect the heterogeneity of preferences among respondents. The CL assumes that the utility is homogenous across all the farmers which might not be true in reality. The LCM provides evidence for systematic heterogeneity in the preference structure of the sorghum farmers. To estimate this heterogeneity, the LCM was run several times with increasing number of classes and different combinations of class membership variables. To identify the optimal number of classes, a balanced assessment of the Log-likelihood function, Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), and the Mcfadden pseudo squared (P^2) were considered following Kikulwe et al. (2011) and Birol et al. (2007).

Considering the information criteria in Table 5, the log-likelihood improved and P^2 increased as more parameters were added until they maximized in class 3. This implied an optimization at class 3. To confirm this, the AIC and BIC decreased from the first class but were minimized at class 3. Therefore, a three class model was selected. The best fitting LCM included in the membership function: 1. the farmers' attitude towards risk; 2. the sorghum yield of farmers; and 2. whether farmers save seed or not.

Secondly, a comparative summary statistics of the features of the latent classes was obtained. The class probabilities of individual respondents were used to assign farmers to a given class. Following Kikulwe et al. (2011), a respondent retains the class which he scores the highest probability.

Table 5: Information Criteria for Determining the Optimal Number of Class

No. of Class	Parameters	Log Likelihood	P^2	AIC	BIC
1	6	-878.8	0.3772	1769	1798
2	17	-795.3	0.5068	1617	1679
3	26	-742.9	0.5393	1537	1663
4	27	-764.1	0.5262	1582	1712

In the 3 class model presented in table 6, 31.2% of the respondents belong to class 1, 14.1 % to class 2 and 54.7% belong to class 3. The class 3 is the reference class, so the coefficients are normalized to zero to allow a comparative interpretation. The first part of the table presents the coefficients for the seed attributes, while the second part shows the class membership function. The third part is the description of individuals in the class.

For the Class 1, the utility coefficients reveal that farmers belonging to this class have preference for sorghum seed with more micronutrients, seed with lower price and seed with higher yields. In terms of seed source, a higher preference is found for public seed providers compared to either a private or public-private partnership. Maturity period does not seem to be a significant determinant of choice for this class. Furthermore, the estimates from the class membership function for class 1 reveal that farmers who are more risk averse but produce relatively higher quantities of sorghum are more likely to belong to this class. We label this class "Micronutrient Preference Group" due to three reasons. First, the coefficient of the increased micronutrient attribute for this class is much higher than that of the other two classes. Second, when we normalized the utility parameters in this class by price attribute, we observed that the class members derive the highest utility from the increased micronutrient attribute. Third, the farmers in the group produce significantly higher quantity of sorghum than other groups. With proper information and awareness of the nutritive quality of the seed, this group could be encouraged to adopt the new sorghum variety.

Class 2 differs from class 1 in a number of ways. For instance, in contrast to class 1, the absolute value for the coefficient of the increased micronutrient attribute was quite small. respondents only show significant preference for public seed sources as compared to public-private partnership, and the days of maturity was a significant determinant of choice for this class. Nevertheless, similar to class 1, farmers in class 2 prefer sorghum seeds in which micronutrients are increased with a lower seed price. They also prefer the seeds to be early maturing and procured through the public sector. The days of maturity attribute is very important to this class, as it was highly significant and gave relatively high values when normalized with the seed price attribute. More so, for the class membership, we observe that farmers who practice seed saving culture and those that produce smaller quantities of sorghum are more likely to belong to this class. We label this group "Small Sorghum Producers Group" because of the following factors. First, the private seed source is not an important determinant factor in their choice. Second, they considered most especially early maturing attribute indicating possibility for subsistence cultivation. Finally, the seed saving culture and production of smaller quantity of sorghum are very obvious characteristics of these farmers. A contract allowing seeds to be reused may influence this group to adopt the transgenic sorghum.

Finally, for the class 3, we observed some similarities in the signs and rankings of both the binary and non-binary attributes. Nevertheless, the utility coefficients reveal that farmers in this class prefer sorghum seed with increased micronutrient, that has lower seed price, that is high yielding, and early maturing. When normalized with the seed price attribute, farmers in class 3 relative to those in class 2, value increased micronutrient more and days to maturity less. Peculiarly for this class, farmers in class 3 attach higher utility to sorghum seed provided by a public-private partnership compared to those coming from public sources. Following Birol et al. (2011), the class membership coefficients of the class can be interpreted as long as the previous two classes have the same signs. Consequently, farmers who take more risk are likely to belong to this class. Following the characteristics of Risk averse farmers identified in PCA, this group of risk takers would likely in average be well informed about new agricultural technology, and are less likely to be influenced by price or private seed source. We labelled this class "Risk Takers". This group may show positive attitude towards a GM sorghum variety, and would most likely be among the early adopters. They constitute a little above half of the farmers sampled (54.7%).

Table 6: Three Class LCM estimate for transgenic sorghum seed attribute

	Class 1 (31.2 %) **Micronutrient Preference**	**Class 2 (14.1 %)** **Small Sorghum Producers**	**Class 3 (54.7 %)** **Risk Takers**
Utility parameter: Transgenic sorghum seed attributes			
Higher Micronutrient levels	23.283*** (5.47)	2.5576**(1.082)	3.2506***(0.2879)
Seed price	-0.0047*** (0.001)	-0.0018***(0.0004)	-0.0010***(0.00012)
Public seed source[1]	5.1014*** (1.453)	2.0309***(0.5474)	0.2016(0.16577)
Private seed source[1]	2.4205*** (0.9192)	-2.7152(3.0654)	-1.0117***(0.2131)
Seed Yield	0.0385*** (0.0079)	0.0121***(0.0028)	0.0081***(0.00069)
Days to maturity	-0.0036 (0.0256)	-0.0459***(0.01614)	-0.0391***(0.00493)
Class membership: Farmers characteristics			
Constant	30.719(0.118D+08)	4.0378(3.5584)	-
Risk averse- attitude towards risk	0.5025***(0.1909)	0.43557(0.6989)	-
Annual sorghum production of farmers	0.00668**(0.0028)	-0.0165**(0.0069)	-
Whether farmer save seed	-36.641(0.118D+08)	5.8351**(2.284)	-
Individual Features			
Total annual yield (kg/ha)***	846	676	783
Sorghum acreage (hectare)	1.61	1.58	1.58
Total acreage (hectare)	6.89	9.63	8.76
Age (average years)	44.6	43.8	43.8

[1]Compared to public-private partnership,

***, **, * = significant at 1%, 5%, 10% level

4.5 Farmers Valuation of Attribute Changes

This section calculates the farmers' valuation or welfare measure for going from the normal seed used by the farmers to a new biofortified variety. The farmers' valuation is the premium they are willing to pay for a change in attribute levels. The WTP reported in Table 7 was calculated from the utility parameter in the LCM. The WTP for changes in some product attributes whose coefficient are insignificant in the LCM were not reported in the table. Although the table showed the mean WTP for changes in different product attributes included in the choice set, in line with the objective of the research, we concentrate more on the farmers WTP for increased micronutrients and higher seed yield.

The results show that generally, the farmers may pay premium for the new sorghum seed with extra micronutrients. However, the extra amount to be paid varies among the classes. For the Micronutrient preference farmers, the mean WTP to go from a local sorghum variety to the biofortified variety is 4953CFA per kg. This implies that the farmers in this class could likely pay on average an additional 4953CFA per kg to get the new biofortified sorghum seed with higher micronutrient. The Risk takers are willing to pay on average an extra 3251CFA per kg for biofortified seed with increased micronutrients. Finally, the Small sorghum producers are willing to pay less than the two groups. Their WTP for a biofortified sorghum seed with increased micronutrients is calculated at 1421CFA per kg. This is however expected as the majority of farmers in this class do not buy their seeds from the market but use saved seeds from previous planting seasons.

It is surprising that the farmers are willing to pay little extra for higher seed yield. Perhaps the best explanation to give for this is that sorghum as the national staple is being cultivated subsistent by the majority of farmers all year round, making it relatively available. It is therefore most likely that farmers produce enough for their household.

Table 7: Farmers Willingness to Pay for a Change in Attribute

WTP for	Class 1 Micronutrient Preference	Class 2 Small Scale Farmers	Class 3 Commercial Farmers
Extra Micronutrient	4953	1421	3251
Public seed source	1085	1128	-
Private seed source	515	-	1012
Higher Seed yield	8	7	8
Early maturing seed	-	26	39

Parameters in CFA per kg; Blank spaces are due to insignificant coefficient in LCM.

5. Conclusion and Recommendations

Transgenic biofortification is emerging as an alternative public health intervention project for the improvement of the nutritional status of people. However, none of such crops have been released to the farmers due to the politics surrounding the process. Hence, there is still limited knowledge on the market potential of the new crops. In Burkina Faso, where biofortified foods might have important health benefits given the high frequency of MNM, new transgenic biofortified sorghum seeds need to possess desirable attributes to be able to contend with the highly valued local sorghum varieties and achieve adequate acceptance by both farmers and consumers.

Far to provide an exhaustive answer at the dilemmas, our work focuses on the farmers' willingness to cultivate biofortified seeds and in simulating farmers' behaviours. Therefore, in this paper, we employed a DCE to investigate the farmers' valuation of various attributes that could make up the ABS seed proposed by AHI. The experiment was conducted using a sample of 150 randomly selected sorghum farmers from 3 districts in Burkina Faso. Districts in the main sorghum growing areas in Burkina Faso were selected. Using a combination of CL and a LCM we were able to properly estimate the utility value that the farmers place on hypothetical attributes that make up the new crop, and at the same time, identifying the characteristics of the farmers' based on their preference structure. Specifically, the sorghum attributes presented to the farmers include increased micronutrients, seed price, seed source, yield, and date of maturity. Farmers characteristics include socioeconomic, farm and motivational characteristics. The farmers' WTP for the biofortified seed was estimated using their marginal valuation of a change in attribute level that makes up the crop with respect to seed price.

The findings of the DCE suggest that all the attributes of the biofortified sorghum presented in the choice set were important determinants of the farmers' choice. Aside from the farmers that have high penchant to the local seed variety, about 63% of farmers in the sample would likely cultivate the transgenic sorghum seed. These farmers however have a high preference for sorghum seeds with increased micronutrients, that mature in shorter periods, have higher yield and lower price, and are preferably provided by the public sector. The increase in micronutrients appeared to be an important attribute considered by the farmers. Furthermore, it was observed that the seed source also is a significant determinant influencing the farmers' choice for the sorghum seeds. The result showed that the farmers would prefer a public seed source followed by public-private seed partnership over a private seed source. This is in line with earlier findings that the seed sector matters for the adoption of transgenic crops in SSA. This goes to suggest that the direct provision of biofortified seeds by multinational seed companies could deter farmers' acceptance of the new variety. It is therefore pertinent that governments should at least partner with companies for proper seed development and distribution.

Secondly, the LCM shows that there was heterogeneity in the preference structure of the farmers. The study identified three distinct classes of farmers. First, the Micronutrient Preference Farmers derive the highest utility from added micronutrient among the three classes. They constitute about 31% of the total sample size and they can be described by their risk averseness and higher production of sorghum. They are willing to pay highest premium to go from the local seed to the seed with added micronutrient. Second, the Small Sorghum Producers' practices seed saving culture and does not favour private seed source. This group constitutes only 14% of the market share, have least sorghum production level, and the lowest WTP value. Finally, the Risk Takers prefer to source their seed from public-private partnership. They are well informed about the biotechnology and are most likely to be among the early adopters of the transgenic sorghum. They constitute more than 50% of the sample. We propose that this group should be the major target for the development of the transgenic biofortified sorghum seed in the short run. As the Risk Takers adopts the new product, it is expected that with adequate awareness, other segments would follow.

Finally, as a general implication for the development of the biofortified sorghum, we agree with Birol et al., (2011) that owing to the heterogeneity in the preference structure, farmers should be offered different varieties of the new products pooled from different combinations of attribute levels and prices. Specifically, we recommend that farmers should be carried along in the development of the product. Adequate information should be provided to farmers, and if possible the sorghum farmers' organizations should partner with AHI in the development of the new biofortified sorghum. We also recommend that strong government involvement is needed in the development of the new product. The role of the government should among other things create awareness of the nutritional values of the new product, subsidies and distribution of the biofortified sorghum seed.

References

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics*, *13*(1), 1–9. https://doi.org/10.1016/0169-5150(95)01142-8

Alpizar, F., Carlsson, F., & Martinsson, P. (2001). Using Choice Experiments for Non-Market Valuation. *Economic Issues*, *8*, 83–110.

Bakshi, A. (2003). Potential adverse health effects of genetically modified crops. *Journal of Toxicology and Environmental Health. Part B, Critical Reviews*, *6*(3), 211–225. https://doi.org/10.1080/10937400306469

Banerji, A., Birol, E., Karandikar, B., & Rampal, J. (2016). Information, branding, certification, and consumer willingness to pay for high-iron pearl millet: Evidence from experimental auctions in Maharashtra, India. *Food Policy*, *62*, 133–141. https://doi.org/10.1016/j.foodpol.2016.06.003

Birol, E., Asare-marfo, D., Karandikar, B., & Roy, D. (2011). *A Latent Class Approach to Investigating Farmer Demand for Biofortified Staple Food Crops in Developing Countries: The Case of High-Iron Pearl Millet in Maharashtra, India*. *HarvestPlus Working Paper* (Vol. 7).

Birol, E., Villalba, E. R., & Smale, M. (2007). *Farmer preferences for milpa diversity and genetically modified maize in Mexico: A latent class approach*. *IFPRI Discussion Paper 00726*. https://doi.org/10.1017/S1355770X08004944

Breustedt, G., Müller-scheeßel, J., & Latacs-Lohman, U. (2008). Forecasting the adoption of GM oilseed rape: Evidence from a discrete choice experiment in Germany. *Journal of Agricultural Economics*, *59*(2), 237–256. https://doi.org/10.1111/j.1477-9552.2007.00147.x

Brookes, G., & Barfoot, P. (2014). *GM crops: global socio-economic and environmental impacts 1996-2012*. *PG Economics Ltd, UK*. Dorchester.

da Silva, L. S., Jung, R., Zhao, Z. yo, Glassman, K., Taylor, J., & Taylor, J. R. N. (2011). Effect of suppressing the synthesis of different kafirin sub-classes on grain endosperm texture, protein body structure and protein nutritional quality in improved sorghum lines. *Journal of Cereal Science*, *54*(1), 160–167. https://doi.org/10.1016/j.jcs.2011.04.009

De Groote, H., Chege, C. K., Tomlins, K., & Gunaratna, N. S. (2014). Combining experimental auctions with a modified home-use test to assess rural consumers' acceptance of quality protein maize, a biofortified crop. *Food Quality and Preference*, *38*, 1–13.

https://doi.org/10.1016/j.foodqual.2014.04.014

De Steur, H., Gellynck, X., Feng, S., Rutsaert, P., & Verbeke, W. (2012). Determinants of willingness-to-pay for GM rice with health benefits in a high-risk region: Evidence from experimental auctions for folate biofortified rice in China. *Food Quality and Preference*, *25*(2), 87–94. https://doi.org/10.1016/j.foodqual.2012.02.001

Greene, W. H., & Hensher, D. A. (2003). A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B*, *37*(8), 681–698. https://doi.org/10.1016/S0191-2615(02)00046-2

Hanley, N., Mourato, S., & Wright, R. E. (2001). Choice Modelling Approaches : a Superior Alternative for Environmental Valuation ? *Journal of Economic Surveys*, *15*(3), 435–462. https://doi.org/10.1111/1467-6419.00145

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, *69*(8), 1595–1603. https://doi.org/10.1016/j.ecolecon.2010.04.011

Hubbell, B., Marra, M., & Carlson, G. (2002). Estimating the Demand for a New Technology: Bt Cotton and Insecticide Policies. *Amer. J. Agr. Econ*, *5*(4), 118–132.

Johnson, F. R., Lancsar, E., Marshall, D., Kilambi, V., Mühlbacher, A., Regier, D. A., … Bridges, J. F. P. (2013). Constructing experimental designs for discrete-choice experiments: Report of the ISPOR conjoint analysis experimental design good research practices task force. *Value in Health*, *16*(1), 3–13. https://doi.org/10.1016/j.jval.2012.08.2223

Kikulwe, E. M., Birol, E., Wesseler, J., & Falck-Zepeda, J. (2011). A latent class approach to investigating demand for genetically modified banana in Uganda. *Agricultural Economics*, *42*(5), 547–560. https://doi.org/10.1111/j.1574-0862.2010.00529.x

Krishna, V. V., & Qaim, M. (2007). Estimating the adoption of Bt eggplant in India: Who Benefits from public-private partnership? *Food Policy*, *32*(5–6), 523–543. https://doi.org/10.1016/j.foodpol.2006.11.002

Kuhfeld, W. F., Tobias, R. D., & Garratt, M. (1994). Efficient Experimental Design with Marketing Research Applications. *Journal of Marketing Research*, *31*(4), 545–557. https://doi.org/10.2307/3151882

Lacy, S. M., Cleveland, D. A., & Soleri, D. (2006). Farmer choice of sorghum varieties in southern Mali. *Human Ecology*, *34*(3), 331–353. https://doi.org/10.1007/s10745-006-9021-5

Lancaster, K. (1966). A New Approach to Consumer Theory. *Journal of Political Economy*, *74*(2), 132–157. Retrieved from http://www.jstor.org/stable/1828835

Lindsay, M. J., Hanson, K., & McPake, B. (2009). How to do (or not to do)...Designing a discrete choice experiment for application in a low-income country. *Health Policy and Planning*, *24*(2), 151–158. https://doi.org/10.1093/heapol/czn047

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods: analysis and application. *Cambridge University Press*. https://doi.org/10.1002/jae.701

Louviere, J. J., Street, D., Burgess, L., Wasi, N., Islam, T., & Marley, A. A. J. (2008). Modeling the choices of individual decision-makers by combining efficient choice experiment designs with extra preference information. *Journal of Choice Modelling*, *1*(1), 128–164. https://doi.org/10.1016/S1755-5345(13)70025-3

Mabaya, E., Fulton, J., Simiyu-Wafukho, S., & Nang'ayo, F. (2015). Factors influencing adoption of genetically modified crops in Africa. *Development Southern Africa*, *32*(5), 577–591. https://doi.org/10.1080/0376835X.2015.1044078

Mogas, J., Riera, P., & Bennett, J. (2006). A comparison of contingent valuation and choice modelling with second-order interactions. *Journal of Forest Economics*, *12*(1), 5–30. https://doi.org/10.1016/j.jfe.2005.11.001

Olembo, K., M'mboyi, F., Kiplagat, S., Sitiney, J., & Oyugi, F. (2010). Sorghum breeding in sub-saharan africa: the success stories. *African Biotechnology Stakeholders Forum*, 37 pages. Retrieved from http://absfafrica.org/downloads/Sorghum Book Series.pdf

Paarlberg, R. (2010). GMO foods and crops: Africa's choice. *New Biotechnology*, *27*(5), 609–613. https://doi.org/10.1016/j.nbt.2010.07.005

Paarlberg, R. L. (2002). The real threat to GM crops in poor countries: Consumer and policy resistance to GM foods in rich countries. *Food Policy*, *27*(3), 247–250. https://doi.org/10.1016/S0306-9192(02)00014-3

Qaim, M. (2009). The Economics of Genetically Modified Crops. *Annaul Review of Resource Economics*, *1*, 665–693. https://doi.org/10.1146/annurev.resource.050708.144203

Qaim, M., & de Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: The case of Bt cotton in Argentina. *American Journal of Agricultural Economics*, *85*(4), 814–828. https://doi.org/10.1111/1467-8276.00490

Rose, J. M., Bliemer, M. C. J., Hensher, D. A., & Collins, A. T. (2008). Designing efficient stated choice experiments in the presence of reference alternatives. *Transportation Research Part B: Methodological*, *42*(4), 395–406. https://doi.org/10.1016/j.trb.2007.09.002

Rungie, C. M., Coote, L. V., & Louviere, J. J. (2011). Structural choice modelling: Theory and applications to combining choice experiments. *Journal of Choice Modelling*, *4*(3), 1–29. https://doi.org/10.1016/S1755-5345(13)70040-X

Saldias, C., Speelman, S., Drechsel, P., & van Huylenbroeck, G. (2016). A livelihood in a risky environment: Farmers' preferences for irrigation with wastewater in Hyderabad, India. *Royal Swedish Academy of Sciences*, 1–14. https://doi.org/10.1007/s13280-016-0824-3

Sanders, J. (2016). A New Sorghum Production System in Burkina Faso. *Purdue Agriculture*, 1–14.

Schreiner, J. (2014). Farmers' Valuation of Incentives to Produce GMO-free Milk: A Discrete Choice Experiment. *System Dynamics and Innovation in Food Networks*, *2*, 312–323. https://doi.org/10.1108/bfj.2009.070111haa.001

Traore, K., & Stroosnijder, L. (2005). Sorghum quality, organic matter amendments, and health: farmers' perception in Burkina Faso, West Africa. *Ecology of Food and Nutrition*, *44*(July 2014), 225–245. https://doi.org/10.1080/03670240590953421

Virgin, I., Bhagavan, M., Komen, J., Kullaya, A., Louwaars, N., Morris, E. J., … Persley, G. (2007). *Agricultural Biotechnology and Small-scale Farmers in Eastern and Southern Africa*. *Biotechnology*. Retrieved from http://www.sei-international.org/mediamanager/documents/Publications/Risk-livelihoods/agricultural_biotech_smallscale_east_south_africa.pdf

vom Brocke, K., Trouche, G., Weltzien, E., Barro-Kondombo, C. P., Gozé, E., & Chantereau, J. (2010). Participatory variety development for sorghum in Burkina Faso: Farmers' selection and farmers' criteria. *Field Crops Research*, *119*(1), 183–194. https://doi.org/10.1016/j.fcr.2010.07.005