# Understanding farmer preferences to guide crop improvement: The case of grasspea in Ethiopia

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## Abstract

Building climate resilience in agriculture may usefully rely on crop improvement informed by social science studies of farmer preferences. Here, we present the case of grasspea in Ethiopia, a resilient and nutritious legume that can survive conditions where many other crops fail. Excessive consumption however carries the risk of an irreversible, crippling disease, this is possible in the future since the weather extremes that climate change is predicted to bring will create the conditions in which grasspea is one of the food sources that will likely see increased consumption. Crucially, farmers are not fully aware of this risk and may therefore not adopt the low-toxin grasspea that crop scientists have developed and that is about to enter the breeding pipeline. In this study we use focus group discussions, key informant interviews and choice experiments to investigate farmer preferences for grasspea improvement. We confirm that farmers do not place much value on reduced toxicity. Instead, they have strong preferences for other improvements, such as resistance to pests. This suggests that improvements that are needed in future but not yet preferred (i.e. reduced toxicity) should be bundled with improvements that farmers already prefer.

**Keywords:** climate-resilience, crop improvement, choice experiments, Ethiopia, grasspea.

## 1. Introduction

Improving climate resilience in agriculture can benefit from combining plant science and social sciences. Through plant science we can adapt crops to become more tolerant to droughts, floods and pests (Acevedo et al., 2020; Dhankher and Foyer, 2018). However, farmers adopt crops for a variety of reasons, not just for resilience traits (Acevedo et al., 2020; Arora and García, 2019). Social science can offer understanding farmer preferences to better inform crop breeder trait targeting and improve adoption rates. Some crop breeding programmes are therefore now the result of plant science for designing new varieties combined with social sciences to understand the socio-economic factors that drive farmer adoption decisions (Glover et al., 2019, 2016; Leeuwis and Aarts, 2020).

Participatory breeding methods are among the tools social scientists use to improve crop breeding programmes. These take socio-economic drivers of adoption decisions into account, but often depend upon long-term relationship building and face challenges with scaling (Almekinders and Hardon, 2006). Given the challenge of lengthy breeding pipelines and the pressing need for climate adaptation, other approaches have been sought that rapidly quantify locally valued traits for breeding strategies. An attractive one among these relies on discrete choice experiments (DCEs), which are well suited to *ex ante* testing of products that have yet to be released (Schaafsma et al., 2019).1 Several studies have used DCEs to test farmer demand for climate-smart agriculture and environmentally resilient crops (Marenya et al., 2014; Schaafsma et al., 2019; Smale and Olwande, 2014; Ward et al., 2014). Recently, DCEs have been more commonly used to uncover farmer varietal trait preferences to inform crop trait targeting (Arora and García, 2019; Birol et al., 2015; Birol and Villalba, 2006; De Groote et al., 2016; Meenakshi et al., 2012; Meressa and Navrud, 2020; Naico and Lusk, 2010).

A limitation of both participatory breeding methods and DCEs is that they may not fully capture what farmers (or future farmers) might prefer by the time the new varieties are released, by which time the environmental changes that the varieties were being developed for will have materialised. The reason is that the consequences of these environmental changes are not fully foreseen. In this paper, we wrestle with this challenge using a particularly pertinent case study in which climate change may plausibly bring about a public health disaster that farmers (as our study shows) are currently not fully aware of , with profound implications for crop breeding.

Our case is that of a legume that has been pitched as a climate-smart crop, formidable in its ability to withstand weather extremes, and included as a priority crop under the FAO Vision for Adapted Crops and Soils (VACS) initiative, but one that is in need of a crucial improvement that farmers are not necessarily fully aware of (Torero, 2023; Sarkar et al., 2019). Grasspea (*Lathyrus sativus L.*), or *guaya* in Ethiopia, is well known as a crop that farmers can rely on (Damene et al., 2020; Girma & Korbu, 2012; Tadesse & Bekele, 2002). It is one of the most drought tolerant legumes, survives well in flooded conditions and shows generally good pest resistance (Getahun et al., 2005; Girma et al., 2011; Lambein et al., 2019). However, its consumption comes at a risk. Grasspea contains a substance called β-ODAP, which is an excitotoxin similar to glutamate— a common neurotransmitter in the brain. β-ODAP has the potential to over-excite nerves and cause damage in humans (Rao et al., 1964; Vaz Patto and Rubiales, 2014). When consumed as the dominant part of the diet for three or more months, the consumer runs the risk of developing neurolathyrism; an irreversible paralysis from the legs down (Enneking, 2011; Haimanot et al., 1990; Lambein et al., 2019).2 However, when grasspea is consumed as part of a balanced diet, it is safe to eat; for example, when consumed with methionine- and cysteine-rich cereals or antioxidant-rich foods (Khandare et al., 2018; Lambein et al., 2019; Saligame, 2011; Singh and Rao, 2013; Vaz Patto and Rubiales, 2014). Methionine and cysteine are considered to be protective against neurolathyrism, based on cell-culture evidence, but grasspea, along with other legumes is low in these amino acids (Lisiewska et al., 2001; Moorhem et al., 2011). However, the challenge is that grasspea is so hardy to weather extremes that it is more likely to remain when other crops perish, causing consumers to face the risk of neurolathyrism from prolonged consumption of grasspea dominated diets during times of food scarcity.

Neurolathyrism epidemics have taken place historically when populations relied on the prolonged consumption of predominantly grasspea diets for survival, as a result of shocks causing other foods to become unavailable (Getahun et al., 2003; Haimanot et al., 1990; Singh & Rao, 2013). Given predicted climate change in Ethiopia (see section 2.1), the possibility of excessive consumption of grasspea during times of drought and food shortages in the future is becoming more likely, along with the potential public health disaster that could entail. Of concern, as we document in the paper, is that a widespread perception has taken hold that grasspea is now safe to consume, which is attributed to spurious causes (ironically including climate change). We therefore have a case in which predicted environmental change points to the need for an improved low-toxin grasspea variety, which farmers currently do not prefer. The reason they do not currently prefer it is an incomplete awareness of the health risks that will materialise when the predicted environmental change occurs.

Crop scientists have developed grasspea with greatly reduced toxicity (Emmrich, 2017; Kumar et al., 2011), and efforts are underway to incorporate the new varieties into breeding programmes. However, it remains to be seen if farmers will accept it given a tendency to think that the varieties they currently grow are always safe for human consumption. What has motivated our paper is that there are other traits Ethiopian farmers may prefer in improved grasspea varieties, which we uncover. Knowledge of these can inform not only grasspea improvement, but also help in increasing adoption rates of new *low-toxin* varieties of the crop, which farmers might otherwise not adopt. This knowledge may thus assist in averting a climate-change induced public health disaster.

The paper proceeds as follows. Section two provides the background to our study, and section three its methodology. Findings from the qualitative work informed the design of DCEs where respondents were asked to choose between grasspea varieties with varying attributes. Analysis of these choice experiments is presented in section four; it uncovers farmer priorities for grasspea improvement and deployment. We conclude with section five.

## 2. Background and context

### 2.1. Climate change in Ethiopia

The agricultural sector in Ethiopia accounts for 35% of the country's GDP and employs around 66% of the population (World Bank, 2022). The majority of Ethiopian agricultural production is managed by small-scale farmers who are vulnerable to weather shocks (Belay et al., 2017; Gezie, 2019). Between 95-99% of Ethiopian farmland is rainfed (Awulachew et al., 2010, The World Bank Group, 2021). These farmers rely on a combination of three rainfall seasons: the *Bega*, *Belg* and *Kiremt*. Ethiopian rainfall is highly variable and subsequently many areas are prone to droughts and floods (Bewket, 2012; Mann et al., 2019). Farmers are aware of these changes and seek resilience through local adaptation methods3 but generally lack the capacity to respond to greater changes to climate (Belay et al., 2017; Tessema et al., 2019). Average temperatures are rising across central and highland areas and these trends are expected to continue (Almazroui et al., 2020; Beyene et al., 2015). Rising temperatures have in turn raised rates of evapotranspiration, causing a subsequent reduction in the available soil moisture for agriculture. Consequently, drought incidence is increasing and the rains of the central and northern areas have become less predictable (Belay et al., 2017; Bewket and Alemu, 2011; Dosio et al., 2019; Mann et al., 2019). These changes in rainfall are expected to reduce agricultural production, reduce GDP by up to 8% and cause knock-on impacts to livelihood and nutritional security (Mann et al., 2019; The World Bank Group, 2021; Yalew et al., 2018).

### 2.2. Grasspea development

Grasspea is classed as an orphan crop. It is cultivated as landraces and for many years received limited crop improvement breeding (Vaz Patto et al., 2006). This is changing, however, and breeding efforts are accelerating. Since the 1990s, breeders have focused on producing high yielding, low β-ODAP (<0.1%) grasspea varieties (Dixit et al., 2016; Girma et al., 2011; Kumar et al., 2013; Vaz Patto et al., 2006). Either low or zero-β-ODAP varieties could potentially offer farmers the resilience benefits of grasspea but with greatly reduced, or zero, risk of paralysis. In 2020, researchers sequenced the grasspea genome, allowing acceleration of improved variety development through tools such as marker-assisted breeding and gene editing technologies (Emmrich et al., 2020, Edwards et al., 2023). In 2021, grasspea.net was launched as a resource to coordinate global efforts to improve this crop. More specifically, researchers have now developed grasspea lines with a 90% reduction in β-ODAP (Emmrich, 2017). These lines are now being used in field trials by breeders in India and Ethiopia. Efforts have been made to develop zero β-ODAP cultivars but no toxin-free lines or landraces have been found to date (Emmrich, 2017 and Dixit et al. 2016). It is unconfirmed what biological role β-ODAP plays and whether zero-β-ODAP lines would be compromised in some way that affects the plant’s function or resilience. While zero-β-ODAP lines remain to be tested, trials of low β-ODAP lines show no indication of being compromised (Emmrich, 2017; Kumar et al., 2011).

### 2.3. Grasspea use in Ethiopia

Smallholders in Ethiopia are aware of climate change and the need to adapt agricultural practices (Belay et al., 2017; Deressa et al., 2009; Guta et al., 2021; Tessema et al., 2019). Grasspea production has been steadily increasing in Ethiopia over the past two decades (see Figure 1). Over the last 20 years, the crop has been grown by an average of 688,000 smallholders on approximately 144,000 hectares, yielding 241,000 tonnes in harvests—with the majority grown in the northern mid and highland areas of the country (Bimerew et al., 2023, Ethiopian Statistical Service, 2024, Haimanot et al., 2006). There are reports of farmers replacing chickpea with grasspea, and others find grasspea cultivation increasing with perceptions of climate risk (Mekonnen et al., 2021, Guta et al., 2021). While grasspea still lags behind the former crop, it has surpassed better known pulses like lentils in terms of growers, acreage and production. Furthermore, grasspea is the second highest yielding pulse on record, which adds to its appeal due to its hardiness. As we shall see in section 4, our sample showcases the importance of grasspea even to a larger extent than the macro data does, since it is reportedly the second most grown crop overall and by far the legume most widely consumed.

[Figure 1 here]

Farmers grow grasspea for its hardy qualities but they also perceive the link between grasspea and neurolathyrism, with women taking steps during its preparation to reduce the risk of toxicity (Girma et al., 2011). These preparation steps are however time-demanding, requiring access to water and fuel that may be absent in times of crisis (Girma et al., 2011). Even when these steps are completed, β-ODAP still remains in resulting dishes (Tekle-Haimanot, 1993). As such, low-toxin varieties could better ensure low β-ODAP levels in grasspea dishes, regardless of the efficacy of preparation methods. What is less clear is whether farmers would value reduced toxicity as a grasspea trait, what other traits they would like to see improved and how they would be willing to access improved cultivars.

As we will show, rural Ethiopians believe grasspea is safe due to reduced toxicity levels in present-day landraces and the effectiveness of local processing methods that reduce toxins. However, in recent studies of Ethiopian grasspea, all collected landraces showed potentially toxic levels of β-ODAP (Emmrich, 2017). There have also been recent reports of high incidence of neurolathyrism across Ethiopian communities (Bimerew et al., 2023 Yesuf et al., 2024). As we show in section 4, farmers show mixed understanding of grasspea toxicity and how to mitigate its effects. Therefore, this divergence in toxicity management understanding, combined with rising levels of grasspea cultivation and increasing weather shocks, raise the potential for growing incidence of neurolathyrism outbreaks. This raises the urgency for widespread adoption of low-toxin grasspea varieties.

## 3. Methodology

A mixed methods design was used, starting with qualitative key informant interviews, focus group discussions and participant observation before moving into quantitative surveys and discrete choice experiments. Findings from the qualitative methods informed the design of the quantitative instruments and aided in the triangulation of the findings.

### 3.1. Site and sample selection

Ethiopian ethnic regional areas are organised into zones, comprised of districts (woredas), which are made up of kebeles. We studied three woredas: Fogera in South Gondar and Bahir Dar Zuria in West Gojjam (both in the Amhara region) and; Welmera in the Oromia Special Zone, Oromia region. These locations were purposively selected to cover the range of agro-ecologies grasspea is grown in. Welmera is temperate midlands, Fogera as flood-prone mid and highlands, and Bahir Dar Zuria is dry midlands. Three kebeles in each woreda were randomly selected. A list of household heads was requested from the chosen kebeles administrative leaders. Household were numbered and selected through a random number generator.

Twenty-five focus group discussions (FGDs) comprised 6-10 randomly selected household heads, in three different groupings: men aged from 18-45; women aged from 18-45; and elders (mixed gender from 46+ years of age). This included five FGDs at Fogera and Welmera respectively, ten at Bahir Dar due to greater time availability. Focus group participants were invited from selected households. Eleven key informant interviews were conducted with purposively selected individuals among researchers, officials and farmers who had knowledge of the grasspea and legume seed systems in Ethiopia.

508 participants responded to our discrete choice experiment and survey, which was derived from a target of 170 for each of our agro-ecology zones, with a shortfall of two respondents. This number of 170 was chosen to ensure statistical strength for analysis even in the event of numerous shortfalls in each location. Either the household heads or their spouse were interviewed, given their implied decision-making power in the household. The decision of whether to speak to the household head or their spouse was decided by a coin toss.

### 3.2. Instruments

### 3.2.1 Qualitative Methods

Focus group one presented six statements and questions on grasspea cultivation for group debate.4 Statements involved arguments from the literature and posed in a way to encourage debates. A facilitator announced a statement, if participants agreed and reasons for their standpoint. Facilitators encouraged participants to debate each statement in turn. Next, the group was asked questions on grasspea is viewed, the local farming situation and climate change.5

Focus group two involved a seed system assessment (McGuire and Sperling, 2016) where all individuals listed: all local crops; methods to obtain seed; seed sources and the advantages or disadvantages of each source. The exercise investigated the range of local crops, how they are accessed and why farmers choose different sources.

Key informants joined in-person or online semi-structured interviews. Questions varied depending on the expertise of the informant. Key informants included government officials, local leaders, agricultural researchers, grasspea researchers, grasspea farmers and neurolathyrism experts. Interviews investigated the setting of Ethiopian legume markets, grasspea cultivation trends, and the future of Ethiopian seed systems.

### 3.2.2 Discrete Choice Experiments

We used discrete choice experiments (DCEs) to understand the attributes that influence farmer investment behaviour (Lancaster, 1966; Louviere and Woodworth, 1983). In a DCE, individuals are asked to make a hypothetical choice between two, or more, alternatives comprised of multiple attributes and their respective levels. These choices can infer the conditional effect attributes have on investment behaviour, and how individuals rank the importance of attributes. Our DCE choices were based around acquisition of grasspea (Mangham et al., 2009). Attributes were chosen that are realistic, important and independent from one another, to avoid multicollinearity.

### 3.2.2.1 Selection of attributes and levels

From our qualitative research and literature review, we identified six attributes comprising: seed source, toxicity, drought tolerance, flood tolerance, disease or pest resistance and price (see Table 1).

[Table 1 here]

**3.2.2.2 Seed source**

Farmer seed sources were categorised into three general groupings: formal, informal and government. Formal sources constitute agro-dealers, seed producers and local shops while informal options include farmers own-saved seed, exchange between farmers, local markets and mobile traders (McGuire and Sperling, 2016). Government sources are where seed is provided by the state or state-owned bodies such as crop breeders or research centres. Grasspea is currently traded entirely on local markets and farmer-to-farmer interactions.

In Ethiopia, improved seed is mainly offered through agro-dealers (McGuire and Sperling, 2016; Odame and Muange, 2011). Ethiopian seed systems became more liberalised in recent years, shifting from previous government allocation, with the aim to increase the proliferation of improved varieties (Beko, 2017). This change to a predominantly free-market model has however been slow and agro-dealer sales have been limited to maize and wheat (Beko, 2017; Sisay et al., 2017; Spielman et al., 2010). Instead, much improved seed continues to be provided to farmers by government groups, such as public seed enterprises and agricultural research institutes (Beko, 2017; McGuire, 2005; Sisay et al., 2017). Against this backdrop of attempted seed system reform, we sought to test how Ethiopian farmers might show preferences for purchasing improved grasspea from formal, informal and government institutions.

**3.2.2.3. Grasspea toxicity**

Ethiopian farmers know about grasspea toxicity and have methods to reduce the risk (Dadi et al., 2003; Girma et al., 2011). Less is known about farmer preferences for varieties with differing toxin levels. Plant science researchers are developing low β-ODAP varieties (Kumar et al., 2013; Vaz Patto et al., 2006). A zero β-ODAP variety however would require use of genetic modification to achieve, which is currently under tight regulation in Ethiopia. While low toxin varieties are likely to have greatly reduced risk of neurolathyrism, some risk remains and these plants could increase β-ODAP content under weather stress conditions (Fikre et al., 2011). Transgenic or gene-edited zero toxin varieties would remove this risk but would require a change to Ethiopian crop genetics policy for release. Our DCE attribute of toxicity investigated if there might be a difference in farmer investment decisions between different three β-ODAP levels: the same toxicity as local varieties; low toxin and; no toxin.

**3.2.2.4. Drought tolerance**

Grasspea’s drought tolerance is regularly cited as a reason why farmers choose it, which was confirmed by FGD participants (Dadi et al., 2003; Fikre et al., 2011; Girma et al., 2011, Guta et al., 2021; Lambein et al., 2019; Vaz Patto et al., 2006). Grasspea has early flowering and a fast life cycle which allows it to produce a harvest from the remaining days of rainfall in the season (Sarkar et al., 2019). When grasspea becomes water-stressed, it prematurely aborts flowers or pods, focusing energy on the remaining seed (Gusmao et al., 2012; Sarkar et al., 2019). Grasspea also develops long roots, allowing it to access residual water in deep soil (Sarkar et al., 2019; Vaz Patto et al., 2006). These adaptations provide the potential for breeders to further develop these traits. However, the genetics involved in these drought adaptations are likely to be complex multi-gene traits and therefore potentially difficult to breed into new varieties.

Offering categories of ‘more drought tolerant’ or 'less drought tolerant is likely to be interpreted inconsistently across the sample. Grasspea needs between 300-600 mm of rain per season to yield well and takes between 90-149 days to reach maturity (Fikre, 2008). Our sample locations experience two rainy seasons, with most growing grasspea as a relay crop after the Kiremt rains (mid-June to mid-September). We offered drought tolerance levels by giving the minimum number of weeks of rain over the growing period required for a harvest. These levels included: five weeks, eight weeks and eleven weeks of damp soil. Using set times gave farmers a less subjective ranking of water requirements and provides breeders with targets to screen field trials against.

**3.2.2.5. Flood tolerance**

3.2.2.5. Flood tolerance

Waterlogging inhibits development in legumes and increases disease likelihood (Zhou et al., 2016). Grasspea is an exception to this, with good tolerance to waterlogging, exemplified by our Fogera sample sowing grasspea into rice paddy fields (Getahun et al., 2005; Girma et al., 2011). Ethiopian grasspea varieties ranked amongst the most flood tolerant globally (Wiraguna et al., 2020). Still, farmers in our wetter agro-ecology reported that grasspea performs better in drier conditions.

Ethiopia has a varied typography and farmland at the base of hills can face sudden floods during the rainy seasons. Wiraguna et al. (2020) found that one week of waterlogging on Ethiopian grasspea lines reduced germination and seedling survival by 12-66% and 17-69%, respectively. Malik et al. (2015) measured the effect on germinated grasspea seed facing 14 and 35 days of waterlogging, showing changes to root structure, chlorophyll content and root porosity. However, surviving plants from the 14 days cycle were able to recover to similar levels as the control. Combined, these studies give us approximations of grasspea tolerance between a week and 35 days. Subsequently, we included the three levels of: not surviving waterlogging, surviving one week and surviving three weeks of waterlogging.

**3.2.2.6. Pests and diseases**

Grasspea has good innate resistance to pests and diseases but still has some biotic threats to yields (Hillocks and Maruthi, 2012; Lambein et al., 2019). Aphids, downy mildew (Peronospora lathyri-palustris), pea rust (Uromyces pisi), powdery mildew (Erysiphe pisi), thrips (Caliothrips indicus) and wilt root rot complex can potentially damage grasspea crops (Lambein et al., 2019; Wale, 2004; Wale and Fentie, 2013). Of these, key informant interviews confirmed that aphids, wilt root rot complex and pea rust are particularly damaging to Ethiopian grasspea harvests. Thus, these three choices defined our levels for the attribute of pests and disease resilience as compared to grasspea varieties with the same resistance as local varieties. We aimed to understand how farmers would value improved innate immunity to these biotic pressures. Such resistance would negate the need to buy and spray pesticides. Focus groups mentioned that grasspea farmers must proactively spray pesticides on the crop to achieve good harvests, which was corroborated in our survey reporting 83.8% of farmers use pesticides on grasspea. Grasspea varieties with innate immunity would therefore provide farmers with reduced resource costs on inputs and improved yields. Knowing which of these pest and disease resistances are particularly sought after by farmers could inform crop breeding strategies.

**3.2.2.7. Price**

Price is a major barrier to farmers purchasing seed (Mesfin and Zemedu, 2018; Odame and Muange, 2011; Sperling et al., 2020). Formal sector seed prices tend to be higher due to the development, production and regulatory costs involved (Bentley et al., 2011). Conversely, seed sold on local informal markets has few of these additional costs. Consequently, formal seed sector groups struggle to offer farmers seed at competitive prices to those of the informal market. Unless improved grasspea cultivars from the formal sector are subsidised, their sustainability on the market relies on repeated farmer demand and purchase. Thus, we wished to discern if farmers might be willing to purchase improved grasspea seed at a higher price. We set our base attribute level at the average grasspea seed price focus groups reported on local markets. Higher levels were set at proportional increases from the local market price. Subsequently, the alternative levels were set at x1.5, x2 and x3 of this local market price. Formal seed costs to seed multiplication mean that improved grasspea is likely to enter the market at prices closer to our highest level or above. However, grasspea seed that is produced by farmer cooperatives or local seed businesses in the integrated seed sector might have less of these overheads (Bishaw and Atilaw, 2016; Borman et al., 2020). Since grasspea has a potential public health risk to it, reduced toxin seed could potentially be subsidised or provided freely through Ethiopian agricultural institutions. Knowing how much farmers are willing to pay for these improved varieties might help guide subsidised prices.

### 3.2.3. Survey and DCE Fieldwork implementation

The DCEs and surveys were conducted at the same meeting, facilitated by an enumerator. Prior to the choices, respondents were presented with a scenario that explained a conceptual setting for the choices.6 Participants were then asked to make a binary choice between two imagined cultivars of grasspea (A or B), comprised of different levels. No opt-out option was provided. We used the measure of design (D-) efficiency to give a fractional factorial design that provided near equal representation of all conceptualised attribute levels, but across only 15 questions (Mangham et al., 2009; Street and Burgess, 2007). Attributes were written in the local languages, combined with images.

### 3.2.4. Analytical framework

Our model for the analysis of the DCE responses follows the Random Utility Theory (RUT) framework developed by McFadden (1974). In RUT, the utility of an alternative presented to the individual is decomposable into a systematic (observable) component, specified as a function of the attributes of the alternatives (term in eq. (1)), and a random element , representing the unobserved variation in preferences (de Bekker-Grob et al., 2012).

(1)

Where is the measurable utility of alternative of attribute for individual . The decision maker will then choose alternative over if:

1. or

(2)

The probability of choosing alternative conditional on the attributes and choice set is:

(3)

This means that the probability of choosing alternative is given by the probability that the difference in the error term (i.e. the random element) is smaller than the difference in the observable utility component (McFadden, 1973; Ryan & Gerard, 2003). A cumulative distribution function is assumed for the difference in the error term, which in our case is the standard normal cumulative distribution function, as we deploy a random effects probit model (REP) in the analysis.

We selected the REP estimator owing to its status as a long-standing method for the study of DCEs, well-illustrated by successive literature reviews (Clark et al., 2014; de Bekker-Grob et al., 2012; Ryan and Gerard, 2003; Soekhai et al., 2019), and because it fits our data generation process well. First, the method is suitable for the analysis of binary choices—strictly our case, given that participants were presented with two choices without an opt-out option (de Bekker-Grob et al., 2012). Second, our data possesses a panel structure, as it contains sets of 30 responses for each participant; specifically, it consists of 15 choices between two grasspea options for the 508 respondents that took part in the experiment. Lastly, REP does not require the stringent Independence of Irrelevant Alternatives (IIA) assumption, which other competing methods must hold and would likely be violated in our application (de Bekker-Grob et al., 2012; McFadden, 1974).

As formulated in eq. (1), the latent relationship between the utility of the alterative and its two components is assumed to be linear; in particular, it takes the following form in our application:

(4)

where is the latent utility of alternative for individual , which is not directly observed, and instead is represented by bivariate variable that takes value 1 if an option is chosen (i.e. > 0) and 0 if it is not. is a set of bivariate variables which define the attributes of every alternative . They include the source of the grasspea seeds, their toxicity, drought and flood tolerance, pest resistance level and price (see Table 1 for a full description of the attributes and levels). Finally, includes the individual level controls, and is the error term.

## 4. Results

### 4.1 Descriptives

Household heads in our sample are on average 47.6 years old. Households are an average of 6 people in size and 79% of our sample was male.7 90.8% of our surveyed sample have primary education or lower (reported in Supplementary Materials 4). Similarly, 65.6% describe themselves as illiterate or that they struggle to read. Agriculture is the main economic activity for 98.2% of our sample. Land area was measured in the Ethiopian measurement oftimads. The exact size of a timad varies across localities (between 0.05 and 0.38 ha); the most common conversion is estimating a timad as 0.25 of a hectare or 0.62 of an acre. Households owned on average 5.8 timads (approximately 3.6 acres) and cultivated 6.3 timads (approximately 3.9 acres); suggesting land is rented in, share-cropped or crops are grown on land that is not owned by the household. The focus cereal crops across our sites are maize, tef, wheat and rice.

Grasspea is grown by 75% of households in our sample during the last year, which makes it the second most widely grown crop in the area behind only teff.On average, grasspea grows on approximately one quarter of a household’s farmed area. These numbers are similar to those found by others in the highest producing areas of grasspea (Dadi et al., 2003; Girma et al., 2011). 81% reported that grasspea is their most consumed legume, mostly due to ease of access. Furthermore, 44.3% of our sample eats grasspea meals more than once a day and another 90% eat it more than once a week.

[Table 2 here]

### 4.2. Changing grasspea consumption

A potentially concerning finding from our survey data is the growth of grasspea consumption combined with perceptions of its safety. Over 70% of our sample knew more than one person with neurolathyrism, which respondents attributed to grasspea consumption. These numbers indicate a common prevalence of the disease in all three of our rural communities and support other results from recent studies (Guta et al., 2021; Hussien et al., 2021). Yet despite this, the crop has become widespread, and demand is growing. Our findings present worrying concerns for potential neurolathyrism outbreaks in the future.

Firstly, people believe that the risk is greatly reduced and avoidable; 73% of our sample believe grasspea was dangerous to eat in the past but 81% claim that grasspea is safe to eat today. People feel safer consuming the crop today due to several factors. The first reason is a belief that grasspea today contains reduced toxin levels. Bioscience studies however find that considerable levels of β-ODAP remain in landraces today (Emmrich, 2017). The other reason people felt safer eating grasspea is that they believe modern day methods of preparation and precaution around grasspea have eradicated all risk. Instead, we found that perceptions of where this toxicity lies—or of how to prevent it—are hazily understood. For example, some associated the toxin with unprocessed consumption while others associated it with evaporation from grasspea fields, eating grasspea with certain foods like milk or making physical contact with grasspea straw. These claims are made despite a lack of scientific evidence to suggest that neurolathyrism is caused by anything other than over-consumption of β-ODAP. In addition to being confident in preventing neurolathyrism, people believed that incidence of paralysis was higher in the past due to carelessness in these risk management practices, and that modern-day Ethiopians are better at managing this risk.

In summary, Ethiopian farmers attempt to reduce their risk of neurolathyrism through a mixture of food processing methods of varying effectiveness at reducing β-ODAP concentrations in the food (Tekle-Haimanot et al., 1993, Tate et al., 1995, Buta et al., 2020). Neurolathyrism is avoided by consuming grasspea as part of a balanced diet, but it seems some individuals might depend on mixed diets unknowingly, believing themselves protected through other local practices. During weather shocks nutritionally diverse diets would become less available. In the absence of cereal compliments to traditional meals, consumers are likely to continue to eat grasspea dishes in the belief that they are safe due to their current risk management strategies. Given the ubiquitous nature of grasspea consumption, a great number of people could potentially start consuming high levels of β-ODAP for extended periods of time. This presents the rising potential for neurolathyrism outbreaks with environmental change.

### 4.3 DCE results

We report two models (Table 3), the first estimates the regression model outlined in equation (4) above, which features the attributes of every alternative and some individual-level controls. The second model adds an interaction between the levels of the drought tolerance and an indicator variable denoting the historically driest region where the study took place. The table reports marginal effects. If these are multiplied by 100, they can be interpreted as the change in percentage points of the probability of a grasspea improved variety being chosen because of the change in the attribute under consideration from its base level to the level associated with the marginal effect. The main effects are the following.

#### 4.3.1. Sources of seed

We find that respondents are 5.9% less likely to want to purchase from agro-dealer sources than local markets. This aligns with other sub-Saharan Africa studies where farmers prefer local markets over formal seed outlets (McGuire and Sperling, 2016; Sperling et al., 2020). This is likely due to restrictions formal sources pose to seed access and availability: higher prices, unavailability before the growing season and distance of outlets from the farm. Furthermore, agro-dealers tend to focus on cereal crops. Therefore, even farmers who purchase from agro-dealers might not do so for legumes. Although farmers reported legumes from agro-dealers as showing higher reliability, they complained that they are not always available. This echoes other reports that improved seed at agro-dealers can arrive late in the season, and that holding out for resupplies puts farmers at risk of missing the favourable weather (Mekonnen et al., 2021). Unsurprisingly then, very few of our focus groups listed agro-dealers as an important source of legume seeds.

Government seed sources were mentioned as important for legumes, thought to be of good productivity and reliability. In our choice experiments however, farmers were 9.7% less likely to want to purchase seed from government sources than from local markets. One possible reason for this was how some respondents reacted to the choice of purchasing from the government. The government was felt to be an institution that donates seed or works through other state bodies like crop improvement centres, rather than a private body through which seed is purchased. This view is understandable as the Ethiopian government has been freely distributing seed to farmers for many years (Beko, 2017). Likely due to this history, our findings suggest that attempting to sell seed through government channels would be viewed unfavourably. However, the reportedly good reputation of the government seed sources of quality seed suggests that these might be an alternative channel to distribute proliferate improved grasspea, if donated to farmers.

#### 4.3.2. Toxicity

We find that farmers are only 3.4% more likely to choose low-toxin varieties over the current local varieties. This suggests that farmers see little extra value in a difference between local landrace toxin levels and low-toxin varieties. Farmers are however 14.9% more likely to choose zero toxin varieties over local varieties. This suggests that respondents see a distinct improved value in zero-toxin varieties compared to low-toxin ones. The former are currently not scientifically obtainable, so this is not yet of practical value. With that said, both effects across our populations are relatively low. One reason for this could be due to how farmers perceived grasspea toxicity. As noted earlier, Ethiopian farmers underestimate the toxicity levels present in current landraces. While our survey and focus group discussions coincide with other reports which reveal awareness about the issue, they also show a widespread belief in a reduction of toxicity and reliance on dubious methods to mitigate the risk (Dadi et al., 2003; Girma et al., 2011).

[Table 3 here]

#### 4.3.3. Drought tolerance

Despite the renowned drought tolerance of grasspea, this attribute had a small effect farmer purchase behaviour. Compared to varieties that require five weeks of damp soil, respondents were 4.8% and 4.3% less likely to choose varieties that required eight weeks and eleven weeks soil moisture, respectively. This effect was consistent across our agro-ecologies and our interaction effects showed that individuals in drier agro-ecologies were only around 3% and 3.3% more likely to choose the most drought-tolerant options. One explanation for this small effect could be that drought tolerance is simply not a major attribute upon which respondents decide upon. This however seems unlikely given that farmers mentioned how part of grasspea’s appeal is as a reliable crop in weather extremes. This leaves three possibilities.

The first is that farmers believe grasspea is sufficiently drought tolerant that they do not see further hardiness as the most important point to base investment upon. For example, focus groups repeatedly stated that grasspea could grow with little to no rain at all. Alternatively, it could be that farmers simply did not keep track of the number of weeks of moisture that grasspea requires. grasspea was reportedly planted as a relay crop, sown shortly before the harvest of the main crop. Thus, farmers might not generally pay as much attention to the number of weeks that follow the main crop’s harvest and processing. Or it could be that the weather at the end of the season is too changeable to have a good estimate for how many weeks of rain grasspea requires. Finally, it is also possible that this way of offering a drought tolerance choice is difficult to understand and therefore farmers made investment choices less often based on this attribute; resulting in a reduced effect as a driver of their choices.

#### 4.3.4. Flooding tolerance

Unlike drought tolerance, farmers in our study showed strong responses to our levels of flood tolerance. Compared to no flood tolerance, respondents were 26.5% more likely to choose varieties that survive one week of flooding and 36.9% more likely to choose varieties that survive three weeks of flooding. These findings suggest that flood tolerance traits in grasspea are of great interest to farmers. This result is perhaps unsurprising in our wettest region of Fogera, given that grasspea is grown in rice paddy fields. However, Fogera farmers do not show significantly different marginal effects for flood tolerance preferences to the other agro-ecologies. Instead, farmer preference for flooding tolerance was also held in our other, drier, agro-ecologies. Overall, these findings suggest that farmers across Ethiopia generally either currently value, or would invest in, grasspea varieties that offer improved flood resistance.

#### 4.3.5. Resistance to pests and diseases

We find that compared to the resistance of local landraces, farmers are; 19.8% more likely to choose rust resistance; 20.6% more likely to choose wilt root rot complex resistance and 24.3% more likely to choose aphid resistance. These findings suggest that although grasspea is often cited for its general pest resistance (Campbell, 1997; Lambein et al., 2019), farmers would be more likely to invest in varieties with improved innate resistance. This makes sense given that it would reduce financial and time costs associated with pesticide use. Further, given that grasspea is often grown when the main crop harvest requires processing and sale, spraying resource costs might further distract from the priority activity.

#### 4.3.6. Price

Respondents in our study were 5% less likely to purchase seed that is 1.5 and 2 times the amount of the local market price. The similarity between these first two levels might suggest that farmers view an increase between 1.5 and 2 times the local price as equally unfavourable. The increase to three times the price however showed a marked difference, with farmers predicted to be 14.2% less likely to purchase this more expensive option. Although all negatively correlated, these estimates are fairly low and suggest that, by and large, farmers are not put off by moderately higher prices (x1.5 or x2 of local market prices) and might be willing to invest in improved grasspea varieties which offer valuable traits. Such a prediction could be promising for formal sector producers of grasspea who struggle to match local market prices. This finding does however need to be contextualised by three other points.

Firstly, our qualitative and survey sections showed that grasspea is grown by farmers of all wealth statuses. It could be that wealthier individuals are able to pay more for grasspea rather than poorer members of the community, for whom reduced toxin varieties could have more impact. We however tested for an interaction effect between wealth and the price attribute and find no additional effect.

Secondly, our survey shows that farmers' most important source of grasspea seed are their own stocks. Our choice presents a single time purchase. It could be that some farmers are willing to purchase more expensive seed but then plan to personally multiply it over subsequent seasons. If so, it presents challenges for the market sustainability of the cultivar, which relies on repeated demand. Nevertheless, Sperling et al. (2021) find that African smallholders generally purchase legumes on markets, rather than relying on saved or shared seed, suggesting that repeated market demand is likely. However, ongoing farmer seed production through local markets presents an additional challenge to retaining breeder-targeted traits. Although grasspea self-pollinates, it will outcross over generations, so later generations could lose the beneficial traits that farmers originally purchased them for.

A final factor could be that respondents are less influenced by these prices due to the hypothetical nature of the choice. Participants in our experiment did not have to pay for varieties. It could therefore be that they felt more ambivalent towards these levels than if they had to pay, reducing the effect size.

## 5. Conclusion

In this study, we test preferences for grasspea improvement for understanding whether farmers will adopt the low-toxin varieties that crop scientists have developed and which are to enter into breeding programmes. We see this as a case study of the contribution social science may make to building climate resilience in agriculture through crop improvement programmes, in particular when new traits required because of climate change are not yet preferred. The new trait we are focusing on here is reduced toxicity of grasspea, needed in future because climate change will bring about the conditions in which grasspea will be the dominant part of an unbalanced diet for a dangerously long period.

Our first key finding, confirming the necessity of our study, is that rural Ethiopians believe that grasspea is now safe to eat because of changes in the crop toxicity over generations and contemporary know-how in processing. The evidence however suggests that grasspea toxicity remains present in local landraces and neurolathyrism risk management methods vary in effectiveness. grasspea’s innate resilience raises the likelihood of it being one of the few crops farmers rely on during weather extremes. Such situations are increasingly likely as climate changes in Ethiopia raise the incidence of extreme weather and subsequent crop failures (Belay et al., 2017; Bewket and Alemu, 2011). Where grasspea harvests persist, while other crops perish, consumers are likely to eat grasspea dominated diets for prolonged periods of time, in the absence of a larger set of available food items. Some will do so while knowing of the risks. Others however will eat grasspea under the belief that they are safe, while exposing themselves to prolonged β-ODAP ingestion. Given the current popularity of the crop, this presents the possibility of widespread neurolathyrism outbreaks.

Our second key finding is that grasspea in Ethiopia is widely consumed, adding to the pertinence of our study. Contrary to much literature, we find that grasspea in Ethiopia cannot be considered as just a crop for the poor (Dadi et al., 2003; Fikre, 2008; Guta et al., 2021; Sarkar et al., 2019). All farmers across our three agro-ecologies now regularly grow and consume grasspea, and demand is growing.

Our third key finding, from our choice experiments, is that reduced toxicity is of little value to Ethiopian farmers. By contrast, our respondents are much more likely to invest in varieties that offer improved flood tolerance and improved pest and disease resistance.9 For this reason, we recommend that flood tolerance and innate biotic resistances are also targeted by breeding programmes of low-toxin varieties and are foregrounded at the point of sale to raise the likelihood of farmer purchase.

An alternative response would be to prevent or ban grasspea. Our data however shows how widely important grasspea has become on resilience, nutritional and cultural grounds. A less stringent approach would be to run information campaigns that provide guidance on the safe consumption of grasspea. Such campaigns assume that farmers have the agency to prepare or consume grasspea in ways that reduce toxicity, when these methods may be difficult during shock events. Another proposed option is to ensure that methionine-rich foods are distributed to grasspea areas as aid in times of famine (Getahun et al., 2003). Such foods could reduce bioavailability of -ODAP in the body, reducing the risk of neurolathyrism developing. This approach would however require ongoing surveillance and significant logistical planning over large remote areas and subsequently could miss famished groups, especially during times of political instability. We argue that safer cultivars of grasspea could maintain grasspea’s benefits for populations, while reducing the risks or urgent need for diet supplementing during a famine. Such an intervention would rely on wide-scale adoption, which in turn relies on offering traits of importance to farmers and utilising factors that enable accessibility.

Other findings, of secondary interest to our study, are that farmers prefer to purchase from local seed markets but only marginally more than from agro-dealers. This finding supports other studies reporting that African smallholders are reluctant to choose from agro-dealers (Odame and Muange, 2011; Sperling et al., 2021). However, the minor difference in preference suggests that Ethiopian farmers might not be as opposed to these channels if they offer preferable varieties. Conversely, paying for seed from government channels was looked unfavourably upon by our sample. Where grasspea seed is sold to farmers, it should try to match the prices found at local markets, but some farmers may be willing to purchase seed at prices of up to twice the local market price if the additional benefits are clear. It however remains to be seen if the formal commercial sector could sustainably supply improved grasspea seed at these price points with the additional overheads formal seed production carries. One alternative would be for improved grasspea to be distributed to farmers as part of wider Ethiopian public seed schemes, where governments cover the overhead costs. Such an initiative could be justified on public health grounds, if wide-scale uptake of low or zero toxin varieties could prevent neurolathyrism incidence. Another alternative might be to use an integrated seed systems approach to bring quality seed to farmers at lower prices (Bishaw and Atilaw, 2016; Borman et al., 2020).

[1]: Although widely used in medical trials, DCEs were rarely used for agricultural technologies prior to 2005 (Breustedt et al., 2008; Windle and Rolfe, 2005). Since then, the number of studies has increased, with notable focus on potential markets for hybrid and genetically modified crops (Birol et al., 2012, 2009; Breustedt et al., 2008; Kolady and Lesser, 2006; Krishna and Qaim, 2007).

[2]: Although the exact level of safe consumption is not known.

[3]: Such as crop diversity, planting date adjustment, soil and water conservation, increasing input use, integration with livestock, tree planting and improving off-farm income. Importantly also, Belay *et al.* 2017 finds that these adaptation methods have a gendered component, with male-headed households having better opportunities to adapt.

[4]: See Supplementary Materials 1.

[5]: Questions in Supplementary Materials 2.

[6]: An example of a scenario can be found in Supplementary Materials 3.

[7]: This imbalance occurred despite our sampling strategy which aimed to achieve an equal balance of men and women. During the fieldwork, male household heads were reluctant to let their spouse speak for them on grounds of cultural norms. Subsequently, male respondents are overrepresented in our survey.

[8]: This includes rented-in land or shared cropping.

[9]: This echoes the recent findings of Meressa and Navrud (2020) who found that Ethiopian coffee farmers prefer resilience traits; although farmers in our sample show little preference for drought tolerance improvements in grasspea.

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# 7. Supplementary Materials

### 1. FG1 statements and questions

#### 1.1 Statements

1. “Grasspea makes food taste better than other pulses.”
2. “Eating grasspea can be dangerous.” (if the group shows no awareness of a toxin in grasspea, ask question A below. If the group seems to know about the toxin, skip question A and jump straight to statement 3).
3. But I heard someone say that eating grasspea for a long time can be a bad for health? Is this not the case?
4. “People only grow grasspea so they have food if there are extremes in weather.”
5. “Grasspea is only for the poorer members of the community.”
6. “Grasspea is becoming more popular now”
7. “It’s better to buy new legume seeds from agro-dealers.”

#### 1.2 Questions

1. Has local farming changed in the last five to ten years? If it has changed, how has it changed?
2. How much does grasspea for food cost locally and where is it normally obtained from?
3. What is important to you when buying grasspea to grow or eat?
4. Who are the best grasspea farmers locally and what makes them so good?
5. How do farmers use grasspea in combination with their other crops?
6. *If the participants showed knowledge of grasspea toxin in the previous statements section, read the question 6 below. If they showed no knowledge of grasspea toxins, skip question 6.*
7. Would you pay more for grasspea that has less of the harmful substance in than the local varieties? Would you pay more than this for grasspea that has no harmful substance in?

### 2. Key informant semi-structured interviews

1. What proportion of the people in this local area grow grasspea?
2. How important do you think grasspea is as a crop for people locally? Why is this?
3. Who are the different types of people who grow grasspea? Why is this?
4. Who are the different types of people who eat grasspea? Why is this?
5. Has farmer demand for growing grasspea changed in the last 10 years and why is this if so?
   1. Do you think this will change in the next 10 years? Why if so?
   2. Why do farmers grow grasspea and what properties of grasspea are valued?
   3. What grasspea traits/qualities are important to farmers?
   4. Are there other legumes farmers prefer to grow instead of grasspea? What are these legumes if so and why do they prefer them?
6. Who are the kinds of individuals that you sell grasspea to? When and how does this take place?
   1. How is the price for selling grasspea determined and how does it vary?
   2. Where and how do you sell grasspea? Are there traders who purchase grasspea from you and how do they arrange this if so?
7. Has consumer demand for eating grasspea changed in the last 10 years and why is this if so? Do you think this will change in the next 10 years?
   1. Why do consumers choose grasspea to eat over other legumes?
   2. What grasspea traits/ qualities are important for consumers?
   3. Are there other legumes consumers prefer to eat instead of grasspea? What are these legumes if so and why do they prefer them?
8. How commonly is grasspea used as livestock feed? Is this in certain areas or by certain groups?
   1. Is grasspea mixed with any particular other animal feeds and why is this if so?
   2. What animals are fed grasspea?
9. Where are all the different places farmers can buy grasspea locally as seed to grow?
   1. Are these different seed sources used by different types of farmers? Who are these types of farmer if so?
   2. How do most farmers locally obtain grasspea seed? For example, with cash, on credit, for free or is it some other form?
10. Where are all the different places consumers can buy grasspea locally to eat?
    1. Are these different places used by different types of grasspea consumers? Who are these types of consumers if so?
    2. How do local people who eat grass obtain it? For example, with cash, on credit, for free or is it some other form?
11. Are farmers sharing different varieties of grasspea? What are these varieties if so?
12. How do new crop varieties arrive in the area and where can they be obtained from?
13. What other crops do farmers grow in combination with grasspea locally?
14. Are people locally worried about any dangers of eating grasspea? What dangers are these if so?
15. Are there people locally who feel they have suffered bad health from eating grasspea?
16. What checks do farmers use to test seed quality for legumes?
17. Are there any other thoughts or advice related to the topics we have discussed but something we haven’t specifically mentioned that you feel would be important to add? What are those thoughts if so?

### 3. Discrete choice experiment scenario

Enumerators first introduced themselves as field researchers working in collaboration with a research project on grasspea. The project was described as a study into how Ethiopians today use and value grasspea. Respondents were told that, as part of this research, we would like them to take part in an experiment and survey where we ask their preferences between some improved varieties of grasspea. They were told that their answers are anonymous, all participation was voluntary, that they could withdraw from the experiment at any point and did not need to provide any reason for why they might withdraw.

Before starting the choices, the enumerators read the following introductory text:

*We would like you to imagine the following situation.*

*You are a farmer who is planning on growing grasspea this year. There are new varieties of grasspea that have just been brought to the Ethiopian market. These varieties differ in their qualities, prices and where they are sold from. Some of these new varieties offer increased resilience to extreme weather and disease threats that would otherwise reduce grasspea yields. Some of these new varieties also have reduced levels of the poison in grasspea that can cause paralysis of the legs (also called limsha or mesebr).*

*You are offered a choice between two different new varieties. We will take you through the different qualities of these two varieties, where they come from and how much they cost. After describing these two alternatives, we will ask you to consider which grasspea variety you would pick for your farm.*

*I’m now going to show you two cards that show you two grasspea varieties. Could you tell me which you prefer?*

Field enumerators had printed copies of the choice experiments, with a page for each individual option. These pages had written and pictorial information to help communicate the level for each attribute. An enumerator would go through one choice completely before describing the next. An example of these choices can be observed below:

Text

Description automatically generatedGraphical user interface, text, application

Description automatically generated

From the prior training and piloting, enumerators clearly understood each level of each attribute and were able to explain clearly what they meant and how they compared to other attributes. Each subsequent pair was presented as a new choice and one that did relate or build on the previous choice or choices.

The full description for each attribute and choice was the following:

**Attribute 1: Seed source**

This attribute was defined as the sole place where respondents would be able to purchase the seed for this specific variety. The levels were described as:

1. Local market: seed for this variety of grasspea can only be purchased on local markets.
2. Government: seed for this variety of grasspea can only be purchased from the government. This might be through government agricultural offices, government owned research institutions or direct arrangements between local government and farmers associations.
3. Agro-dealers: seed for this variety of grasspea can only be purchased from agro-dealers. These stores are physical buildings that specialise in farming goods and often are found in towns.

**Attribute 2: Toxicity**

This attribute was defined as the toxicity within the grasspea that can cause neurolathyrism (using the local word for this condition). Farmers are aware of this toxicity. In the rare case where farmers were encountered that didn’t know about this toxicity, enumerators explained that that some of the varieties we presented contained less of the toxin in the plant that can cause neurolathyrism. The levels were explained as follows:

1. Same toxin as local varieties: this variety has no difference in the toxin levels that cause neurolathyrism than from the toxin levels found in locally available grasspea.
2. Almost no toxin: this variety has much lower levels of toxin that causes neurolathyrism than in locally available grasspea. It does however still have some of the toxin in but this amount is almost nothing.
3. Zero toxin: this variety contains none of the toxin that cause neurolathyrism.

**Attribute 3: drought tolerance**

Drought tolerance was defined by the number of weeks of damp soil. This attribute aims to estimate water presence from both rain and that residing in the surface levels of the soil. Estimates were given in a combination of months and weeks as this was felt by field enumerators to align with out farmers estimate time. The attribute levels were explained as:

1. Five weeks: this variety requires one month and one week of damp soil in order to yield well.
2. Eight weeks: this variety requires two months of damp soil to yield well.
3. Eleven weeks: this variety requires two months and three weeks of damp soil to yield well.

**Attribute 4: flood tolerance**

Flood tolerance was defined as the number of weeks that grasspea varieties could survive waterlogging. Waterlogging here means when the soil is saturated with water and visible on the surface as puddles. Levels were described as follows:

1. Does not survive: this variety does not survive waterlogging and begins to perish if it becomes waterlogged.
2. Survives one week: this variety can survive one week of water logging. It will recover and yield if the waterlogging resides after this time.
3. Survives three weeks: this variety can survive three weeks of water logging. It will recover and yield if the waterlogging resides after this time.

**Attribute 5: pest and disease resistance**

There are certain pests and diseases that can damage grasspea plants and reduce yields. Four levels were chosen that compared innate resistance to the current resistance in local varieties of grasspea. Photos of the types of pests and diseases were used in order to aid communication. These levels were defined as follows:

1. Same resistance as local: this variety as the same natural resistance to all pests and diseases as the grasspea varieties found locally.
2. Pea rust: this variety has an innate resistance to pea rust.
3. Resistance to wilt rootrot complex: this variety has an innate resistance to wilt root rot complex.
4. Resistance to aphids: this variety has an innate resistance to aphids.

**Attribute 6: price for seed**

This attribute described the price for the grasspea seed from the source in attribute one. The levels were based proportionally to the price of seed found on local markets. These levels were therefore described as:

1. Local price: the seed for this variety costs 35 Birr for a kilogram bag.
2. x1.5 the local price: the seed for this variety costs 53 Birr for a kilogram bag.
3. x2 the local price: the seed for this variety costs 70 Birr for a kilogram bag.
4. x3 the local price: the seed for this variety costs 105 Birr for a kilogram bag.

### 4. Sample characteristics

**Table A.1: Demographics and socioeconomic indicators**

|  |  |
| --- | --- |
| **Study sample characteristics (n=508)** | **Percentage** |
| Sex |  |
| Male | 79.0 |
| Female | 21.0 |
| Education |  |
| None | 51.0 |
| Basic | 19.5 |
| Primary | 20.3 |
| Secondary and tertiary | 6.6 |
| Religious | 1.9 |
| Literacy |  |
| Cannot read or struggles to read | 65.6 |
| Mostly and fully literate | 33.6 |
| Agriculture as main economic activity | 98.2 |
| Has electricity | 23.0 |
| Has piped water | 41.0 |
| Uses wood or charcoal for cooking fuel | 94.7 |
| Has an earth or sand floor at home | 83.0 |

# Declarations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Figure 1: Grasspea production in Ethiopia.**

A graph with green and blue lines

Description automatically generated

1. **Table 1: DCE attributes and levels**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Alternative attributes** | **Level 1** | **Level 2** | **Level 3** | **Level 4** |
| Purchase source type | Local market | Government | Agro-dealer |  |
| Toxicity | The poison that breaks legs is the same as local grasspea | The grasspea contains almost none of the poison that breaks the legs | The grasspea contains none of the poison that breaks the legs |  |
| Drought tolerance | After planting, the soil needs to be damp for five weeks for the crop to yield well. | After planting, the soil needs to be damp for eight weeks for the crop to yield well. | After planting, the soil needs to be damp for eleven weeks for the crop to yield well. |  |
| Flood tolerance | Doesn’t survive waterlogging | Survives one week of waterlogging | Survives three weeks of waterlogging. |  |
| Pest resistance | Same resistance as local | Rust | Wilt root rot complex | Aphids |
| Price for seed | The same as in the village (35 Birr) | 50% more than in the village (53 Birr) | Double the price than in the village (70 Birr) | Three times the price in the village (105 Birr) |

**Table 2: Sample overview**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Mean** | **S.D.** |
| Age | 47.6 | 14.0 |
| Household size | 6.0 | 2.0 |
| Total owned land (timads) | 5.8 | 4.0 |
| Land cultivated (timads8) | 6.3 | 3.4 |
| Number of timads planted with grasspea | 1.5 | 1.7 |
| Grass pea most consumed legume (rate) | 0.81 | 0.39 |
| Eat grasspea >1/day | 0.44 | n/a |
| Eat grass pea >1/week | 0.90 | n/a |

**Table 3: Random effects probit estimation**

|  |  |  |
| --- | --- | --- |
| ***Models*** | **(1)** | **(2)** |
| **Attributes** |  |  |
| *Seed source (base: local market)* |  |  |
| Government | -0.097\*\*\*  (-6.98) | -0.097\*\*\*  (-6.98) |
| Agro-dealer | -0.059\*\*\*  (-4.86) | -0.059\*\*\*  (-4.85) |
| *Toxicity (base: Same as local varieties)* |  |  |
| Almost no toxin | 0.034\*\*\*  (2.66) | 0.034\*\*\*  (2.65) |
| No toxin | 0.149\*\*\*  (10.27) | 0.149\*\*\*  (10.27) |
| *Drought tolerance (base: requires five weeks of damp soil)* |  |  |
| Requires eight weeks of damp soil | -0.048\*\*\*  (-3.88) | -0.078\*\*\*  (-3.99) |
| Requires eleven weeks of damp soil | -0.043\*\*\*  (-3.07) | -0.076\*\*\*  (-3.16) |
| *Flood tolerance (base: does not survive waterlogging)* |  |  |
| Survives one week of waterlogging | 0.265\*\*\*  (17.88) | 0.265\*\*\*  (17.87) |
| Survives three weeks of waterlogging | 0.369\*\*\*  (21.77) | 0.369\*\*\*  (21.77) |
| *Pest and disease resistance (base: same as local varieties)* |  |  |
| Resistant to pea rust | 0.198\*\*\*  (11.75) | 0.198\*\*\*  (11.74) |
| Resistant to root rot wilt complex | 0.206\*\*\*  (12.96) | 0.206\*\*\*  (12.95) |
| Resistant to aphids | 0.243\*\*\*  (16.22) | 0.243\*\*\*  (16.23) |
| *Price for seed (base: 35 Birr per kg)* |  |  |
| 53 Birr per kg | -0.049\*\*\*  (-3.55) | -0.049\*\*\*  (-3.56) |
| 70 Birr per kg | -0.050\*\*\*  (-3.75) | -0.050\*\*\*  (-3.76) |
| 105 Birr per kg | -0.142\*\*\*  (-8.10) | -0.142\*\*\*  (-8.12) |
|  |  |  |
| Wald Chi-Squared | 810.54\*\*\* | 855.91\*\*\* |
| Observations | 15,240 | 15,240 |

Number of observations = 15,240 (508 respondents making 15 choices each between 2 options). Marginal effects reported with z-statistics in parentheses. \* indicates statistical significance at the 10%, \*\* at the 5% and \*\*\* at the 1% level. Heteroskedasticity-robust standard errors reported in parenthesis. Model (1) estimates the attributes of every alternative and some controls, including: respondents’ age, sex, years of education and land owned. Model (2) adds an interaction between the levels of the drought tolerance and an indicator variable denoting the driest region.