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Citizen's Science approach to climate smart and nutrition sensitive seed value chains for food and nutrition security in Uganda and Ethiopia

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Field Activities Report

Cover Photo: Crowdsourcing training in Hoima, Uganda.
Credit: Alliance of Bioversity International and CIAT/T. Recha

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Table of Contents

Acknowledgements i

List of abbreviations 3

1. Introduction 4

2. Project sites 5

3. Crowdsourced varietal evaluation and selection of beans and finger millet in Hoima, Uganda ... 6

   3.1 Seed multiplication 6

   3.2 Varietal testing and selection through crowdsourcing trials 7

   3.3 Establishment of trial plots and data collection 7

   3.4 Crowdsourcing ranking and selection results 8

   3.5 Participatory varietal selection of beans and finger millet at the on-station (Mother) trials in Hoima, Uganda 9

   3.6 Establishment of on-station trials for participatory varietal evaluation and breeder assessment 9

   3.7 Participatory varietal selection results 11

   3.8 Evaluation of culinary and organoleptic attributes of the top-performing and selected varieties of bean and finger millet 12

   3.9 Evaluation of bean and finger millet products 13

   3.10 Sensory evaluation and organoleptic test results 15

   3.11 Overall varieties ranking and acceptability by farmers 17

   3.12 Analysis of nutritional benefits from the selected varieties of beans and finger millet 18

   3.13 Nutritional evaluation results of the selected bean and finger millet varieties 19

4. Crowdsourced varietal evaluation and selection of durum wheat and barley in Degua Tembien district in Tigray region, Ethiopia 22

   4.1 Durum wheat and the crowdsourcing methodology 22

   4.2 Result obtained from durum wheat crowdsourcing experimentation 23

   4.3 Farmers' traits of preference for evaluation and ranking of wheat varieties 24

   4.4 Participatory Varietal Selection (PVS) 26

   4.5 Seed multiplication and distribution 28

   4.6 Barley crowdsourcing trials 28

   4.7 Preliminary result 29

   4.8 Seed multiplication for dissemination and nutrient content analysis 30

4.9 Dissemination of selected varieties through seed value chains using QDS frameworks 31
5. Knowledge sharing and learning 31
6. Sustainable Agricultural Intensification indicators (SAI) 32
7. Information ecosystem 34
8. Gender approach in seed production, multiplication and commercialization 37
9. Remaining activities 37
10. References 38

List of abbreviations

BoARD	Degua Tembien Bureau of Agriculture and Rural Development
DWB	Dry weight basis
FANEL	Food and Nutritional Evaluation Laboratory
FAO	Food and Agriculture Organization of the UN
GeRRI	Genetic Resources Research Institute (Kenya)
HFIAS	Household Food Insecurity Access Scale
ITPGRFA	International Treaty for Plant Genetic Resources for Food and Agriculture
KALRO	Kenya Agricultural Research organization
MoA	Ministry of Agriculture
MU-ISSD	Mekelle University-Integrated Seed Sector Development Protgramme (Ethiopia)
NARO-BUZARDI	National Agricultural Research Organization-Bulindi Zonal Agricultural and Research Development Institute (Uganda)
NARO-PGRC	Plant Genetic Resources Centre of the National Agricultural Research Organization (Uganda)
NPGRC	National Plant Genetic Resources Center (Tanzania)
NET	Number of effective tillers
NWO	Netherlands Organization for Scientific Research
PELUM	Participatory Ecological Land Use Management (Uganda)
PVS	Participatory varietal selection
QDS	Quality declared seed
RHOMIS	Rural Household Multi-indicator survey
SAI	Sustainable agricultural indicators

1. Introduction

Lack of food and/or nutritional security is evident in our target countries. In Uganda, the rate of undernourishment is 26% (FAO, 2014) while in Ethiopia it is 28.8% (Abegaz, 2018). In Hoima, Uganda, only one-third of the households are food secure throughout the year and 10% of the families face food deficits for more than six months every year. Climate change poses yet a further serious threat to the food and nutrition security of these resource-poor farmers. Agricultural production rates are low and are estimated to drop on average by 22% by 2050, sending farmers who are already struggling to feed their families deeper into poverty traps and malnutrition. Erratic rainfall and droughts are expected to become more frequent because of climate change, affecting agricultural production and productivity. Homogenization of agriculture to single crops or varieties in the hope of higher yields, coupled with the associated loss of biodiversity, have decreased the resilience of these farmers and contributed to food and nutrition insecurity. The loss of genetic diversity in farmers' custody has greatly narrowed the gene pool from which to depend on.

Local communities currently have limited access to information and the diversity of planting materials that would allow them to diversify their production systems to cope with unpredictable weather and stabilize their livelihoods. There are currently limited and scattered mechanisms in place to share and increase the diversity of farmers' varieties beyond the local level. Establishing new community seed banks and linking them with the existing ones will create an effective network, which will allow the national system to monitor the status of on-farm conservation and enhance the flow of seeds between them.

This project 'Citizen's science approach to climate smart and nutrition sensitive seed value chains for food and nutrition security in Uganda and Ethiopia' aims to improve farmers' adaptation to climate change and enhance food and nutrition security by increasing the availability of quality, diverse and adapted seeds within local communities through participatory varietal evaluation using a crowdsourcing approach and innovative seed value chains.

2. Project sites

The project is being implemented in Hoima, Uganda and in Ayba and Melfa in Ethiopia, as shown in Figure 1.

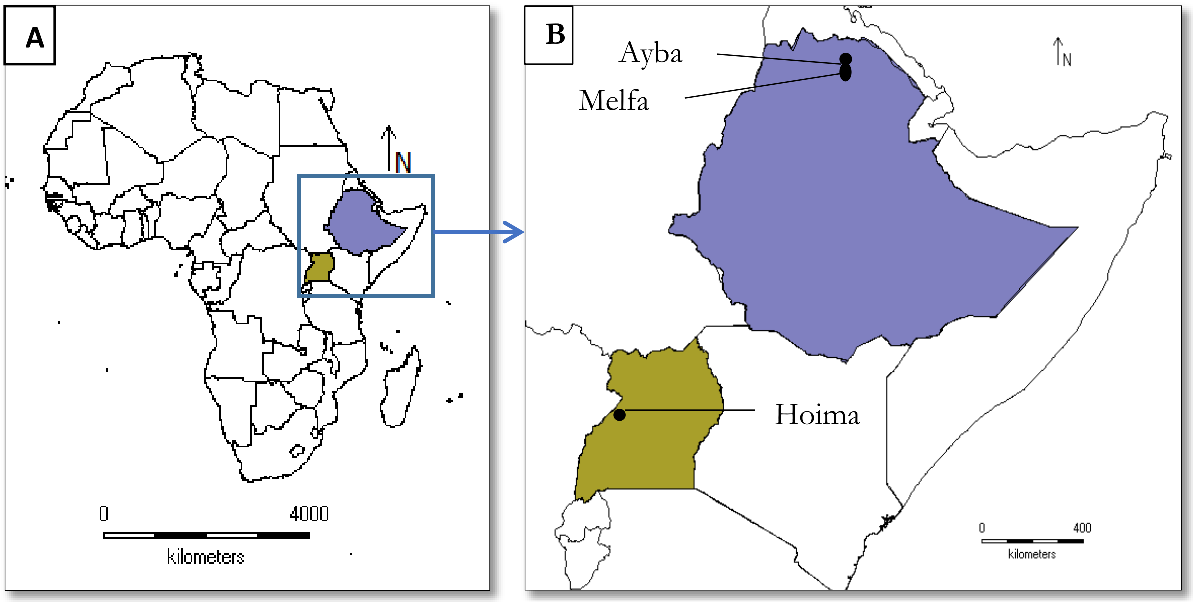

Figure 1: Project sites in Uganda and Ethiopia

Hoima district is located along 01 24N, 31 18E with a land area of 3,664 km². It has an average rainfall of 1400 mm per year, with bimodal peaks in April to May and August to November. The area experiences a mean annual temperature slightly above 20⁰C with a maximum and minimum temperature of about 26⁰C and 15⁰C, respectively. The aridity index is mainly humid. The major resource challenges in Hoima are soil erosion and reducing soil fertility.

Ayba and Melfa are located in the highlands of Northern Ethiopia, Southern Zone of Tigray, Emba Alaje District. Ayba and Melfa "*Kebele*", represents the lowest administrative unit. The elevation of the area is 2350 m with an annual average rainfall of 912 mm and a mean daily temperature ranging between 9ºC and 23ºC. The rainfall pattern is bi-modal with the "*B elg*" rain (short rains) occurring March to May and the "*M eher*", which is the main season, rain lasting from June to September. Melfa and Ayba are characterized by wet and cool climatic conditions during the cropping season.

SECTION 1: ACTIVITIES IN UGANDA

3. Crowdsourced varietal evaluation and selection of beans and finger millet in Hoima, Uganda

3.1 Seed multiplication

Following successful exchange of bean, sorghum and finger millet accessions by the national genebanks of Kenya, Uganda and Tanzania in 2016 through Standard Material Transfer Agreement (SMTA), seeds were multiplied to increase the quantities available for distribution and further testing by farmers. In Uganda, multiplication was carried out at NARO Bulindi in 2016 and 2017 (Photo 1).

Photo 1: Assessing finger millet trials and seed multiplication plots at NARO Bulindi in 2017 Credit: Alliance of Bioversity International and CIAT/ T. Recha

Since these were collections originating from several regions in East Africa, multiplication provided an opportunity to further evaluate these varieties in an area different from their collection points. Some varieties did not survive in their new locations despite similarity in climate with their original production areas. In such cases, a number of factors played a key role in determining their survival like soil fertility, rainfall patterns and new pests and diseases. Table 1 shows that only 51 and 48 percent of the bean and finger millet varieties, respectively, survived after multiplication.

Table 1: Number of varieties that survived during multiplication of the germplasm that was exchanged between the national genebanks of Kenya, Uganda and Tanzania

Country	**Site**	**Crop**	**Total accessions before multiplication**	**Total accessions after multiplication**	**Survival rate (%)**
Uganda	Hoima	Beans	99	50	51%
		Millet	147	70	48%

3.2 Varietal testing and selection through crowdsourcing trials

The term 'crowdsourcing' originated from an article written by Howe (2006) defining it as "outsourcing from a large crowd of people". According to King (2009), he defines it as "tapping into the collective intelligence of the public to complete a task." Therefore, key features of crowdsourcing include voluntary and participatory, and its tasks can be of variable complexity and modularity.

In Hoima, a crowdsourcing approach was combined with triadic comparison of technologies. Triadic comparison of technologies is a good method when introducing new varieties, practices and/or inputs. The methodology engages a larger number of farmers in testing three different varieties or technologies and finally selecting the best one. In this case, farmers are regarded as researchers due to their involvement in the selection process. Many farmers are engaged by setting up small trials on their own farms and then providing feedback and findings to the agricultural research centres and vice versa, allowing the research centres to collaborate with a large number and typology of farmers (Steinke & van Etten, 2016).

The main objective of this activity was to identify and select climate-smart and resilient varieties of beans and finger millet, based on farmers' preferences using many farmers and a methodology called triadic comparison of technologies.

3.3 Establishment of trial plots and data collection

Crowdsourcing trials for 34 bean and 44 finger millet varieties were carried out over three seasons in 2017, 2018 and 2019 by a total of 250 farmers. Before the trials, farmers were trained on the seven steps of tricot methodology which involved registering as a participant, receiving of trial package, planting the seeds, filling in the observation card, responding to the technicians or field assistants, participation in the final workshop and sharing out the knowledge with neighbours and friends after a successful trial period (Photo 2). During the trainings, farmers were shown how to set up trial plots of 2 by 3 meters, and plant using the right spacing for beans. They were also encouraged to plant finger millet in rows unlike their conventional way of broadcasting. Since they were fully in charge of information collection, they were taken through the observation sheet that was used to collect data on their plots. For this to be effective, farmers were given the opportunity to discuss each data parameter in detail. These parameters include faster maturity, pest resistance, disease resistance, drought tolerance, yield, value in the market and taste. Once they understood these parameters, they were willing and ready to start preparing their trial plots and each received three varieties of bean and three varieties of finger millet.

Photo 2: Training farmers in the crowdsourcing methodology in Hoima, Uganda. Credit: Alliance of Bioversity International and CIAT/ T. Recha

The farmers were also registered and given unique numbers from 1 to 250. These unique numbers were known as package numbers in ClimMob app and ClimMob manager, the software that was used by field assistants to collect and analyze data. The details of the famers were taken. They included name and surname, name of the father or name of the husband/wife, village, district, telephone number, gender and age.

An automated weather station called the Trans-African Hydro-Meteorological Observatory (TAHMO) was installed at the NARO Bulindi research station in Hoima. The weather station collected weather data during the trial seasons. TAHMO stations have sensors and data loggers. An active sim-card of the local network service provider was inserted in the data loggers to send the collected information to an online platform at an hourly interval. The data was then downloaded from https://datahmo.org/login. The climate data that was collected include rainfall, minimum and maximum temperature and solar radiation.

3.4 Crowdsourcing ranking and selection results

Table 2 presents the results of the crowdsourcing trials conducted in Hoima, Uganda (to identify the most highly ranked varieties by farmers. For beans, three farmers' varieties FR1, FR2 and FR3 were ranked high, in addition to three varieties from Tanzania, TZA-4174, TZA-3165 and TZA2443, and four varieties from Uganda, UNGB-2907, UNGB-2364, UNGB-131 and UNGB-2443.

For finger millet, four highly-ranked varieties were from Tanzania (TZA1693, TZA1701, TZA1693 and TZA186), one from Kenya (GBK-000920) and the rest from Uganda, which include UNGB43, UNGB4146, UNGB208, UNGB-2350 and UNGB4295. No local variety was found nor included in the trial due to genetic erosion. This project introduced finger millet varieties in Hoima, Uganda.

Table 2: Top-ranked bean and finger millet varieties from crowdsourcing with farmers

Varieties ranking positions	Bean varieties	Finger millet varieties
Position 1	TZA4174	TZA1701
Position 2	FR2	UNGB4149
Position 3	UNGB2907	TZA1693
Position 4	FR1	TZA3934
Position 5	UNGB2364	UNGB4400
Position 6	UNGB131	TZA3676
Position 7	TZA3165	UNGB208
Position 8	FR3	UNGB2321
Position 9	TZA3990	UNGB4146
Position 10	UNGB2443	UNGB2423

3.5 Participatory varietal selection of beans and finger millet at the on-station (Mother) trials in Hoima, Uganda

Many programmes on breeding and cultivar introduction tend to produce and evaluate numerous varieties of different crops. Participatory varietal testing is a modest approach for agronomists and breeders to understand and identify varieties that have good performance on-farm and have traits preferred by farmers. Breeders and agronomists measure and collect data alone and together with farmers on various traits such as pest and disease resistance, yield, flowering date, height at maturity, maturity date and other relevant attributes. In addition, farmers are invited to rate the varieties using a technique known as preference analysis.

The main purpose of this activity was to explore the attributes that were considered relevant to both farmers and breeders for improved productivity and quicker adoption of the introduced varieties of bean and finger millet.

3.6 Establishment of on-station trials for participatory varietal evaluation and breeder assessment

On-station trials for beans and finger millet were established at NARO Bulindi research station for three seasons in 2017, 2018 and 2019 (Photo 3). In 2017, 2018 and 2019, a total of 43, 42 and 30 varieties of bean were evaluated. The number of finger millet varieties evaluated included 46 in 2017, 44 in 2018 and 24 in 2019. Some varieties dropped off along the seasons due to pests, diseases and heavy or less rainfall to support their growth and productivity.

Photo 3: Preparing plots for on-station trials at NARO Bulindi in 2017. Credit: Alliance of Bioversity International and CIAT/ T. Recha

The plots were laid out in randomized block design with three replications of 2 by 2m plot sizes. No fertilizer or any special treatment was applied to the plots, apart from weeding. Characterization data for beans was collected on plant growth habit, days from sowing to 50% flowering, colour of flower standard, colour of flower wings, days to 90% pod maturity, seed coat pattern, seed coat colour, brilliance of seed, seed shape, 100-seed weight (g) and weight of seeds per plot. For finger millet, data was collected on pigmentation, number of productive tillers, days to flowering, ear shape, finger branching, finger length (cm), number of grains per spikelet, grain coat colour, number of fingers, days to maturity, 1000 grain weight (g) and total weight per plot.

Prior to data collection through PVS, 20 farmers (10 men and 10 women) were invited to a meeting and discussed on the variables they would prefer to assess. They agreed upon pest resistance, disease resistance, maturity, number of pods, pod size, pod filling and general performance for beans. For finger millet, the variables agreed upon included pest resistance, disease resistance, early maturity, tillering lodging, ear size, finger length, grain cover and general performance.

The farmers used a five point Likert scale to score the performance of the varieties against the variables. During scoring, 1=Very bad, 2=Bad, 3=Fair, 4=Good, 5=Very good. This activity enabled farmers to express their level of satisfaction in performance of the varieties.

3.7 Participatory varietal selection results

The results in Table 3 show that farmers expressed a high level of satisfaction in TZA-4174, UNGB-2364, UNGB-4399 and TZA-3990, which had a mean of 3.6, 3.1, 2.9 and 2.8, respectively. The varieties considered to be fast maturing were TZA-4174, UNGB-2364 and TZA-3990 with respective means of 3.6, 3.2 and 3.1. The top pest- and disease-resistant bean varieties were TZA-4174, UNGB-2364 and UNGGB-4399.

Table 3: Results of participatory varietal selection for beans in Hoima, Uganda

	Mean level of satisfaction of bean genotypes for seven traits							
Germplasm	**Pest rest**	**Disease**	**Maturity**	**Growth**	**Pod no**	**Pod size**	**Pod filling**	**Average**
FR1	1.9	2.4	1.9	2.7	2.3	2.3	2.4	2.3
FR2	2	2.1	1.8	2.5	2.3	2.4	2.5	2.2
TZA-2533	2.4	2.4	3	2.8	2.4	2.7	2.4	2.6
TZA-2791	2.5	2.6	3.7	2.8	2.1	2.4	2.4	2.6
TZA-4174	3.6	3.9	2.5	3.2	3.6	4.1	4	3.6
TZA-3100	2.3	2.6	2.5	2.8	2.5	2.4	2.7	2.5
TZA-3165	1.8	1.9	1.8	2.1	1.6	1.9	1.9	1.9
TZA-3990	3.1	2.9	1.9	2.8	2.5	3.1	3.4	2.8
TZA-4121	1.8	1.9	1.7	2.6	1.8	2.1	2.1	2.0
TZA-2856	2.7	2.6	3	2.9	2.3	2.6	2.6	2.7
TZA-4221	2.3	2.4	2.1	2.5	2	2.5	2.4	2.3
UNGB-2444	2.5	2.9	2.4	2.4	3	3.2	3	2.8
UNGB-2364	3.2	3.2	3.6	3.1	2.7	3	3.1	3.1
UNGB-4397	2.6	2.8	1.9	2.2	3	3	3	2.6
UNGB-4399	2.8	3	3.5	2.9	2.5	2.8	2.8	2.9
UNGB-4436	1.8	2.1	2.7	2.3	2	2.6	2.4	2.3

Table 4 shows farmers' satisfaction in performance of finger millet varieties, with UNGB-4195, GBK-000920, UNGB-2321 and TZA-3934 scoring the highest preference, with means of 3.2, 3.1, 3.1 and 3.0, respectively. Early maturing varieties were GBK-000920, GBK-000461 and UNGB-4195 while top pest and disease resistant varieties were UNGB-2321, TZA-3676 and TZA-1693.

Table 4: : Results of participatory varietal selection for finger millet in Hoima, Uganda

Germplasm	Pest resistance	Disease resistance	Early maturity	Tillering	Lodging	Ear size	Finger length	Grain colour	Mean
GBK-000460	2.4	2.6	3.2	2.5	2.7	2.2	2.2	2.7	2.6
GBK-000920	2.6	2.6	4.1	2.4	2.4	3.5	3.4	3.6	3.1
GBK-000862	2.4	2.6	3.3	2.1	2.3	2.6	2.6	2.8	2.6
GBK-000461	2.4	2.7	3.8	2.9	2.7	2.9	3.1	3	2.9
TZA-1693	2.8	2.7	3.1	2.6	3	2.8	2.8	2.9	2.8

TZA-1696	2.1	2	2.1	2.4	2.2	2.4	2.4	2.3	2.2
TZA-1701	2.3	2	2	2.3	2	2.2	2.5	2.3	2.2
TZA-3676	2.8	2.9	3.1	3.1	2.7	2.9	2.6	2.9	2.9
TZA-3934	2.6	2.6	3.5	3.1	3.1	2.9	2.9	3.3	3.0
UNGB-43	2.1	2.1	1.7	1.9	2.1	2	2.2	2.1	2.0
UNGB-2350	1.9	2	1.5	2.1	2.8	2.1	2.1	1.9	2.1
UNGB-4146	1.7	1.9	3.2	2.6	2.6	2.3	2.1	2	2.3
UNGB-4195	2.9	2.8	3.7	3.2	3.4	3.4	3.2	3	3.2
UNGB-4247	2.1	2.1	1.7	2.3	2.4	2	2.1	1.9	2.1
UNGB-2321	3.4	3.4	2.9	3.3	2.9	2.8	2.9	2.9	3.1

3.8 Evaluation of culinary and organoleptic attributes of the top-performing and selected varieties of bean and finger millet

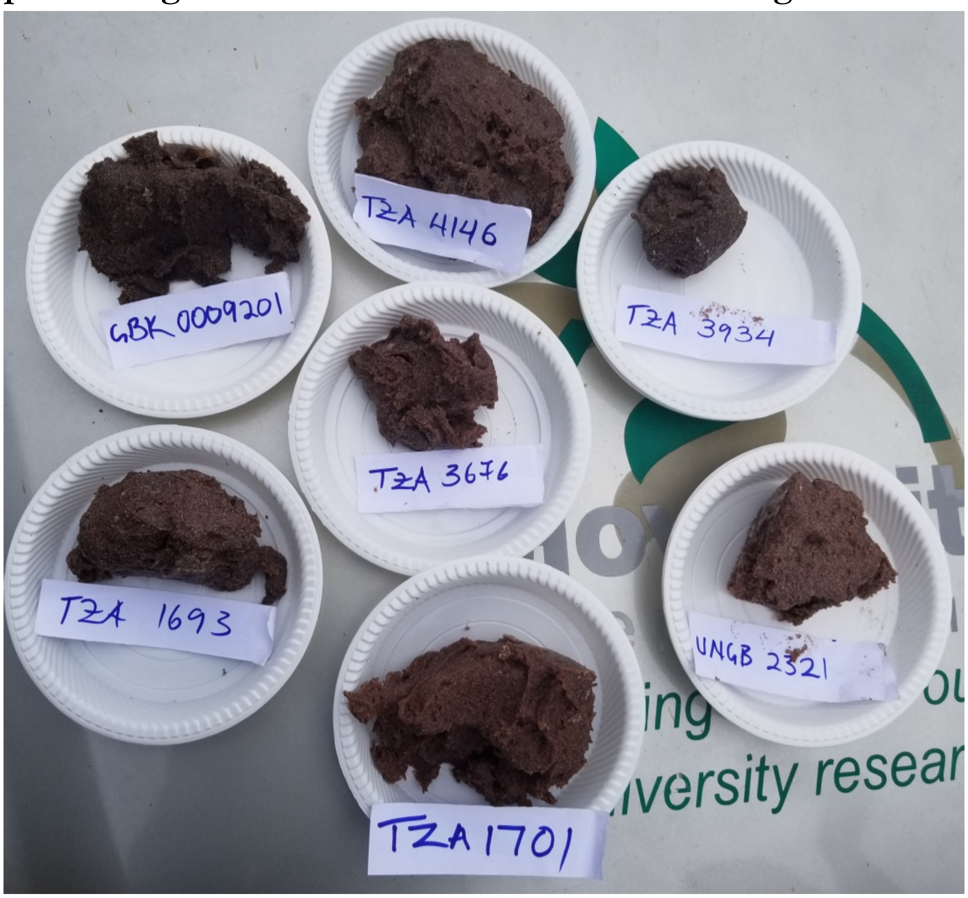

Photo 4: Organoleptic testing of kalo, a type of bread made from finger millet. Credit: Alliance of Bioversity International and CIAT/ D. Mubiru

Photo 5: Organoleptic testing of cooked beans in Hoima, Uganda. Credit: Alliance of Bioversity International and CIAT/ D. Mubiru

Organoleptic testing, also known as sensory evaluation, can be referred as testing of food through senses of taste, touch, smell and sight. The aim of organoleptic testing is to determine food quality characteristics together with degree of compliance with consumer habits and legal requirements (Gupta, 1976). The testing involves assessing odour, flavour, mouthfeel and appearance of a food product. This activity was conducted in Hoima aimed at identifying finger millet varieties that were good for making products such as *kalo* (a type of bread made from finger millet), beans (Photos 4 & 5) *obushera* (a fermented drink from finger millet), hot porridge and local alcoholic drinks (*Malwa* and *Kwete*). The activity aided in gathering insights on farmers' perceptions and preferences regarding taste and acceptability of the products made from different finger millet and bean varieties.

3.9 Evaluation of bean and finger millet products

The study used varieties that had performed well during agronomic evaluation through PVS and crowdsourcing trials. Seven varieties of bean (FR1, FR2, UNGB-23642, TZA-41742, TZA-31002, TZA-39902 and TZA-31652) and seven of finger millet (TZA-3676, TZA-1701, TZA-3934, TZA-1693, UNGB-4146, UNGB-2321 and GBK-000920) were selected..

Six traditional Ugandan food products—porridge, *malwa and kwete (alcoholic beverages), kalo* (bread) and *obushera* (a fermented drink) were made from seven varieties of finger millet. A sauce was also prepared from seven selected varieties of beans. A total of 101 (54 men and 47 women) farmers from (Hoima)Uganda, Tanzania and Kenya were invited to provide feedback on their level of satisfaction on the products made from the selected varieties, using a five-point Likert Scale (1=Very poor, 2=poor, 3=fair, 4=good and 5=very good) against the parameters shown on Table 5.

Table 5: Variables used to assess the quality of the products during organoleptic testing

Finger millet products		
Product	Quality assessment variables	Questions to assess preferences in product taste and aroma, and responses provided on product consistency
Hot porridge	Aroma before tasting	How is the aroma before tasting?
	Aroma in the mouth	How is the aroma in the mouth?
	Consistency in smoothness	How smooth is the consistency?
	Thickness	How is the thickness?
	Taste	How tasty is it?
	General acceptability	General acceptability
Kalo	Elasticity when pinched	How elastic is it when you pinch it?
	Aroma before tasting	How is the aroma before tasting?
	Taste	How does it taste?
	Aroma after tasting	How is the aroma after tasting?
	Texture smoothness	How smooth is the texture in the mouth?
	General acceptability	General acceptability
Obushera	Colour/ appearance	How is the colour?
	Consistency of the mixture	How is the consistency of the mixture?
	Lightness	How light is it?
	Aroma before tasting	How is the aroma before tasting?
	Level of sweetness	How sweet is it?
	Aroma in the mouth	How is the aroma in the mouth?
	Texture in the mouth	Does it leave flour particles in your mouth?
	General acceptability	General acceptability
Malwa	Colour/appearance	How do you like the external appearance?
	Smoothness	How does it feel in the mouth?
	Thickness of the mixture	How is the thickness?
	Aroma before drinking	How is the aroma before drinking?
	Aroma in the mouth	How is the aroma in the mouth?
	Taste	How does it taste?
	Easy to make someone drunk (high alcohol content)	How strong is it?
	General Acceptability	General Acceptability
Kwete	Colour/appearance	What is the colour?
	Aroma before tasting	How is the aroma before tasting?

	Aroma after tasting	How is the aroma after tasting?
	Taste	How sweet is the taste?
	Easy to make someone drunk (high alcohol content)	How strong is it?
	Thickness of the mixture	How is the thickness?
	Bubbling attribute	How bubbling is it?
	General acceptability	General acceptability
Beans		
Bean varieties	Colour/appearance	What is the colour of the soup?
	Thickness of the soup	Soup thickness?
	Ability to split after cooking	Have the beans split after cooking?
	Aroma before tasting	What is the aroma before taste?
	Softness of the beans	How soft are the beans?
	Aroma after tasting	What is the aroma after taste?
	Taste	Do you like the taste?
	General Acceptability	General Acceptability

3.10 Sensory evaluation and organoleptic test results

Graphs A to E in Figure 3 show results for products that were made from finger millet and graph F shows the results of bean sauce. Graph A shows that varieties TZA3934 and TZA1693 were ranked best for making *kalo*, with an average score of 3.69 and 3.60, respectively. Farmers ranked them highly due to their good elasticity, good texture, colour and a pleasant aroma.

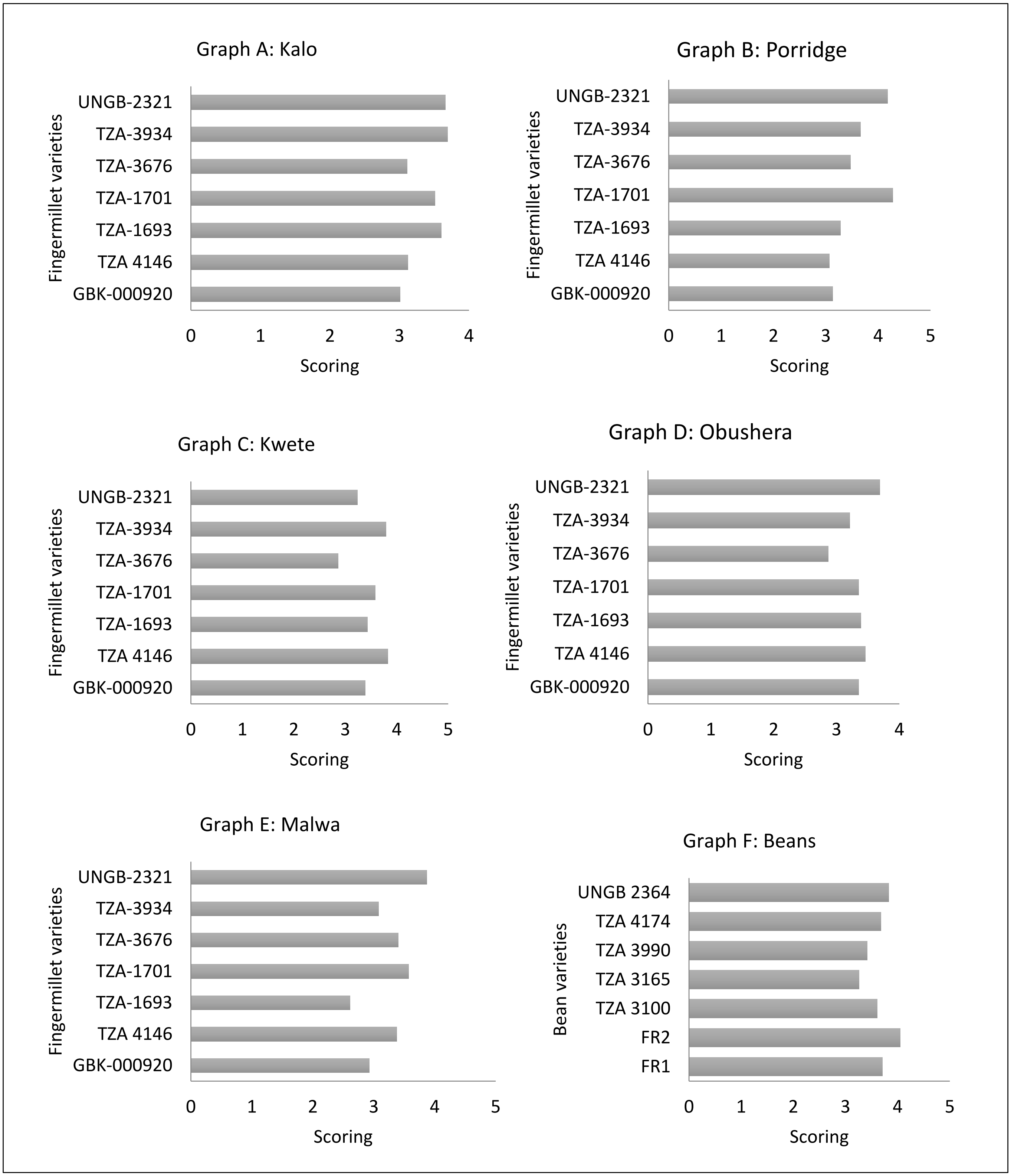

Figure 3: Organoleptic test results

The least preferred varieties were GBK-000920 and TZA-3676 with an average score of 3.01 and 3.11, respectively with farmers preferring local varieties over them. The main setbacks for GBK-000920 and TZA-3676 were poor texture, colour and a less-pleasing taste.

In graph B for porridge tests, TZA-1701 was the most preferred by farmers with an average general acceptability score of 4.28 followed by UNGB-2321 with an average score of 4.18. These varieties had a good aroma and attractive colour, and felt smooth with favourable thickness in the mouth compared to local varieties. However, GBK-000920 and TZA-4146 with a scores 3.13 and 3.07, respectively, were ranked the lowest with a reported poor taste, irregular smoothness and less attractive colour.

Graph C for *kwete* shows that TZA-4146 and TZA-3934 were the most preferred with an average score of 3.83 and 3.79, respectively. They were ranked high due to their ability to remain bubbly, for their good colour and sweet taste with a desired thickness and alcohol content that was able to make one drunk. TZA-3676 and UNGB-2321 were regarded undesirable because of their bad colour and taste in the mouth with less alcoholic strength (needing to consume more to feel drunk).

Graph D for *obushera* indicates that UNGB-2321 was the most preferred by farmers with an average score of 3.69 followed by TZA-4146 with a score of 3.46. Both of these varieties had good consistency of the mixture, good colour, attractive aroma and sweet taste. The lowest-scoring varieties were TZA-3934, with an average score of 3.21, and TZA-3676, with 2.87, due to their bad taste, unattractive colour and inconsistency of the mixture during consumption.

Graph E indicates that the best varieties for making *malwa* were UNGB-2321 and TZA-1701 with an average score of 3.87 and 3.57, respectively. They had good taste, good colour, good mouthfeel and alcoholic strength that can make one drunk easily. The least preferred were TZA-1693 and GBK-000920 with average scores of 2.61 and 2.93, respectively. They were rejected because of their bad taste and aroma, bad mouthfeel and less alcoholic strength.

And lastly, bean sauce was prepared by boiling the varieties with salt to taste. Graph F shows that Bean variety FR2 and UNGB-2364 were highly ranked by farmers with a general acceptability of 4.05 and 3.83, respectively. They had good and attractive colour, good thickness of soup, good taste, attractive aroma and split during cooking. While TZA-3165 and TZA-3990 were least preferred by farmers with an average score of 3.26 and 3.42 because of their less attractive soup colour, less tasty and poor ability to split during and after cooking.

3.11 Overall varieties ranking and acceptability by farmers

Table 6 shows the ranking of both finger millet and bean varieties on a general scale based on the overall scoring per variety per variable.

Table 6: The overall ranking results for bean and finger millet varieties

Rank	Beans	Score	finger millet	Score
1	FR2	4.05	UNGB-2321	3.728
2	UNGB-2364	3.83	TZA-1701	3.658
3	FR1	3.71	TZA-3934	3.486
4	TZA-4174	3.68	TZA-4146	3.372
5	TZA-3100	3.61	TZA-1693	3.262
6	TZA-3990	3.42	GBK-000920	3.162
7	TZA-3165	3.26	TZA-3676	3.142

For beans, variety FR2 and UNGB-2364 were highly ranked by farmers with a general acceptability of 4.05 and 3.83, respectively while TZA-3165 and TZA-3990 were the least preferred by farmers with an average score of 3.26 and 3.42. The highly ranked bean varieties possessed majority of interesting traits such as attractive colour, good thickness of soup, good taste, aromatic and ability to split during and after cooking.

For finger millet, varieties that were ranked high included UNGB-2321 and TZA-1701 with a general acceptability average score of 3.73 and 3.66, respectively. These varieties had majority of desirable traits like good aroma, attractive colour, good taste, good alcoholic strength and good texture in the mouth. However, GBK-000920 with an average score of 3.16 and TZA-3676(lowest) with an average score of 3.14 ranked lowest and therefore less desirable.

3.12 Analysis of nutritional benefits from the selected varieties of beans and finger millet

Food composition data provides information on chemical forms of nutrients. This in addition to presence and amounts of interacting components in food can guide on nutrient bioavailability. Plant foods provide a variety of nutritional benefits which are necessary in the diet to sustain life and human health. Good nutrition includes adequate and well balanced diet that results into good health. Poor nutrition leads to reduced immunity, increased susceptibility to diseases, impaired physical and mental development and reduced productivity.

It was important for Hoima farmers to be made aware of the nutritional benefits they are receiving from the use and consumption of the selected bean and finger millet varieties. Therefore, the top seven varieties of bean and finger millet, after successfully being tested through sensory evaluation were sent to the Food and Nutritional Evaluation Laboratory (FANEL-BeCa ILRI Hub) in Nairobi Kenya. The nutritional evaluation included determination of moisture content, proteins, ash, fat, crude fibre, carbohydrate, iron, zinc, calcium and total phenolics.

3.13 Nutritional evaluation results of the selected bean and finger millet varieties

a. Nutritional information of selected bean varieties

The moisture and ash contents of bean varieties as given in Table 7 ranged between 11.50% and 12.70% and 3.90% to 6.20%, respectively. The crude protein content of the beans ranged from 26.21% to 28.34% with FR2 recording the least and FR1 the highest. This makes them a good source of proteins.

Table 7: Proximate composition of bean varieties based on dry weight basis (dwb)

Bean Varieties	Testing Location	% Moisture	% Protein	% Ash	% Fat	% Crude Fibre	% Carbohydrate
TZA-3100	Uganda	12.02±0.2[bc]	27.47±1.3[a]	5.32±0.6[bc]	1.81±0.1[a]	6.47±0.2[bc]	46.91±1.6[ab]
TZA-3165	Uganda	11.50±0.0[c]	26.76±0.7 [a]	4.81±0.1[cd]	1.86±0.2[a]	6.40±0.5[bc]	48.66±0.8 [ab]
TZA-3990	Uganda	12.70±0.2[a]	26.58±0.4 [a]	6.20±0.1[a]	1.87±0.1[a]	11.29±0.0[a]	41.34±0.4[c]
FR1	Uganda	11.97±0.1[bc]	28.34±1.2 [a]	4.55±0.1[de]	1.27±0.2[b]	6.18±0.1[c]	47.69±1.5[ab]
FR2	Uganda	11.57±0.0[c]	26.21±0.3 [a]	3.90±0.1[e]	1.20±0.2[b]	7.26±0.4[b]	49.86±0.7[a]
UNGB-2364	Uganda	12.51±0.3[ab]	26.37±0.4 [a]	4.41±0.0[de]	1.47±0.0[b]	7.05±0.5[bc]	48.19±0.6[ab]
TZA-4174	Uganda	11.96±0.4[bc]	28.18±1.1 [a]	5.86±0.1[ab]	1.55±0.2[ab]	7.00±0.6[bc]	45.45±2.1[b]

Values are mean ± SD: Analysis of samples done in triplicates: Means that do not share a letter are significantly different

Besides, FR1 and FR2 contained about 1% fat content, which ranged between 1.20% and 1.87% among the bean varieties. The carbohydrate content of beans ranged between 41.34% and 49.91%, with FR2 having the highest among the bean (about 50%). The total phenolics and mineral (iron, zinc and calcium) content in the beans is reported in Table 8. The iron content in the beans varied significantly, ranging between 6.55 and 8.34 mg/100g with TZA-3165 scoring highest (8.34mg per 100g). The zinc content among the bean varieties ranged between 2.53 and 3.19 mg/100g with TZA-4174 (3.19mg/100g) scoring highest. In addition, UNGB-2364 and TZA-4174 scored the highest calcium content with 228.54 and 228.94 mg/100g, respectively among the bean varieties. Among the bean varieties, total phenolics content was highest in TZA-3100 (17.70%) and ranged between 6.72 and 17.70mg/100g.

Table 8: Total phenolic and selected mineral content in selected bean varieties (dwb)

Bean Varieties	Testing Location	Total Phenolics (mg/100g)	Minerals (mg/100g)		
			Iron	Zinc	Calcium
TZA-3100	Uganda	17.70±0.9[a]	7.61±1.4[a]	2.79±0.3[ab]	209.99±4.3[a]
TZA-3165	Uganda	6.72±0.1[e]	8.34±1.0[a]	2.53±0.3[b]	205.01±6.6[ab]
TZA-3990	Uganda	10.10±0.3[cd]	7.65±0.8[a]	3.17±0.0[a]	181.75±14.8[b]
FR1	Uganda	15.73±1.1[ab]	7.40±0.9[a]	2.74±0.0[ab]	129.31±8.5[c]
FR2	Uganda	13.15±2.2[bc]	6.55±0.2[a]	2.75±0.3[ab]	151.77±5.3[c]
UNGB-2364	Uganda	7.83±1.3[de]	7.70±0.1[a]	3.08±0.2[a]	228.54±14.2[a]
TZA-4174	Uganda	11.74±0.2[c]	6.88±0.3[a]	3.19±0.0[a]	228.94±6.1[a]

Values are mean ± SD: Analysis of samples done in triplicates: Means that do not share a letter are significantly different.

Based on the proximate analysis TZA-3990 was the best variety with about 27% protein, 6% ash, 2% fat, 11% crude fibre and 41% carbohydrate. Although it had the lowest carbohydrate content its protein content is almost the same as the other varieties but higher than that in common beans (6.15% to 22.86%) (Kumar and Baojun, 2017). In addition, it contained the highest ash content, which could imply a higher mineral content. However, it is the highest in crude fibre content, which could affect mineral bioavailability implying the significance of processing. It had the highest zinc content while its iron and calcium content scored well compared to the other varieties. It also was among the varieties with lower total phenolics, which could imply higher bioavailability of the minerals and proteins.

b. Nutritional information of selected finger millet varieties

The moisture content of finger millet varieties ranged between 9.03% and 10.890%, as presented in Table 9 while their ash content ranged between 0.26% and 43.31%. The protein content ranged between 7.62% and 11.43%. The higher the protein content in finger millet the better because it is a staple crop which is drought tolerant and could contribute to achieving food and nutrition security in populations. The fat content of the finger millet varieties ranged between 1.16% and 1.67% with TZA-3934 scoring the highest (1.67%). Generally, cereals are known to be low in fat. The crude fibre content of the finger millet varieties ranged between 8.54 and 13.72% with UNGB-4146 scoring the highest (13.72%).

Table 9: Proximate composition of finger millet varieties (dwb)

Sample	Location	% Moisture	% Protein	% Ash	% Fat	% Crude Fibre	% Carbohydrate
TZA-1701	Uganda	10.25±0.6	11.43±0.2	2.79±0.3	1.26±0.1	11.24±0.2	63.03±0.6
TZA-1693	Uganda	9.85±0.1	8.65±0.4	2.18±0.3	1.19±0.0	11.75±0.2	66.38±0.7
TZA-3934	Uganda	10.45±0.2	10.99±0.8	2.67±0.0	1.67±0.2	11.44±0.5	62.79±1.2
TZA-3676	Uganda	10.90±0.1	11.04±0.3	1.54±0.3	1.60±0.2	11.38±0.5	63.54±0.6
UNGB-4146	Uganda	10.27±0.1	10.71±0.4	3.29±0.0	1.23±0.1	13.72±0.5	60.78±0.3
UNGB-2321	Uganda	9.53±0.1	7.62±0.1	3.31±0.5	1.38±0.1	8.54±0.9	69.62±1.5
GBK-000920	Uganda	9.03±0.3	10.55±0.1	0.26±0.0	1.16±0.0	11.72±0.7	67.28±1.0

Values are mean ± SD n=3 ND =Not done

The iron content of the finger millet varieties ranged between 3.99 and 8.29mg/100g with UNGB-2321 (8.99 mg/100g) scoring the highest (Table 10). Also the zinc content ranged from 2.20 to 2.80mg/100g with TZA-3676 (2.80) scoring highest and the calcium content ranged between 325.89 and 519.53mg/100g with UNGB-2321 (519.53 mg/100g) scoring the highest. According to FAO (2020), finger millet is a traditional crop that is rich in iron and calcium.

Table 10: Total phenolics and selected minerals contents in finger millet samples (dwb)

Sample	Location	Total Phenolics (mg/100g)	Minerals (mg/100g)		
			Iron	Zinc	Calcium
TZA-1701	Uganda	14.87±0.1	6.14±0.7	2.60±0.1	392.25±7.0
TZA-1693	Uganda	8.16±0.4	5.93±1.3	2.51±0.1	431.81±4.4
TZA-3934	Uganda	5.94±0.9	4.89±0.5	2.56±0.3	400.67±21.0
TZA-3676	Uganda	6.98±0.9	5.42±0.2	2.80±0.2	511.18±56.8
UNGB-4146	Uganda	6.88±0.9	3.99±0.5	2.72±0.2	325.89±7.3
UNGB-2321	Uganda	8.72±0.6	8.29±1.2	2.20±0.0	519.53±7.7
GBK-000920	Uganda	8.59±1.3	8.04±0.8	2.30±0.1	389.96±11.6

Values are mean ± SD n=3

Among the finger millet varieties, the total phenolics content ranged between 5.94 and 14.87mg/100g, with the highest in TZA-1701 (14.87%).

Based on proximate analysis, TZA-3934 ranked the best among the finger millet varieties, as it showed the highest protein, fat content and carbohydrates. It had a relatively lower total phenolics content which could imply lower tannins thus more bioavailability of minerals and proteins. Its iron and zinc content were comparable with the other varieties, while its calcium content was among the lowest.

4. Crowdsourced varietal evaluation and selection of durum wheat and barley in Degua Tembien district in Tigray region, Ethiopia

Photo 6: Assessing durum wheat trial plots in Ethiopia. Credit: Alliance of Bioversity International and CIAT/ T. Recha

4.1 Durum wheat and the crowdsourcing methodology

The Seeds4Needs project introduced the concept of citizen science in 2012 in the Tigray region (Photo 6) to address the problem of seed shortage at farm level. Twenty-one durum wheat genotypes (20 landraces and 1 improved variety), selected from 400 genotypes through PVS were distributed to farmers in twelve wheat growing villages of Degua Tembein district. Degua Tembien is located in Tigray region, northern Ethiopia and is among the major wheat and barley growing zones of the region. The grower farmers were identified, based on prior consent (voluntarily), in consultation with Degua Tembien Bureau of Agriculture and Rural Development (BoARD) extension service department. Participants were all small-scale farmers. As the concept was new to farmers and local crop production experts and extension agents, a training was provided to all participating farmers and district experts on the concept, principle, and practices of citizen science (crowdsourcing) approach. The training included practical demonstration of planting small seed packages in rows and practical orientation on how farmers were to compare and evaluate the provided varieties. After the training, enumerators were recruited to assist farmers in recording evaluation data.

After the trainings were completed, packs of seeds (10 grams of each variety) were distributed to 200 farmers by the enumerators, in equal replication across the villages. The standard check variety was distributed to all 200 farmers. The distributed varieties were unknown to the farmers to blind test, and were marked with a code to avoid bias toward the varieties known in the area.

Two types of data were recorded: farmers' data and breeders' data. Farmers, with the help of enumerators evaluated the varieties and ranked them individually on a scale from 1 to 4, based on their own traits, mainly for earliness, biomass yield, spike quality and stress tolerance. The recruited enumerators also collected basic agronomic data such as day to maturity, plant height, number of effective tillers (NET), spike length, seeds per spike and grain yield for all varieties on trial in all the farmers' fields. The purpose of recording these data types was to enable comparisons between farmers' varietal ranking and breeders' ranking, based on agronomic traits mainly for grain yield.

4.2 Result obtained from durum wheat crowdsourcing experimentation

The piloting of crowdsourcing was successful as 166 out of 200 farmers, 83%, of them completed the trial and provided the required feedback on varieties evaluation, ranking and selection. The preliminary data analysis showed that farmers' ranking of varieties were quite different from ranking generated from recorded grain yield data (Table 11). The top ten-ranked varieties by farmers and their respective ranking, based on grain yield, are presented in Table 11.

Table 11: Ranking and score by farmers of the top ten grain varieties, and grain yield data, disaggregated by gender

	Male farmers (MF)					Female farmers (FF)				
Sn	Variety	Score	Rank	Rank (FF)	Rank (GY)	Variety	Score	Rank	Rank (MF)	Rank (GY)
1	*Assassa*	*4.18*	1	5	8	228862	4.67	1	16	12
2	238537	*4.13*	2	9	16	222542	4.61	2	15	30
3	222434	*4.03*	3	16	23	222554	4.44	3	10	4
4	206551	*3.97*	4	4	24	206551	4.44	4	4	24
5	208365	*3.94*	5	15	21	*Assassa*	4.39	5	1	8
6	208136	*3.9*	6	11	18	222499B	4.33	6	17	31
7	212415	*3.85*	7	18	27	226834B	4.28	7	22	29
8	208474	*3.82*	8	24	5	8208	4.17	8	9	14
9	8208	3.8	9	8	14	238537	4.11	9	2	16
10	222554	*3.76*	10	3	4	208328	4.06	10	13	22

The result showed that male and female farmers had different preferences as their ranking of varieties did not match in most cases. Only the 4^{th} ranked variety, accession 206551, was consistently ranked by the two groups. Male participants ranked Asassa, accessions 238537 and 222434 as their first, second and third preferred varieties while the female participants ranked accessions 228862, 222542 and 222554 as their preferred varieties. However, 50% of the top ten ranked varieties by both male and female farmers were same. This implied that there was significant agreement between male and female farmers in evaluating and ranking varieties. The disagreement in ranking positions as well as varietal choice between the two groups could stem from their experience as well as use value associated with each variety. Female farmers mainly looked at grain workability, end use quality traits and marketability while male farmers look at pest and disease resistance nature, grain and straw yield and marketability of varieties.

4.3 Farmers' traits of preference for evaluation and ranking of wheat varieties

Farmers used different traits to evaluate and select genotypes that fit their preferences. They preferred varieties that combined earliness and high grain yield, a trait that is most difficult to combine in a genotype by breeders. It was noticed that farmers did not evaluate varieties only for grain yield as breeders did but also looked for straw yield. They preferred varieties that combined both high grain and straw yield as straw is equally important for livestock feed. Figure 4 clearly depicts a variety had to give both high grain and straw yields to be selected as first priority by majority of the farmers.

Each farmer ranked four varieties on a scale of 1 to 4, where 1 was excellent and 4 was very poor. The local variety *Asassa* that was evaluated by all 166 farmers as standard check, was ranked 1st by 33% of participant farmers for its denser spike, earliness and quality seeds (Table 12). A farmer variety Number 31 (8208) was also ranked first by 33% of farmers for its uniform stand, good tillering capacity, long spikes and stay green nature.

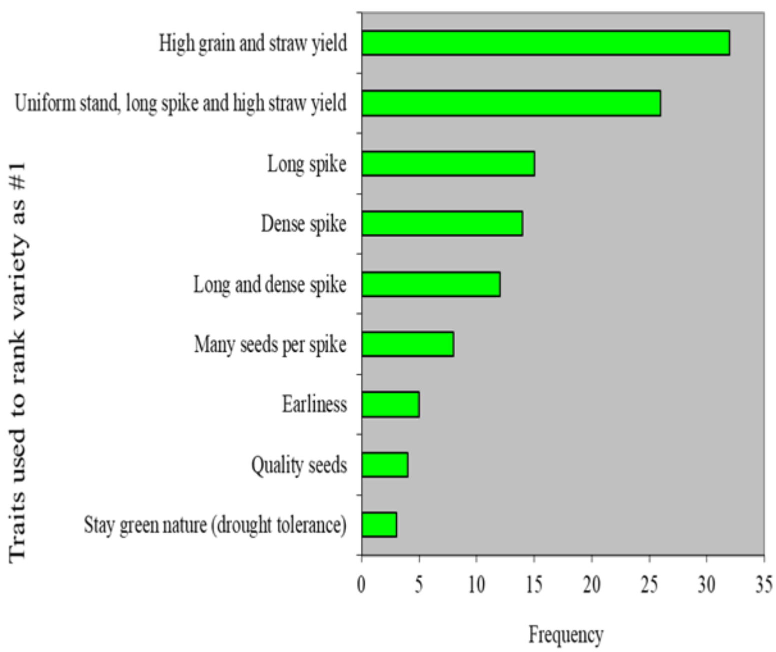

Figure 4: Type and distribution of traits used to rank varieties as number 1 (top-ranking varieties)

Though it was late in maturity, accession 29 (208113) was the first choice for 40% farmers due to its tall height, good tillering capacity, long spikes and also higher yield. According to the farmers, this landrace had good potential of drought tolerance as manifested through its stay green nature for more than six weeks after the last rain. Twenty-eight percent of the farmers ranked it as their second choice.

Table 12: Summary table showing durum wheat varieties' ranking (1 - 4 scale) by participant farmers involved in crowdsourcing trials in Tigray, Ethiopia in 2013

Varieties	No. of participants (farmers)	Number of farmers for each rank								Overall (average of rank1 and rank2)
		1	%age	2	%age	3	%age	4	%age	
1	25	3	12%	8	32%	7	28%	6	24%	22%
2	25	5	20%	10	40%	2	8%	8	32%	30%
3	26	3	12%	4	15%	7	27%	12	46%	13%
4	22	6	27%	4	18%	7	32%	5	23%	23%
5	26	3	12%	8	31%	8	31%	7	27%	21%
6	27	4	15%	4	15%	6	22%	13	48%	15%
7	21	4	19%	5	24%	8	38%	4	19%	21%
8	28	8	29%	5	18%	9	32%	6	21%	23%
9	26	4	15%	6	23%	6	23%	9	35%	19%
10	22	7	32%	7	32%	4	18%	4	18%	32%
11	25	6	24%	4	16%	10	40%	5	20%	20%
12	27	8	30%	7	26%	9	33%	3	11%	28%
13	22	6	27%	8	36%	3	14%	5	23%	32%
14	27	5	19%	13	48%	5	19%	4	15%	33%
15	26	6	23%	11	42%	4	15%	5	19%	33%
16	23	4	17%	8	35%	2	9%	9	39%	26%
21	166	55	33%	35	21%	39	23%	37	22%	27%
29	25	10	40%	7	28%	3	12%	5	20%	34%
30	21	5	24%	4	19%	4	19%	8	38%	21%
31	27	9	33%	3	11%	9	33%	6	22%	22%
32	24	3	13%	6	25%	10	42%	5	21%	19%

By considering the average of 1st and 2nd ranking values, six farmers' varieties were selected by more than 30% of participating farmers. The genotypes that were ranked 1st and or 2nd by more than 30% of the participant grower farmers were all farmers' varieties and they included accessions 208328, 208304, 214357, 222360, 208279 and 208136. Therefore these six varieties were the most preferred by farmers, and they showed stable performance across the 12 test villages.

4.4 Participatory Varietal Selection (PVS)

After being tested in farmers' fields using crowdsourcing, a set of crowdsourced varieties, together with other varieties from the breeding block, were subjected to multi-location trials in 2016. Thirty-six durum wheat varieties 931 farmer varieties and 5 improved varieties were tested at four sites in Tigray during 2016 and 2017 to fulfil the requirement for national variety release criteria. The detailed methodology and results were published in Mengistu et al (2019). The most stable varieties identified through this study were those previously identified through a crowdsourcing approach. Two varieties, 'Rigeat' (meaning stable) and 'Wehabit' (meaning high yielder) were nationally registered for official release as a result of this study. These varieties were known by accession numbers 8208 and 208304, respectively, in crowdsourcing trials. Rigeat and Wehabit were the first durum wheat varieties released in Tigray region through a participatory plant breeding approach and the success of this selection approach was a revelation for Ethiopian research system, which promoted a centralized breeding approach for certain commodities such as durum wheat, tef and malt barley.

Table 13: Genotypic BLUP means for phenological and quantitative traits presented for top 10, the standard check and bottom five genotypes with grand mean and LSD values

	SN	Variety	Entry	DB	DF	DM	NET	PH	SPL	SPS	BY	GY	TGW
Top 10 high yielding genotypes	1	226834	G22	67.42	75.51	114.1	4.92	90.85	7.68	38.5	9.86	3.51	43.40
	2	208474	G15	64.73	71.88	115.0	5.29	101.58	7.11	32.1	8.36	3.40	43.75
	3	222360	G21	72.01	80.13	121.4	4.22	92.60	6.42	35.2	9.56	3.40	44.87
	4	**208304**[a]	G10	**69.13**	**77.35**	**119.0**	**4.75**	**93.85**	7.04	40.5	**10.03**	**3.34**	**45.00**
	5	**8208**[a]	G30	**65.56**	**74.03**	**116.2**	**4.81**	**102.04**	**6.60**	**31.3**	**9.68**	**3.30**	**49.78**
	6	238137A	G27	68.81	77.01	116.9	3.98	98.02	5.91	39.7	10.08	3.21	46.79
	7	208482	G16	69.46	76.9	118.5	3.97	92.05	6.25	37.0	10.08	3.17	42.85
	8	228763	G24	69.09	77.39	117.8	4.66	91.65	6.83	40.4	9.07	3.16	43.25
	9	208315	G12	66.86	74.56	115.9	5.59	97.09	6.63	36.3	9.46	3.15	43.84
	10	228771	G25	65.85	74.04	117.1	4.12	93.35	7.12	33.3	9.67	3.10	50.17
Check	11	*Asassa*	G33	60.21	68.95	116.1	4.25	95.35	5.15	41.4	9.08	3.07	44.98
Bottom poor yielders	32	Mangudo	G34	60.31	69.0	117.5	3.56	78.82	4.90	38.6	7.31	2.55	49.94
	33	206556	G2	64.52	73.52	114.5	5.04	90.26	6.01	37.0	8.52	2.52	37.44
	34	Mukiye	G35	58.83	67.96	115.2	3.69	78.33	5.44	42.2	7.15	2.44	43.65
	35	238492B	G28	62.17	69.63	116.3	4.20	79.7	5.53	50.6	7.00	2.43	38.49
	36	Arendato	G32	68.42	76.47	113.8	4.88	85.57	5.93	35.0	7.89	2.20	37.00
Grand mean			**G37**	**67.11**	**75.2**	**117**	**4.66**	**94.68**	**6.54**	**36.7**	**8.99**	**2.88**	**43.93**
		LSD0.05	**G38**	**2.1**	**2**	**1.58**	**0.83**	**5.4**	**0.59**	**3.66**	**1.56**	**0.57**	**3.57**

Ranking was done on the basis of GY.
[a]Most stable genotypes which were registered nationally as variety with the name of *Rigeat* and *Wehabit*, respectively.

Source: Mengistu et al., 2019

In summary, the use of a crowdsourcing methodology enabled identification of superior durum wheat farmers' varieties, two of which, Rigeat and Wehabit, were nationally registered and approved for commercial production. Many farmers' varieties —showing yield advantage, terminal drought tolerance (e.g. accession 208474—have been submitted to the Ministry of Agriculture as candidates for registration, but the national variety trial evaluation is pending due to Covid-19 travel restrictions.

4.5 Seed multiplication and distribution

The seed of the two registered durum wheat varieties Rigeat and Wehabit was multiplied on 11 hectares (7 ha in Degua Tembien and 4 ha in Emba Alajie districts) during the 2017/18 cropping season. Before harvest, field performance of both varieties was inspected by Tigray seed quality inspection office. The inspection office approved the distribution of the harvested pre-basic seeds to farmers and seed producer cooperatives. About 35 tons of seeds of Rigeat and Wehabit varieties were harvested and distributed to farmers, local seed producer cooperatives, Mekelle agricultural Research Center and Alamata Agricultural Research Center for further multiplication.

During the 2018/19 cropping season, these varieties were widely grown in Degau Tembien and Emba Alajie districts of Tigray region. Seed multiplication is still ongoing by the above mentioned institutions and farmers. Currently, it is estimated that more than 1500 smallholder households are growing these varieties. Furthermore, multiplication of the two varieties done on 2ha of land during the 2020 cropping season was carried out for basic seed maintenance, organoleptic testing and nutritional profiling, as well as for further distribution to farmers in the project's impact areas. Moreover, the seeds of other crowdsourced winning accessions, e.g.accession 208474, are being multiplied for dissemination to farmers producing durum wheat in drought-prone areas of Tigray like Bora and Ganta-Afeshum districts.

4.6 Barley crowdsourcing trials

Barley is among the major cereal crops grown in the highlands of Tigray region mainly for consumption. It is also blended with other cereals to make bread and *injera* (a bread). Despite its importance, the production and productivity of barley in the region is mainly challenged by lack of improved adaptable varieties. Barley crowdsourcing trials were conducted by the Mekelle University Integrated Seed Sector Development (MU-ISSD) Ethiopia project to strengthen the barley seed system in the region during the 2018/19 cropping season in Degua Tembien district, at three villages: Hadnet, Melfa and Mehabre Selassie. Eight barley varieties have been distributed in combination of three varieties to 300 farmers, 100 in each village, to increase the varietal portfolio of participant farmers and target villages. Nearly half of the participant farmers were women. The approach used to conduct the experiments was as described for the durum wheat crowdsourcing trials. Data was collected from 97 farmers in Hadnet (97%), 95 farmers in Melfa (95%) and 62 farmers in Mehbere Selassie (62), with overall success rate of 84.6%.

The evaluation of the distributed barley varieties was done following the tricot approach, whereby farmers were asked to identify the best and the worst out of three varieties for trait under consideration. The remaining variety assigned the rate of intermediate by default due to identification of the best and the worst. This rating data was fed into ClimMob software to generate the overall ranking of varieties in the villages and for each farm.

4.7 Preliminary result

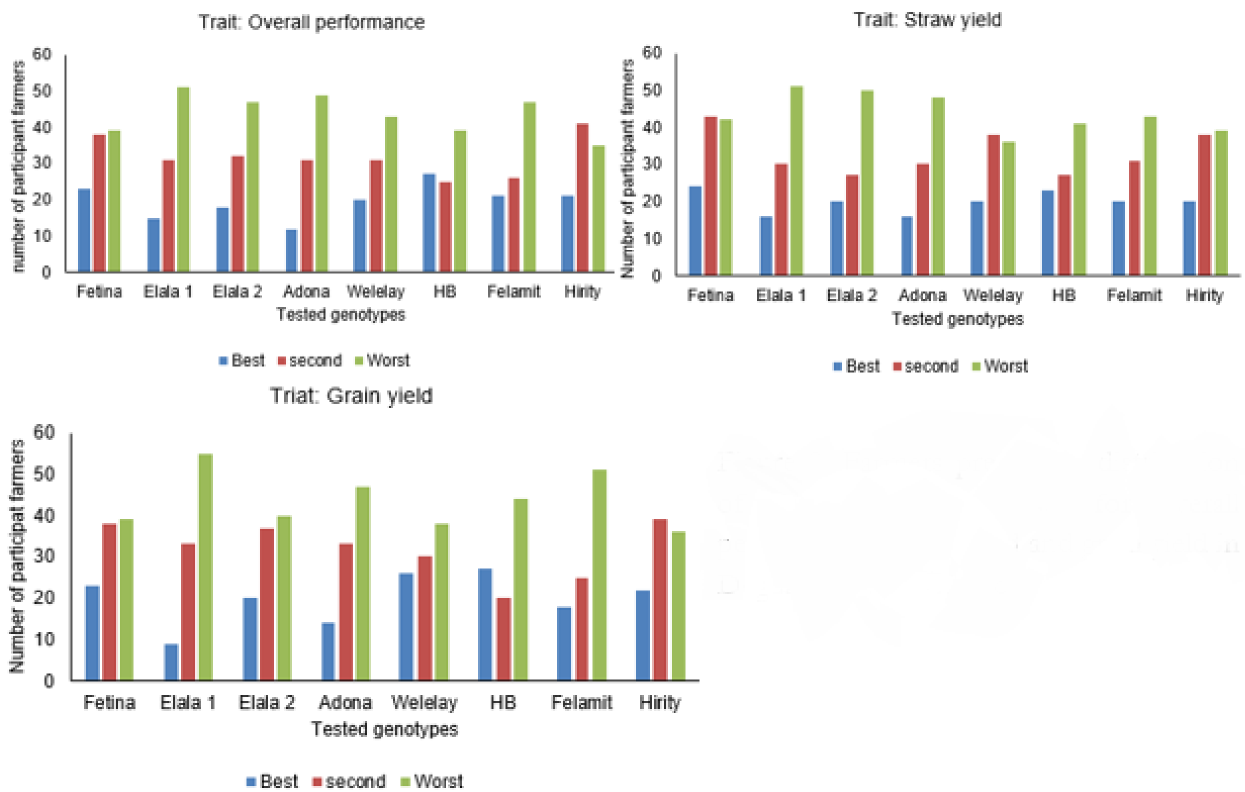

Figure 5: shows the preference of the eight barley varieties by participant farmers. It was clear that different farmers prefer various varieties.

In Figure 5 on overall performance, HB, Fetina and Felamit were rated as better than other varieties, while Ellala 1, Adona and Felamit were disliked by many participant farmers. Considering grain yield and straw yield, Fetina and HB were the most liked varieties over the others. Similarly, Ellala 1, Adona and Felamit were the most disliked varieties in Degua Tembien district. Ellala 2 was also disliked by most farmers in the district. It can be concluded that HB and Fetina were the favourite varieties for their overall performance, grain and straw yield, and further work is needed to disseminate them to wider community.

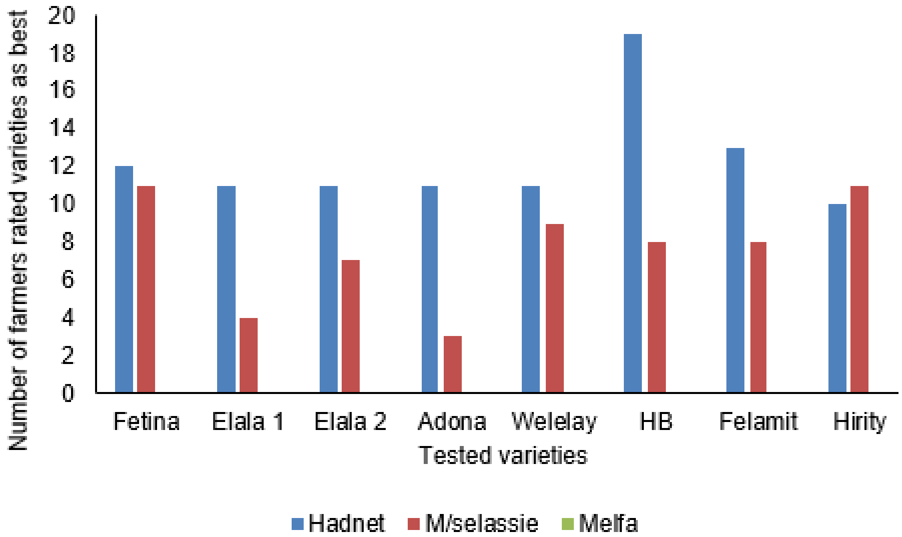

Figure 6: Number of farmers' preferred barley varieties as their best choice in Hadnet and Mehbre Selassie (M/Selassie) villages of Degua Tembien district. No varieties rated as best at Melfa village

There were spatial differences in preference of varieties across the three test villages. At Hadnet village, HB, Fetina and Felamit barley varieties were rated as best for their overall performance while Fetina, Hirity and Welelay were the favourite varieties for farmers in Mehbre Selassie Village. Adona and Ellala1 were not the preference of many farmers at Mehabre Selassie village. At Hadnet, Ellala1, Ellala2, Adona, Welelay and Hirity have comparable preference. The data showed that none of the varieties were rated as best by any farmer at Melfa village, probably none of the varieties liked by the participant farmers.

It can be inferred from Figure 6 that HB and Fetina barley varieties received wider acceptance and could be distributed to a broader community in Degua Tembien district over the other tested varieties. Felamit and Hirity could be the second-choice varieties in the event that the first two are not available in the area. Most participant farmers did not like Adona variety for any trait and consequently the adoption rate of this variety could be considerably lower if the variety were to be extended to the area.

4.8 Seed multiplication for dissemination and nutrient content analysis

Seed multiplication of the selected varieties HB, Fetina, Felamit and Welelay has been underway during the 2020 cropping season and the crops are ready for harvest currently. All the four varieties were multiplied on 3ha of land, with unequal allocation of land, and an expected harvest of more than 100 quintal of seeds. Most of these seeds will be distributed to farmers, while some will be utilized for organoleptic testing and nutritional profiling of the selected barley varieties.

4.9 Dissemination of selected varieties through seed value chains using QDS frameworks

The Food and Agriculture Organization of the UN (FAO) introduces the concept of 'quality declared seed' (QDS) that allows three kinds of varieties that can be registered, namely, bred varieties, local varieties and varieties developed through participatory plant breeding. The requirement for the farmers' variety registration is submitting the local name, its origin, morphological description, its value for cultivation and use, with an indication of the agroecological zone for which the variety is suited and information about its management (FAO, 2006). This system, to which Ethiopia is signatory, has flexibility for registration of and participation farmers' varieties at the commercial scale and could also play a pivotal role in empowering smaller organizations like farmers' groups and cooperatives. The Ministry of Agriculture (MoA, Ethiopia) also drafted and published a manual and formal procedure that should be followed by institutions (research or agricultural office) and farmers' groups that seek to register their locally adapted and widely grown varieties. One of the requirements is planting the local variety in a contiguous cluster of plots and submitting primary agro-morphological data collected by research institutions (including and farmers' consensus) to the federal office of the MoA.

Thus, the objective is to consolidate farmers' perception, field and laboratory data collected from different farmers' varieties growing in different agroecologies within the Tigray region and to bring onboard evidence that supports the legitimacy for registration and policy dialogue. One of the crop species subjected to this study listed above is sorghum.

5. Knowledge sharing and learning

We are working closely with farmers, community seed banks and local seed producer cooperatives. Before varietal distribution both for PVS and crowdsourcing trials, participant farmers, local extension agents and crop experts received training on the subjects and concepts listed in the next paragraph. Because of the participatory nature of both crowdsourcing and PVS experiments, knowledge sharing and learning is a two-way reciprocal process, in which researchers learn the indigenous knowledge of farmers and farmers become acquainted with scientific knowledge.

Participant farmers learned:

- Principles and concepts of crowdsourcing and its power as a quick means of varietal evaluation and selection
- The use of crop diversity to improve their production resilience to existing and predicted climate conditions
- Crop diversification as a means of nutritional diversification
- Scientific varietal evaluation and selection of winning varieties from provided varieties
- In-situ and ex-situ conservation of genetic resources on their farm and in their community seed banks.

Lessons learned by Researchers from participant farmers:

- Farmers evaluate varieties for multivariate traits instead of considering only single trait
- Farmers have the experience and skill to evaluate and select varieties that meet their demand
- Farmers are keen to devote their land and time for experimentation if they believe that the trial is for them and they are the decision makers at every step of the experimentation.

6. Sustainable Agricultural Intensification indicators (SAI)

An endline survey was conducted in 2019 to assess agronomic practices that are supposed to lead to sustainable intensification of agricultural production in two districts of Tigray: Degau Tembien and Emba Alajie. The baseline survey was conducted in 2017 by agricultural intensification project. Multiple indicators characterizing the local farmers were studied (Table 14). Information from 250 smallholder farmers was collected on the indicators using the Rural Household Multi-indicator survey (RHOMIS) lean indicator household survey during the 2019 cropping seasons, to measure the changes observed between baseline and endline in the farming communities and the impacts of these changes on their livelihoods. While the RHOMIS survey questionnaire used here was standardized, the conditions under which baseline and endline surveys were conducted differed slightly. For example, enumerating dietary diversity recalls at different times of the year (with different temporal distance to the latest harvest) allows only limited comparability. Some of the indicators below, such as those measuring food security and income, refer to a one-year recall period and are thus more representative of long-term changes (although they also partly reflect how favourable the weather was in the recent farming season).

Results: It seemed that food security of the target community had improved: **The mean number of food-insecure months** (in the year before survey enumeration) **decreased from roughly two and half months to about three weeks**. Overall, household access to adequate food supply had improved, and 60% of all households enumerated were classified in a better Household Food Insecurity Access Scale (HFIAS) category in 2019 than in 2017.

At household level, both household income and nitrogen fertilizer usage increased by about five-fold. The increase in income was due, in largest extent, to increased farm sales (as opposed to off-farm income). A requisite for increased sales, the average monetary value of farm production had increased, albeit not as strongly as the increase in fertilizer application. This suggested that a rather conventional, not necessarily sustainable agricultural intensification had occurred. The results seemed to suggest the emergence of higher farm productivity and resulting crop sales, e.g. through increased fertilizer use in combination with more site-adapted wheat cultivars. It was however, noteworthy that women's decision-making power over their household's farming, income-generating activities, and consumption had also increased to be almost in equity with the men's. Since social equity was an important concern of sustainable agricultural indicators (SAI), empowerment of rural women was a trend that contributed to SAI in Tigray.

The role of female farmers in controlling farm activities and farm resources had increased by about 31% during 2019 compared to the baseline survey period two years earlier. This might be because of the sampling bias during endline survey, as many more female participants were involved compared to those involved at the baseline survey. Crop diversity on the farm showed significant decrease probably due to the introduction of cluster farming in the areas that encouraged the cultivation of the same variety by clusters of farmers. This is in fact not a good indicator of sustainability.

Table 14: Changes in SAI achievement in Tigray, Ethiopia. Columns 2 and 3 show overall mean values, while the column 'Mean individual change' shows the average of individual changes. Colours indicate positive (green) and negative (red) changes from a sustainability perspective.

SAI Indicator	Baseline (2017)	End line (2019)	Mean individual change
Food-insecure months	2.4	0.8	- 1.6
HFIAS	Median at *Moderately food insecure*	Median at *Mildly food insecure*	Improved: 60 % Stayed in the same category: 28 % Worsened: 12 %
HDDS	5.1	3.7	- 1.4
Total income (PPP$/a)	2,296	10,979	+ 8684
Value of farm production (PPP$/a)	4,218	11,595	+ 7,320
Female control	17%	48%	+ 31 %
Crop diversity	4.2	2.2	- 2.0
Information exchange diversity	7.1	3.4	- 3.8
Information source diversity	n.a.	2.3	-
Market orientation	48%	n.a.	-
Nitrogen fertilizer use	27 kg/ha	246 kg/ha	+ 283 kg/ha

7. Information ecosystem

Agricultural extension services in developing countries have increasingly introduced modern information and communication technologies to deliver advice. In line with this, we assessed the available heterogenous agricultural advisory contents available to farmers in the target area.

Method: Questionaries developed in RHOMIS containing questions addressing information sources to advise on agricultural production were used to collect data from farmers in 2019 using the Kit open data software. To determine farmers' individual information preferences, we used a choice experiment and farmers were asked to rank the different information sources according to their preference in receiving it. Through this simple ranking experiment, we determined farmers' individual information source preferences using hand-held cards.

Results: In Degua Tembien district, farmers actively used a range of information sources, with each farmer using an average of 2.3 ± 1.2 different types of sources (out of 9 categories enumerated). The most widespread way of accessing agricultural information was through direct interaction with extension agents (78% of farmers) (Table 15). The remaining 22% of farmers, without access to extension agents, were more likely to use digital channels to obtain agricultural information: 65% used the radio (compared to 43% of the farmers with access to extension agents), 26% used mobile phone (compared to 20%), and 13% used TV (6%). This demonstrated that farmers in Ethiopia already use digital tools to receive agricultural information, and that these tools have potential to fill gaps in the coverage of public extension. Nevertheless, , the mobile phone is currently mostly use in addition to other means by farmers who already have good access to other information sources inside and outside the public extension system. Farmers who used a mobile phone used 3.5 different types of information sources on average.

Table 15: Overview of information access and use habits of selected farmers in Tigray, Ethiopia

	Share of farmers who use	**Average information source diversity of users of this source**	**Average information exchange diversity of users of this source**	**Share of users who prefer this source**	**Share of users who attribute reliability**
Extension agent	78%	2.5	3.4	80%	77%
Radio	48%	2.9	3.4	59%	53%
Neighbours	47%	3.1	3.8	42%	28%
Farmer group	25%	3.7	3.6	26%	28%
Mobile phone	21%	3.5	3.3	22%	20%
TV	8%	3.4	3.4	44%	50%
Newspaper	5%	3.6	2.9	18%	18%
Other	3%	1.6	2.3	50%	50%
Agrovet shop	0 %	-	-	-	-

Therefore, the data suggested that there was scope for development of more widely-used mobile phone-mediated agro-information services: While only 26% of the farmers currently use the mobile phone to access agricultural information, 69% have access to a mobile phone. Of these, however, 32% share a device with other users, which has important implications for services that intend to tailor information to individual farmers. Network coverage is at an acceptable level: 88% of the mobile phone users report they "usually" or "always" have network at home. At the moment, expenditures on mobile telephony are relatively low, suggesting that fee-based services may have limited potential: On average, farmers spend 55 ± 6.5 ETB (the equivalent of about USD 1.89) per week. Another important factor that can affect the design of future mobile phone-mediated agro-information services is access to electricity, which is far from ubiquitous in Ethiopian rural homes. Only 72% of the farmers indicated that they are able to charge their phone at home. This can limit the potential of sending contents to farmers' phones (as phones may often be out of battery or switched off), suggesting that on-demand services (where farmers request contents as needs occur) may be better suited to the local context in rural Tigray.

Interestingly, whether farmers used the mobile phone for accessing agricultural information was negatively associated with airtime expenditures, suggesting that poorer farmers were actually more likely to resort to using the mobile phone to access agricultural information. Use of the mobile phone as a channel for agricultural information access was also positively associated with network coverage. Gender did not seem to affect the choice of information channels, however, the women's access to extension agents, as well as their use of mobile phones, was no different from the men's.

Among farmers who used mobile phone for accessing agricultural information, only 22% of them named mobile phone among their two most-preferred sources of information, and only 20% mentioned the mobile phone among the two most reliable sources. The overall low rates of usage and popularity of accessing agro-information via mobile phone was remarkable, since Ethiopia—compared to other countries in the region—does emphasize ICT use in agricultural extension, and has a fairly developed digital service established by the public agricultural extension service.

During the 2019 survey period, farmers in Ethiopia shared information with their neighbours on average about 3.4 ± 2.3 different topics. Information exchange occurred in reciprocal networks: In general, farmers who asked their neighbours for information directly were also more likely to provide information in turn to their neighbours (3.8 topics on average). It was not fully clear whether farmers who access a larger number of types of information were also more often approached for information by fellow farmers: our data suggested a weak but not negligible positive association between the number of information sources used by a farmer and the number of topics they were asked about ($r = 0.14$, $p<0.1$). This suggested that diversifying the local information ecosystem, i.e. increasing the number of different sources farmers have access to, could also encourage social learning, farmer-to-farmer learning, and further diffusion of extension messages.

8. Gender approach in seed production, multiplication and commercialization

The participation of women farmers has been ensured in all activities related to PVS, crowdsourcing crop improvement and participatory seed multiplication. In our PVS and crowdsourcing trials, about half of the participants were women farmers. Half of the members of the two community seed banks built by Bioversity International and Mekelle University were women. We have been training them to become seed producers and sellers of the traditional crop varieties identified through crowdsourcing approaches. About 34 women farmers multiplied the seeds of Rigeat and Wehabit wheat varieties identified through crowdsourcing, and sold their seeds at a premium price to Mekelle University and Mekelle Agricultural Research Center in 2019. The local seed producer cooperatives, with whom we are working, include women farmer seed producers who benefit from capacity building and easy market access for their produce.

9. Remaining activities

a. Uganda

- Conduct four cell analysis to determine crop diversity especially for beans and finger millet being used and maintained by farmers compared to 2016 at the start of crowdsourcing trials.
- Engage the Ministry of Agriculture, Animal Industries and Fisheries' seed certification body to finalize a working document for the commercialization of selected varieties of bean and finger millet through the QDS system pathway.
- Engage a private sector company to uptake and commercialize varieties of bean and finger millet for food production.

b. Ethiopia

- Assess the impact of crowdsourcing crop improvement on farmers' seed portfolio and livelihood wellbeing of sampled participant farmers in the wheat and barley crowdsourcing project in Degua Tembien district.

- Conduct organoleptic testing and nutritional profiling of selected crowdsourced winner durum wheat and barley genotypes. The organoleptic test will be carried out after the harvesting of the crops (January – March 2021). The nutritional profiling of the selected durum wheat and barley crowdsourced winner varieties will be carried out until June 2021.
- Compiling all the datasets and writing manuscripts and thesis will be carried out throughout 2021.

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