Participatory Crop Improvement for Farm Productivity and Climate Resilience

A Training manual

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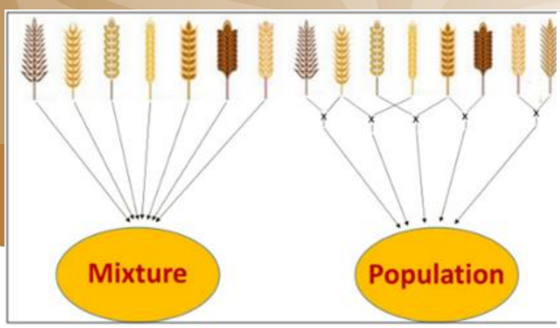

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The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities will be implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

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Executive summary

The challenge of feeding the growing population under the current changing climate is most difficult especially for the subsistent farming systems. These systems are characterized by incredible diversity, not of crops alone, but of micro-environments, socio-economic contexts, and cultural preferences. For decades, conventional plant breeding, optimized for uniform, high-input environments, has struggled to serve this heterogeneity, leading to low adoption rates of improved varieties and missed opportunities for enhancing food security.

This manual presents a paradigm shift: a move from a top-down, transfer-of-technology model to a collaborative, farmer-centric approach to crop improvement. We detail an integrated framework that synergistically combines three powerful participatory methods: Participatory Variety Selection (PVS), Evolutionary Plant Breeding (EPB), and Crowdsourcing (Tricot), supported by the digital platform ClimMob. This framework is not merely about evaluating varieties; it is about building a decentralized, adaptive, inclusive learning system and end users empowerment for agricultural innovation.

Empirical evidence from across the globe demonstrates that this approach delivers tangible impacts:

- Accelerates genetic gain: Reduces the variety evaluation cycle from a decade or more to just 2-3 years.
- Enhances adoption & Equity: Increases adoption rates by 30-50% by ensuring varieties align with farmer preferences, with specific gains among women and marginalized farmers.
- Builds climate resilience: Generates location-specific recommendations and develops dynamically evolving populations that buffer against climate shocks.
- Strengthens seed systems: Creates robust feedback loops between formal research and informal seed networks, enhancing both the supply of and demand for adapted varieties.

This manual is a practical guide. It provides step-by-step protocols, ethical frameworks, advanced statistical foundations, in-depth case studies, and ready-to-use templates. It is designed for practitioners seeking to make crop improvement more relevant, rapid, and resilient.

1. Participatory crop improvement approaches

1.1 Introduction

Conventional plant breeding has achieved remarkable successes, but its central paradigm selecting for broad adaptation under optimal, research-station conditions is a poor fit for the complex, variable, and often resource-limited realities of smallholder farms. This disconnects manifests as:

- Low Adoption: Even when improved varieties are available, adoption rates often remain below 40% in sub-Saharan Africa because the varieties do not meet farmers' complex criteria.
- Ignored Traits: Critical farmer and consumer traits like cooking time, storability, fodder quality, and taste are rarely selection criteria in conventional breeding.
- Genetic Vulnerability: Widespread monocultures of a few genetically uniform varieties increase systemic risk to pests, diseases, and climate variability.

Participatory approaches reconfigure this relationship with a paradigm shift that farmers are the centre of the breeding strategy (Fig.1). Farmers are not passive recipients but active co-developers of technology. This recognizes their expertise as practical agro ecologists who have been selecting and adapting crops for generations. The goal shifts from breeding for farmers to breeding with farmers, leveraging both scientific and local knowledge to develop solutions that are both technically sound and contextually appropriate.

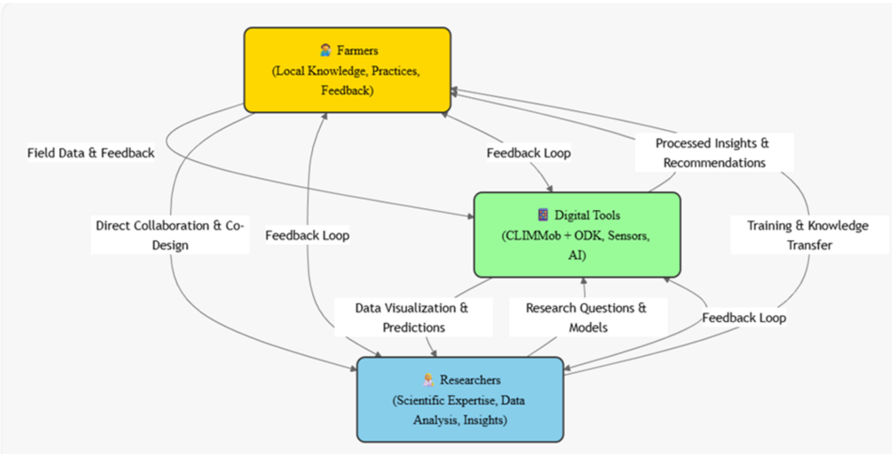


Figure 1. Conceptual framework of participatory crop improvement in a cyclical learning system; showing feedback loops between farmers, researchers, and digital tools.

1.2 Core participatory methods: A comparative overview

PVS, EPB and Crowdsourcing (Tricot) are the three participatory crop improvement methods covered in this manual, represent a gradient of scale, farmer involvement, and objectives (Table 1).

Table 1. Comparative analysis of participatory methods

Feature	Participatory variety selection (PVS)	Evolutionary plant breeding (EPB)	Crowdsourcing (Tricot)
Primary Objective	In-depth validation of a few promising lines	Create and evolve genetically diverse, resilient populations	Large-scale screening of many lines across micro-environments
Scale of Participation	Medium (10s to 100s of farmers)	Small to Medium (10s of sites, multi-year engagement)	Very Large (1000s of farmers)
Farmer Role	Evaluator and Co-Decider: Deep, qualitative assessment	Custodian and Co-Evolver: Guides population through selection	Citizen Scientist: Provides replicated, quantitative data points
Key Output	1-2 validated, farmer-preferred varieties (FPVs) for dissemination	A dynamic, locally adapted population variety	Statistical rankings of all varieties, with environmental and social correlates
Ideal Use Case	Final stage of selection before scaling; seed multiplication	Addressing complex, unpredictable stresses (drought, diseases)	Early-stage screening to identify promising candidates from a large pool

1.3 Ethical foundations: Principles for equitable partnership

Engaging farmers as partners requires a commitment to ethical practice that goes beyond mere consultation.

- Free, prior, and informed consent: This is a process, not a form. It involves transparent, ongoing dialogue about the project's goals, methods, potential risks and benefits, and farmers' rights. Consent must be given voluntarily before any activity begins and can be withdrawn at any time.
- Gender equity and intersectionality: It is not enough to simply include women. Projects must analyse and address the barriers to their participation (e.g., time, mobility, cultural

norms). An intersectional lens considers how gender interacts with age, wealth, and ethnicity to shape experiences and preferences.

- Recognition of knowledge and innovation: Farmer knowledge is a form of intellectual property. Projects must formally acknowledge farmers' contributions and ensure they are recognized as innovators.
- Tangible benefit sharing: Agreements must be clear on how benefits will be shared. This can include:
  - ✓ Direct benefits: Access to seed, training, and project outputs.
  - ✓ Indirect benefits: Support for community development projects (e.g., a seed storage facility).

2. Participatory variety selection (PVS)

2.1 Definition, rationale, and historical context

Participatory crop improvement (PCI) uses various methods that rely on local farmers' indigenous knowledge. In contrast to the conventional crop improvement approaches, participatory crop improvement aims to combine scientific and indigenous knowledge from researchers and farmers to identify crop varieties that are productive and acceptable by end-user farmers and consumers. PVS is one of the participatory crop improvements, emerged in the 1990s as a response to the problems of top-down transfer of technology model. It is defined as the process of involving farmers in the testing and selection of advanced, stable breeding lines in their own environments, using their own management practices with twofold rationale:

1. Biological: To account for strong Genotype × Environment × Management (G×E×M) interactions that are invisible on research stations.
2. Socio-Economic: To incorporate the multi-criteria decision-making that farmers use, which balances production, consumption, and market traits.

PVS does not replace formal breeding; it makes it more efficient by ensuring that only the most relevant and acceptable materials enter the final stages of testing and dissemination. PVS is an approach used to improve local landraces through selection and to evaluate the near-final breeding materials in farmers' fields that were obtained from research institutions. The evaluation and selection of varieties is done through the collaborative participation of breeders and farmers.

2.2. Steps and activities

PVS involves the following steps and activities:

i) Assessing needs: Identifying key community problems in relation to the lack of adaptable crop or livestock varieties in the target area is the first necessary step. This can be done in consultation with the farming community through FGD or key informant interviews. Improving the performance of existing varieties or introducing new promising varieties might be an alternative approach.

ii) Preparing list of varieties for test: Collecting local landraces/finished materials from research institutions with known traits for adaptation to the target area is a second critical step. Include as many varieties as possible (usually 25 – 100 varieties) to offer farmers a wide range of options for thorough selection.

iii) Selecting participant farmers: The PVS process then requires selecting groups of farmers with good knowledge and skills in variety selection and management, in consultation with the community. Disaggregating the participants by sex and age is needed to harness indigenous knowledge from elderly and female, participants and transfer knowledge to the younger generations in the community.

iv) Formulating PVS activities: Specific trial site selection; land preparation; and designing the experiments and planting trials, are some of the activities. Participation of farmers in crop husbandry decisions and practices is also important to further familiarize the farmers with the different varieties.

vi) Participatory evaluation and selection of varieties: Firstly, help farmers to establish variety evaluation and selection criteria. Farmers usually evaluate crop varieties based upon adaptation, productivity, use value (suitability), and market perspectives. Varieties are also preferred for their socio-cultural values. Resource use efficiency of varieties is usually considered as a major criterion for variety selection by smallholder farmers. Steps include: – During evaluation, varieties are rated using scales of 1 - 5 or 1 – 3, where 1 is very poor, 2 = poor, 3 = good, 4= very good and 5 = excellent; on a scale of 1 – 3, 1 = poor, 2 = good, and 3 = excellent. Where the evaluation is based on observation for quantitative traits, a scale of 1 – 5 is preferred over the 1 – 3 scale. It is important to stress that 1 = the poorest ranking, as it is quite common for evaluators to use the inverse where 1 = the top or most preferred, and any inversion will completely skew the overall results. – Give 5 beads to each participant and instruct them to show 1 bead, 2 beads, 3 beads, 4 beads, or 5 beads for their rating of the variety under evaluation as very poor, poor, good, very good, or excellent, respectively (Mancini et al 2017). Avoid peer influence during evaluation. Each evaluator should do his/her own evaluation rating. In one of our PVS trials, we used finger display instead of beads and found it effective in controlling peer influence (Fig. 2).

- ♣ The rating should be done separately for each agreed trait of evaluation.
- ♣ Calculate the arithmetic mean of farmers' ratings as the sum of each farmer rating divided by the number of participant farmers, for each farmer group (male and female, usually).
- ♣ Rank the genotypes based on the magnitude of farmers' ratings mean (from largest to smallest) for each farmer group.

Figure 2. Women and men farmers evaluating durum wheat and faba bean participatory breeding program in Surmo, Hadiya and Abamote, north Shewa, Ethiopia during 2023-2024 cropping season. *For each defined trait, the participant farmers were asked to show their fingers simultaneously (to reduce peer influence) to score the varieties in the field on a scale of one to five (1=poor, 2=fair, 3=average, 4=good, 5=excellent).*

It is advisable to collect necessary crop, climate, and soil data via the researchers from each PVS trial to base the decision of selected varieties on concrete evidence. The final selection of varieties for production should include: – Variety registration for formal production: if the PVS trial is systematically conducted according to the protocol required, selected varieties (usually two to three) can be submitted for registration. Afterdocument submission for registration, planting the selected varieties in standard plots subject to standard monitoring is required.
A) Seed multiplication and dissemination: seeds registered or selected by farmers from local varieties can then be multiplied by interested seed-producer farmers or by the research group. Seed multiplication can be outsourced to local seed-producing farmer groups for bulk seed multiplication for use by other farmers in the community, after approval for production.

B) Seed inspection and approval: during seed production, seed quality regulation and inspection should be done by the relevant inspection and regulatory bodies for approval and certification. For commercial production, only certified seeds are distributed.

C) Field days: organizing field days, during PVS and/or seed multiplication, with the participation of participant and non-participant farmers, extension agents, local agricultural offices, seed producers, seed traders, and local administration is important for adopting and disseminating new varieties. The participants can be drawn from farmers, academics, media, national genebanks, and research organizations.

2.3 Phases of PVS

PVS involves the following four Phase:

Phase 1: Participatory planning and site selection (Pre-season)

- ♣ Conduct stratified farmer recruitment: Move beyond random selection. Use participatory wealth ranking and social mapping to ensure the inclusion of different farmer types: male/female, small/larger landholders. Target: At least 50% women participants.
- ♣ Contextual diagnosis: Understand the farming system constraints and opportunities.
- ♣ Variety pool (8 - 12 entries or more):
    - ✓ Elite improved lines from breeding programs.
    - ✓ Locally important landraces.
    - ✓ Farmer-preferred checks (the current best variety).
    - ✓ Optional*:* 1-2 promising lines from an EPB population.

Phase 2: Mother trials (Season 1)

- Experimental design: Use a randomized complete block design (RCBD) with 2-3 replications for statistical robustness. For larger variety sets (>15), an augmented design can be used, where checks are replicated but new entries are not.
- Management: This is critical. The trial must be managed by the farmer, not the researcher. The researcher's role is to monitor and record the management practices used (e.g., planting date, fertilizer type and amount, weeding frequency). This ensures the results are relevant to real-world conditions.

- Data collection: A blend of quantitative and qualitative data is collected throughout the season.

Phase 3: Farmer led preference analysis (End of Season 1)

This phase is the heart of PVS and is best conducted during a farmer field day.

- **Employ Matrix Scoring**: This is a highly effective PRA tool.
    - ✓ *Setup:* On the ground or a large board, draw a matrix. Rows are the varieties, columns are the traits (e.g., yield, drought tolerance, grain size, grain yield, straw quality, market value, taste).
    - ✓ *Process:* Give each participating farmer a set of 5 counters (e.g., beans, stones) or ask them to show their fingers for *each trait* (Fig. 3). Allow them to distribute the counters across the varieties for that trait. A variety that is excellent for a trait gets many counters or fingers; a poor one gets few.
    - ✓ *Analysis:* The aggregated counters provide a visual and quantitative measure of group preference for each trait and reveal key trade-offs (e.g., the high-yielding variety has poor taste).
- Pairwise ranking: For more detailed insights, facilitators can ask farmers to compare two varieties at a time: "Between variety A and variety B, which has better disease resistance?" This continues until a full ranking is established. This method is good for understanding the reasons behind preferences in depth.

Figure 3. Farmers conducting participatory pre-harvest evaluation and ranking of durum wheat varieties using their fingers during a PVS mother trial in Shurmo kebele, Hadiya (2023). Farmers scored varieties based on key traits including grain yield, drought tolerance, and disease resistance to select the top 1–2 varieties for advancement to baby trials.

Phase 4: Baby trials, seed systems, and scaling (Seasons 2–3)

- Baby trials: The top 1-2 varieties from the mother trials are given to a larger, new group of farmers (25-50) for testing in unreplicated, larger plots. This serves as a final validation and the first stage of seed multiplication.
- Linking to formal systems: The data from PVS (especially if collected rigorously) can be used to support the official release of a variety. Simultaneously, the seed can be channelled into informal and formal seed systems (e.g., through seed producer cooperatives).

2.4 Data collection: Blending agronomic science with farmer knowledge

A comprehensive PVS data collection sheet includes the following key traits:

- Agronomic data: Days to key phenological stages, plant height, yield and its components (e.g., thousand-kernel weight), disease severity (scored using standard scales).
- Farmer perception data: Collected individually from each participating farmer. Uses a 1-5 Likert scale for pre-defined traits and open-ended questions for "reasons of preference."
- Post harvest trait data: Organize cooking and tasting sessions. Score for key qualities (e.g., for *injera/bread*: color, sponginess, taste, texture, etc.).

2.5 Advanced analysis of preference data

- Non parametric statistics: The Friedman test is used to determine if there are statistically significant differences in the rankings of the varieties.
- Principal component analysis (PCA): This multivariate technique is used on the matrix scoring data. It reduces the many correlated traits (yield, height, taste) into 2-3 independent "components" that explain most of the variation. For example, PCA might reveal:
    - ✓ PC1 (Productivity vs. Quality): Separates high-yielding, tall varieties from high-quality, short varieties.
    - ✓ PC2: Might separate early-maturing from late-maturing types. This allows breeders to visualize the "preference landscape" of their farmers and select varieties that fit different niches.

Case Study 2.1: The Story of Quncho Teff: from PVS to national impact

Teff, a staple crop in Ethiopia, is notoriously difficult to breed due to its small seed size and susceptibility to lodging. For years, improved varieties saw limited adoption. In the early 2000s, a participatory approach was used. The variety that would become 'Quncho' (Dz-Cr-387) was included in PVS trials across multiple regions. Farmers consistently preferred it for its high yield, white seed color, and, crucially, its strong straw that resisted lodging. Because farmers were involved in its selection, trust in the variety was high. Through farmer-to-farmer exchange and support from extension, Quncho spread rapidly. It became the first widely adopted improved teff variety in Ethiopia, now covering over 500,000 hectares and significantly boosting national teff production. This case underscores that farmer preference, not just yield potential, drives adoption.

3. Evolutionary plant breeding (EPB): Breeding for a dynamic world

3.1 The scientific basis: Harnessing natural selection and diversity

Evolutionary plant breeding is an approach that combines diversity usage and evolutionary processes in order to increase on-farm buffering capacity against changing environmental conditions. It harnesses existing crop diversity and exposes crop varieties together to these changing farm conditions to enhance the genotypic adaptation of component plants of the local populations. Farmers living in marginal environments have been instinctively growing interspecific and/or intraspecific varietal and crop mixtures to manage these environmental risks. For instance, growing mixtures of wheat and barley, technically called Hanfets, in the northern Ethiopian and Eritrean drylands is an age-old practice. Agricultural modernization has promoted growing single improved varieties that respond well to chemical inputs and require mechanization. This leads to high risk of crop failure, mainly due to abiotic and biotic stresses and severe genetic erosion. In recognizing monocropping limitations, evolutionary breeding has emerged to better understand and plant varietal and crop mixtures.

The practice of harnessing evolutionary populations is at least a century old (Harlan and Martini, 1929) and has subsequently been better defined by Suneson (1956). For a more detailed understanding of evolutionary breeding, refer to the Manual developed by Ceccarelli and Grando (2020). Evolutionary plant breeding utilizes all forms of genetic resources: cultivars, landraces, advanced lines, and modern improved varieties or evolutionary populations. As a result, evolutionary plant breeding could be regarded as a sustainable way of managing genetic resources to boost productivity and adaptation to abiotic and biotic stresses as well as stabilizing crop production in marginal environments. Changing climate, the instability of monocrops, and increasing demand for diversified nutrition has forced farmers and consumers to look for crop varieties that can better adapt to these changing conditions, and satisfy required nutritional diversity. EPB creates and maintains a high degree of genetic diversity (polymorphic populations) and is a preferred approach for breeders and farmers for accelerating the development of climate-resilient and sustainably high-performing crop varieties (Joshi et al., 2020). An evolutionary population can be compared to a living gene bank, not only because it brings greater yield stability and better agronomic traits, but also because it provides greater diversity in aroma, nutritional value, and quality. Evolutionary populations have the potential to produce higher yields and perform better than their local or improved counterparts in adverse conditions. Under stress conditions, evolutionary populations have also been shown to be more resistant to weeds, diseases, and pest damage than homogenous crop populations

EPB represents a fundamental shift from maintaining genetic purity to embracing controlled diversity. Its scientific foundation rests on three pillars:

1. Population genetics theory: Large, genetically diverse populations contain ample genetic variation upon which natural selection can act. In contrast to uniform varieties that may fail completely under unexpected stress, a diverse population ensures that some individuals will survive and reproduce, maintaining yield stability.

2. The insurance hypothesis: Genetic diversity provides a buffer against environmental variability. Different genotypes within the population respond differently to biotic and abiotic stresses, ensuring that the population performs more consistently across seasons and locations.
3. Evolution in real time: By subjecting diverse populations to actual farming conditions, we accelerate the natural evolutionary process, favouring alleles that confer adaptation to local stresses like drought, soil salinity, or emerging pest pressures.

"The strength of EPB lies in its recognition that we cannot predict future climate conditions with perfect accuracy, but we can create populations that have the inherent capacity to adapt to those conditions." Ceccarelli and Grando, 2022) . Based on the source of diversity used in EPB, two different types of populations – Composite Cross populations (CCP), and Composite Mixtures populations (CMP) – are developed (see Figure 4).

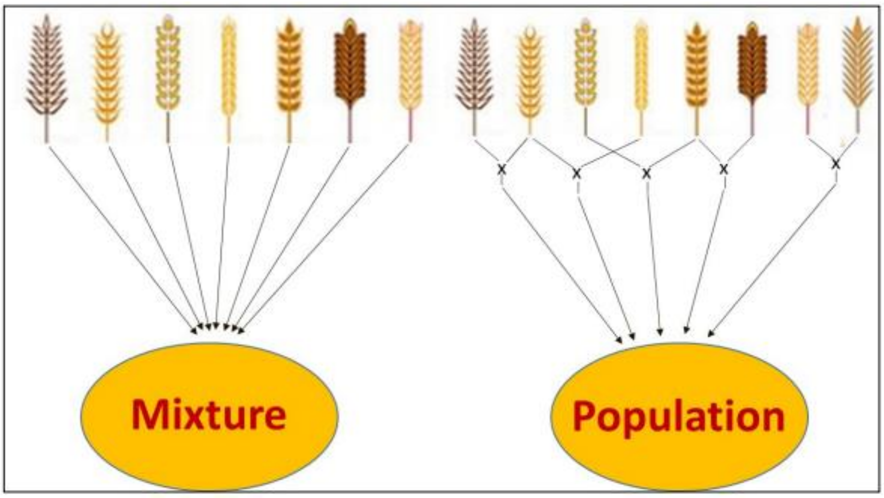


Figure 4. Types of evolutionary populations. A mixture is obtained by mixing seed of different varieties while a population is obtained by mixing the seed obtained by crossing different varieties (Adopted from Ceccarelli and Grando, 2020).

Composite cross population (CCP)

- Process: Creates novel genetic combinations through deliberate crossing. Typically, a half-diallel mating design is used where multiple parents are crossed in all possible combinations. The F1 seeds are harvested and bulked, and the resulting F2 and subsequent generations are grown in bulk populations.
- Genetic outcome: High recombination generating entirely new genotypes not present in the original parents.

- Implementation requirements: Requires controlled crossing infrastructure and expertise. More time-consuming initially but offers greater long-term adaptive potential.

Composite mixture population (CMP)

- Process: Physically mixes seeds of existing varieties, landraces, or breeding lines. No controlled crossing is involved.
- Genetic outcome: Maintains the genetic identity of component varieties but in a mixed stand. Some natural crossing will occur over generations.
- Implementation requirements: Simple and immediate to implement. Ideal for contexts with limited breeding infrastructure.

3.2. The state of evolutionary populations

There are two main states of evolutionary populations, which can be described as follows:

1. Static mixtures: – The state of populations that are established by physically mixing the seed of each of the components at the beginning of each cropping season. They are static because they do not capture the effects of natural selection occurring in the field. This is despite such physical seed mixtures being genetically more complex than monocultures that can therefore be subject to natural selection (Ceccarelli and Grando, 2020).

2. Dynamic mixtures: – Populations that are subject to natural selection from a cyclical production of static populations or populations generated from genetically mixed segregants. Over generations, out-crossing decreases and the genetic structure of such dynamic mixtures becomes a cross-composite population (CCP) (Wolfe and Ceccarelli, 2020).

EPB programs are initiated with the following objectives:
– Developing dynamic evolutionary populations or static varietal mixtures on which natural and artificial selections take place. Natural selection increases the frequency of fit components and eliminates the weak, non-adaptive varietal components of the populations.
– Harnessing the buffering capacities of the populations, thus minimizing the risks of crop failure due to biotic and abiotic stresses and ensuring high yield even under low-input farming regimes.
– Ensuring farmers' access to diversified crop varieties, based on which they make continuous selections to sustain their crop production and improve their livelihoods.

– Enhancing on-farm conservation of crop diversity and creating new varieties through evolutionary recombination. – Providing both locally adaptable varieties and ecological services due to its reduced reliance on intensive inputs.

3.3. Principles for constituting an evolutionary population

The principle of constituting dynamic evolutionary populations and varietal mixtures differs. Thus, we have to consider:

i) The mating system of target crops: Mixing the seeds of pure-line varieties of self-pollinating crops makes a mixture which relies on a low level of natural cross-pollination. Such mixtures take a longer time to become a population because of few or limited opportunities for recombination. On the other hand, if segregant populations from crosses of self-pollinated species are composed, many more opportunities for recombination can be realized in shorter periods, and consequently, evolutionary populations are created much more rapidly. For cross-pollinated crops, evolutionary populations are created at every generation.

ii) Breeding objectives: The choice of how many or which varieties to mix or cross depends on the breeding/farmers' objectives and the characteristics of the crop (Ceccarelli and Grando, 2020). For instance, if disease susceptibility is one of the problems affecting productivity in the target environments, one or more parents of the EP or one or more varieties in the mixture should carry the desirable genes for disease resistance.

iii) Compatibility of component varieties: Compatibility for agronomic and end-use quality traits is required from the component varieties making populations. For instance, when varieties that are very diverse for their phenology (days to maturity) are mixed, it becomes difficult to decide when to harvest. Similarly, cooking time may differ considerably between varieties for crops such as beans, chickpeas, lentils, and rice. Hence, it is necessary to mix varieties with similar maturity times or cooking times. When grain color is the major determinant of market attraction and market price, it is important to consider this factor. For example, the grain color of tef, an Ethiopian staple cereal, is an important factor for producer farmers as well as buyers; a mixed white with red-seeded varieties may not be desirable.

iv) End use value: For specialty crops such as coffee and spices, the flavor or aroma of a particular variety may be different when mixed with other varieties. In such cases, a strict selection of component varieties is important, or indeed, making EPs or mixtures does not have to be extended to such crops.

Mixing diverse genotypes, for example 10 to 1000 or even more, and growing them together in a single plot is the main method of EPB. Component varieties are proportionally mixed. The components can be landraces, improved varieties, hybrids, segregating lines, breeding lines, or wild relatives. EPB can be applicable to self-pollinated, cross-pollinated, and vegetatively-propagated crops. The different varieties, advanced lines, inbred lines, or segregants can be bulked without selection, and can be mixed to form a heterozygous and heterogeneous population. These populations are grown at a location over several seasons to allow evolutionary processes to occur. Population seeds harvested from a location are preferably grown over years at that given location, so as not to interrupt with the evolutionary process and help them thrive through adaptation. The detailed steps of EPB programs are described in Figure 5 below.

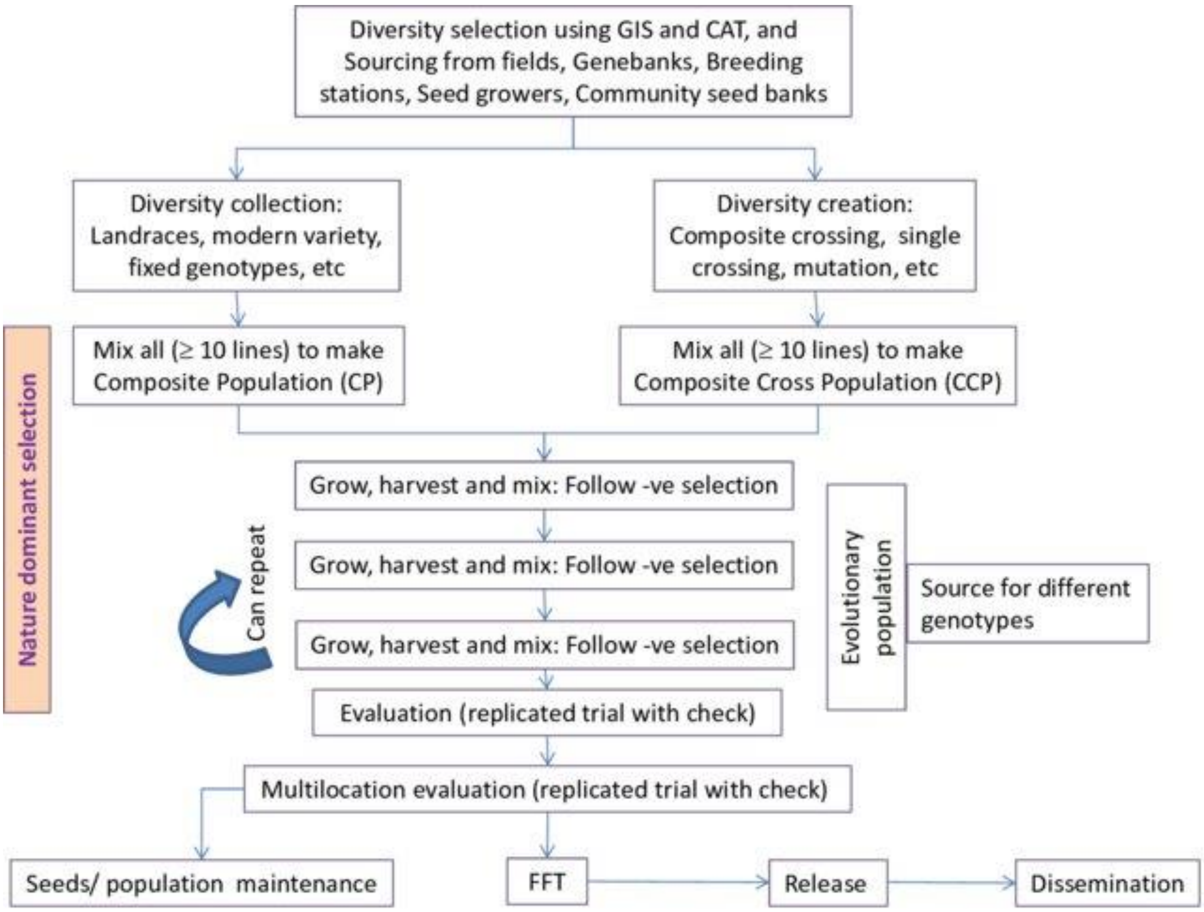


Figure 5. General steps of EPB (either on-station, or on-farm participatory evolutionary plant breeding). Source: Mengistu et al., 2022.

3.4. Functions of EPB

Research has shown that reincorporating diversity into agro-systems to promote ecosystem services is a viable approach for reducing environmental impact while maintaining and even increasing yields (Kremen and Miles, 2012). EPB is supposed to play these roles. As summarized by Ceccarelli and Grando (2020), this wealth of research has shown:

1. Evolutionary populations and mixtures can adapt their phenology to the location in which they are multiplied.
2. Evolutionary populations evolve to become more and more productive.
3. Evolutionary populations, and to a lesser extent, mixtures, have a more stable yield over time than uniform varieties but not over space, i.e. they become specifically adapted.
4. Evolutionary populations and mixtures evolve to become more and more disease resistant (Fig. 6).
5. Evolutionary populations and mixtures can provide a source of new genetic material for formal breeding programs.

Figure 6. Differential reaction of faba bean EP component varieties to chocolate spot and faba bean gall diseases at Abamote, north Shewa, during the 2024 cropping season. a) VM component variety showing resistance (green arrow) and susceptibility (red arrows) to faba bean gall disease, b) VM component variety showing reduced resistance to faba bean gall disease, c) VM component variety tolerant to chocolate spot and faba bean gall, and d) Susceptible line to chocolate spot.

3.5. Participatory evolutionary plant breeding (PEPB)

This approach explicitly incorporates farmer selection alongside natural selection. Farmers are trained to identify and save seed from plants exhibiting desirable characteristics, actively steering the evolutionary trajectory of the population (Table 2).

Table 2. Detailed comparison of EPB methods

Aspect	Composite Cross Population (CCP)	Composite Mixture (CMP)
Genetic diversity	High, with novel combinations	Moderate, limited to parental variation
Recombination rate	High from F_2 generation	Low, increases slowly over generations
Implementation time	Longer (requires crossing phase)	Immediate
Technical requirements	High (crossing expertise needed)	Low (simple mixing)
Best use cases	Long-term adaptation programs, well-resourced institutions	Rapid deployment, resource-limited contexts, community seed banks

3.6 A Multi year implementation protocol: From population creation to release

Year 1: Population design and creation

- Germplasm selection: Curate 15-50 parental lines with complementary traits. Include:
    - ✓ Adapted landraces (local adaptation)
    - ✓ Modern varieties (yield potential)
    - ✓ Exotic lines (specific stress tolerance)
    - ✓ Genetic markers for key traits (if available)
- Crossing/mixing strategy:
    - ✓ For CCP: Use a partial diallel design to manage crossing workload
    - ✓ For CMP: Mix by seed number (not weight) to ensure equal genetic representation
- Quality control: Document parentage and maintain backup seeds

Years 2-4: On-farm evolutionary phase

- Network establishment: Identify 20 - 50 farmer-collaborators across target environments
- Standardized protocol: Provide uniform seed quantities and basic management guidelines while allowing natural stresses to act
- Monitoring framework: Track:
  - ✓ Population structure and diversity (using morphological markers)
  - ✓ Phenological changes across generations
  - ✓ Yield stability under different stress conditions

- Farmer selection: Implement structured selection protocols where farmers:
  - ✓ Practice positive selection (identifying superior plants)
  - ✓ Practice negative selection (removing clearly undesirable types)
  - ✓ Document their selection criteria

Years 5+: Evaluation and institutionalization

- Multi-location testing: Compare evolved populations with commercial varieties across key environments
- Stability analysis: Use Eberhart-Russell or AMMI models to quantify adaptation patterns
- Seed system integration:
  - ✓ Community seed banks for local maintenance
  - ✓ Formal recognition as "Population Varieties" in national catalogues

3.7 On-farm management: The roles of natural and human selection

Natural selection dynamics

- Stabilizing selection: Favors intermediate phenotypes under consistent conditions
- Directional selection: Shifts population characteristics under changing environments
- Disruptive selection: Maintains diversity under heterogeneous conditions

- Monitoring: Use simple morphological markers (seed color, awning presence, plant height) to track selection dynamics

Structured farmer selection protocols

1. Positive selection:
   - ✓ Timing: At maturity, before general harvest
   - ✓ Method: Farmers flag 20-50 best plants based on their criteria
   - ✓ Seed handling: Harvest selected plants separately, bulk seeds
   - ✓ Documentation: Record selection criteria for each farmer
2. Negative selection:
   - ✓ Timing: Can be done at multiple growth stages
   - ✓ Method: Remove obviously diseased, off-type, or poorly performing plants
   - ✓ Goal: Reduce frequency of undesirable alleles
3. Trait specific selection:
   - ✓ Focus on specific adaptation traits (early flowering, deep roots)
   - ✓ Requires farmer training in trait identification
   - ✓ Can accelerate adaptation to specific stresses

4. Crowdsourcing (Tricot): Scaling discovery with citizen science

4.1 The tricot method: Unpacking the theory and design

The Tricot (Triadic comparisons of technologies) approach represents a breakthrough in agricultural experimental design, overcoming the traditional trade-off between number of test entries and number of test locations.

Statistical foundations:

- Balanced Incomplete Block Design (BIBD): Each farmer evaluates a subset (typically 3) of the total varieties, with the design ensuring that:
  - ✓ Each variety appears the same number of times across the network
  - ✓ Each pair of varieties is compared together a roughly equal number of times

- Plackett-Luce model: The statistical backbone that converts thousands of individual rankings into a unified preference scale, estimating the probability that one variety is preferred over another

Information efficiency:

- A traditional trial with 20 varieties would require farmers to manage 20 plots and impractical at scale
- With tricot, each farmer manages only 3 plots, but data from 1000 farmers provides around 3000 plots for statistical comparisons
- This design captures both main effects (overall performance) and G×E interactions (specific adaptation)

4.2 The "Why": Advantages for complex, heterogeneous farming landscapes

For researchers:

- Unique environmental resolution: Capture variety performance across real-world heterogeneity that cannot be simulated on research stations
- Rapid screening: Evaluate 20-30 varieties in a single season instead of multiple years of sequential testing
- Cost efficiency: Lower cost per data point compared to conventional trials
- Real time analytics: Digital platforms like ClimMob provide immediate insights as data flows in

For farmers:

- Manageable commitment: Small plots (typically less than $16m^2$ for cereals) fit into existing farming operations
- Empowerment through participation: Farmers contribute to developing solutions for their own contexts
- Early access: Exposure to new genetic materials before formal release
- Capacity building: Learn evaluation skills and scientific thinking

For policy makers:

- Evidence based targeting: Data to support decentralized, context-specific recommendations

- Inclusive innovation: Democratize the breeding process through the involvement of farmers
- Climate adaptation: Identify varieties for specific climate scenarios

4.3 A step by step field implementation guide

Step 1: Define the technological challenge and option pool

- Problem framing: Clearly define the selection environment and key constraints (e.g., "Identify wheat varieties for terminal drought stress in mid-altitude areas")
- Option selection: Curate 10-30 diverse options representing:
  - ✓ Advanced breeding lines
  - ✓ Released varieties
  - ✓ Farmer varieties
- Quality control: Ensure seed is genetically pure, disease free, and of good germination quality

Step 2: Experimental design via ClimMob

- Platform Setup: Create project in ClimMob (climmob.net)
- Design parameters: Input number of varieties, sample size, and plot specifications
- Automated randomization: ClimMob generates the randemization and assigns triads to farmers
- Kit preparation: System generates packing lists and farmer instructions

Step 3: Kit distribution and plot establishment (Fig. 7)

- Logistics planning: Coordinate with extension services, NGOs, or farmer cooperatives for distribution
- Seed packaging: Label clearly with treatment codes (A, B, C) and include pictorial instructions
- Plot specifications: Depend on the crops and the available seed amount
- Quality assurance: Spot checks to ensure correct establishment

Step 4: Multi modal data collection

- Digital (Preferred): ODK-based forms with built-in validation
- Paper based: For areas with limited connectivity, with later digitization
- Trait Selection: Focus on 3-5 key traits relevant to farmers:

- ✓ Yield potential
- ✓ Drought tolerance
- ✓ Disease resistance
- ✓ Market traits
- ✓ Post-harvest qualities

Step 5: Covariate collection for contextual understanding

- Biophysical: GPS location, soil type, elevation, rainfall data
- Socio-economic: Gender, age, farm size, livelihood strategy
- Management: Planting date, input use, weeding frequency
- Climate: Link to historical weather data and seasonal forecasts

Figure 7. A tricot seed kit and plot layout *(Photo showing kit holding three clearly labelled seed packets (A (7), B (17), C (11)) next to three small adjacent plots with marking stakes showing the simple layout.)*

4.4 Ensuring data quality in large-scale, distributed experiments

Pre collection quality assurance

1. Enumerator training:
    - intensive training covering protocol, ethics, and data collection
    - Field practice with mock trials
2. Farmer orientation:
    - ✓ Simple, visual instruction materials
    - ✓ Group sessions explaining the process and importance
    - ✓ Clear communication about expectations and rights

During collection monitoring

1. Digital validation:

    - ✓ Range checks for numerical values
    - ✓ Consistency checks within forms
    - ✓ GPS verification of plot location

2. Back check protocol:

    - ✓ 10% random revisits by supervisors
    - ✓ Verification of plot establishment and data accuracy
    - ✓ Feedback loop to enumerators

Post collection data cleaning

1. Automated flagging:

    - ✓ Identify incomplete records
    - ✓ Flag inconsistent rankings
    - ✓ Detect outlier values

2. Manual review:

    - ✓ Expert review of questionable entries
    - ✓ Consultation with field team
    - ✓ Decision on inclusion/exclusion

4.5 Statistical power, design considerations and the Bradley terry model

Sample size calculations

- Basic rule: 50-100 complete replications per variety for reliable rankings
- For 15 varieties: ~500 farmers providing complete data
- For 30 varieties: ~1000 farmers needed
- Adjustment: Increase by 20% to account for attrition and incomplete data

The Plackett-Luce Model in practice

The model estimates a "worth" parameter for each variety based on the probability it is preferred over others.

Advanced Applications:

- Incorporating covariates: Model how preferences vary by gender, soil type, or management
- Trait-based analysis: Relate preference to measured agronomic traits

Case study 4.1: Uncovering Micro-Niches for durum wheat in Ethiopia

In the highlands of Ethiopia, where complex topography creates micro-climates within small areas, a Tricot experiment with 1900 farmers tested 14 durum wheat farmers and improved varieties.

Gender dimensions:

- Women preferred varieties with test and market price
- Men prioritized yield and market price

Impact:

- Extension recommendations became location-specific rather than regional
- Seed production was targeted to appropriate areas
- The approach is now being scaled to other locations in the Ethiopian highlands

5. ClimMob software: The digital engine

5.1 Definition

CLIMMOB is an online platform designed specifically for managing and executing tricot projects. It enables farmers to explore and test new agricultural technologies, fostering innovation in crop production and sustainability.

5.2 Importance

With ongoing climate change posing significant challenges to agricultural productivity, CLIMMOB provides farmers with vital tools to adapt. By facilitating the exploration of various technologies that are tailored to local conditions, CLIMMOB helps ensure that agricultural practices remain resilient and effective.

5.3 Key features

- Participatory: Involves farmers directly in the process of testing new crop varieties, ensuring that the varieties chosen to meet local needs.

- Mobile app interface: The platform is accessible via an intuitive app available for Android devices, allowing easy data entry and access.
- Data collection and analysis: CLIMMOB enables the gathering of real-time data from multiple users, which is crucial for timely decisions.
- User-friendly design: The interface is designed to be accessible even for users with low literacy levels, making it easy for all farmers to engage.
- Open source: The platform is freely available for anyone to use and customize, promoting community-driven innovation.

5.4 Purpose

- Enhance farmer participation: Facilitate greater involvement of farmers in agricultural research and development.
- Accelerate technology adoption: Speed up the process of adopting improved crop varieties that can withstand climate challenges.
- Provide rapid feedback: Create a system for quick responses from farmers to breeders and extension services, improving research outcomes.
- Support data driven decisions: Enable farmers and researchers to make informed decisions based on practical, real-world data.

5.5 How CLIMMOB works: Process overview

The workflow of CLIMMOB is streamlined to facilitate efficient project management:

1. Selection of trial materials: Researchers select seeds or other trial materials to be tested.
2. Distribution to farmers: Farmers receive these samples and implement them in their fields.
3. Feedback collection: Participants provide feedback through the mobile app or paper forms regarding the performance of the crops or the technology.
4. Centralized data analysis: All collected data is analysed centrally to inform future breeding strategies and technology dissemination.

5.6. Benefits of Using CLIMMOB

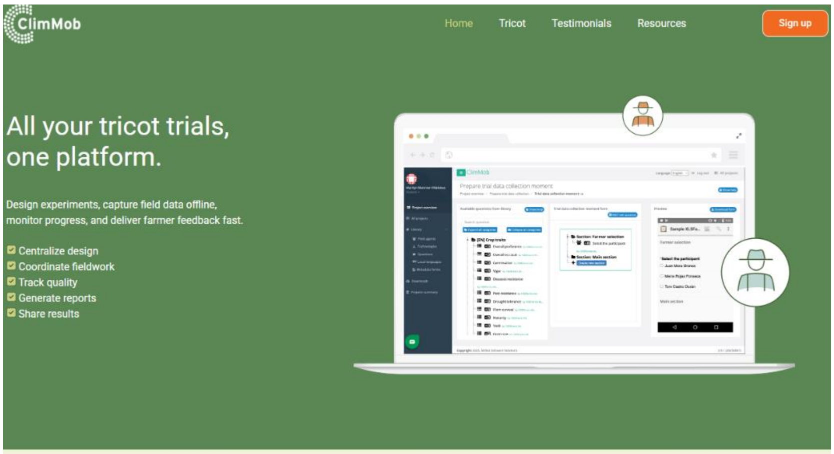
Using CLIMMOB brings several advantages, such as:

- Bridging gaps: It connects researchers and farmers, fostering collaboration and mutual understanding.
- Increasing engagement: Farmers are more likely to engage with innovations that they have a hand in testing and adopting.
- Localized data collection: The platform provides localized, real-time data directly from farmers in their specific regional conditions.
- Transparency and Accountability: Trials conducted through CLIMMOB are transparent, allowing stakeholders to track progress easily.
- Cost-Effective Trials: CLIMMOB provides a scalable solution that is less expensive than traditional trial methods.
- Gender Inclusivity: The platform promotes inclusivity, encouraging participation from all community members, including women.

5.7 Challenges & Limitations

However, there are some challenges to consider:

- Digital Literacy: A basic understanding of digital tools is necessary; some farmers may need additional training.
- Internet Accessibility: Internet access may be limited in some rural areas, restricting usage.
- Resource Requirements: Initial setup and training demand time, which can be a challenge for busy farmers.
- Cultural and Language Adaptations: The platform may require adjustments to fit local languages and cultural contexts better.



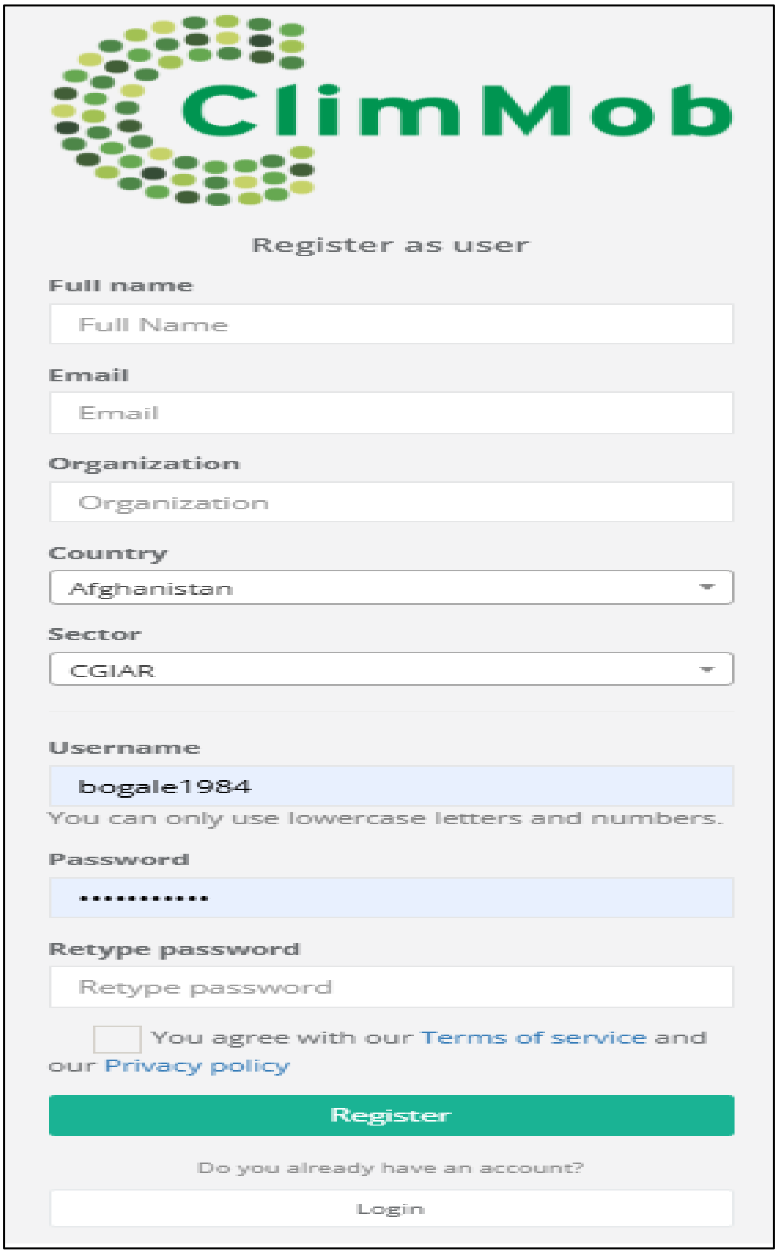
For more information and to access the platform, visit: [https://climmob.net]

Figure 8. First Climmob interface

5.8 Steps to work in CLIMMOB

Step 1: Create an Account

To establish a personal account on CLIMMOB, enabling you to participate in projects and access features.



Instructions:

1. Visit the platform:

✓ Navigate to the CLIMMOB website: Https://climmob.net

2. Sign up/Login or register:

✓ Click on Login (if you have an account) or Register (to create a new account).

3. Account creation:

✓ Fill in required fields:

✓ Full Name, Email

✓ Organization

✓ Country, Sector

✓ Username, Password

✓ Retype password

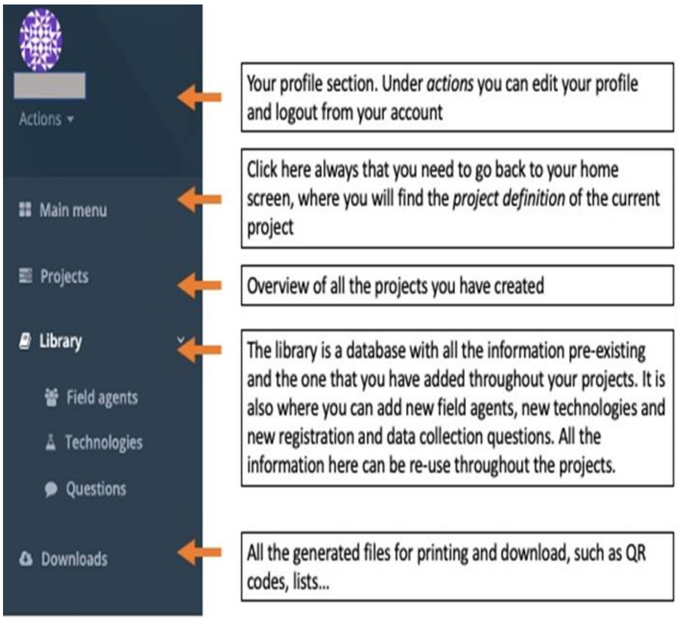
4. Complete registration:

✓ Click register to complete setup of your account.

Figure 9. User registration page of the Climmob

Step 2: Navigate the main menu

Familiarize yourself with the CLIMMOB user interface for easy navigation.



Instructions:

- Spend some time exploring the main menu.
- Use the options available to understand where to find different functions.
- Clicking Main Menu will always bring you back to the homepage.

Figure 10. Climmob main menu to register technology and assign field agents

Step 3: Create a new project

Set up a new profile for your tricot project, laying the groundwork for all future activities.

Instructions:

Add a new project:

✓ Click on Add a New Project.

1. Fill in the project details:

✓ Project code: Enter a unique identifier (e.g., DW2025).
✓ Project name: Use a descriptive name for the project (e.g., Durum_Hosaena_2025).
✓ Description: Provide detailed information about the goals and scope of the project.
✓ Tags: Enter keywords to make the project easily searchable (e.g., farmer's variety, durum wheat, …).
✓ Trial coordinator: This is typically filled in with your name; change if necessary.
✓ Email address: Ensure that this is correct for communication.

2. Geographic information

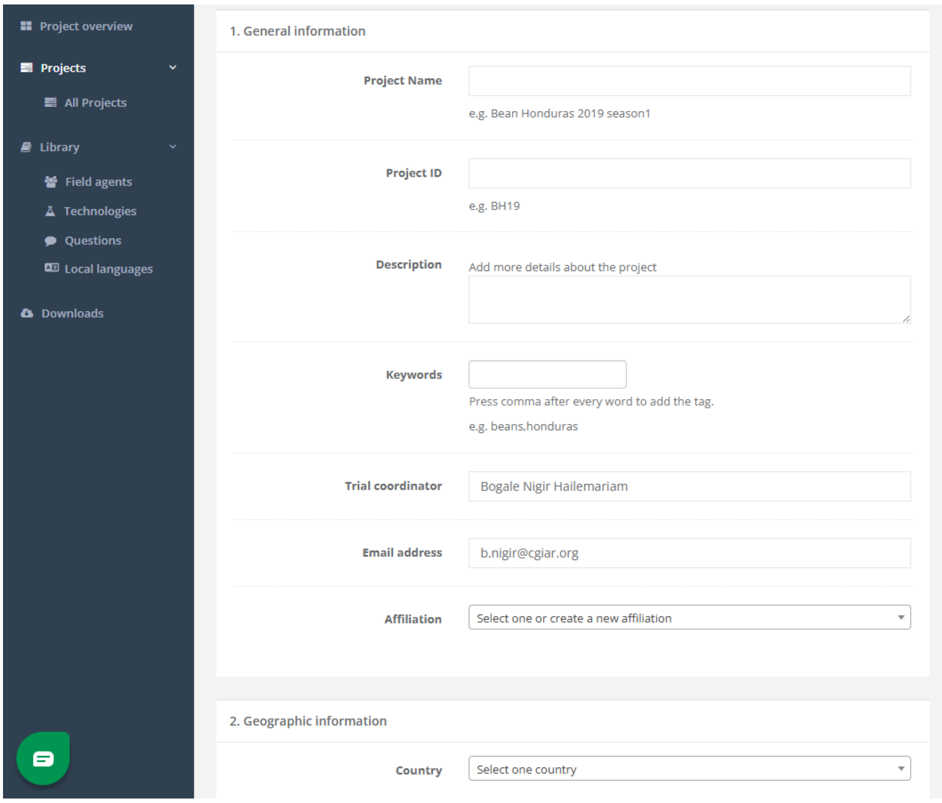
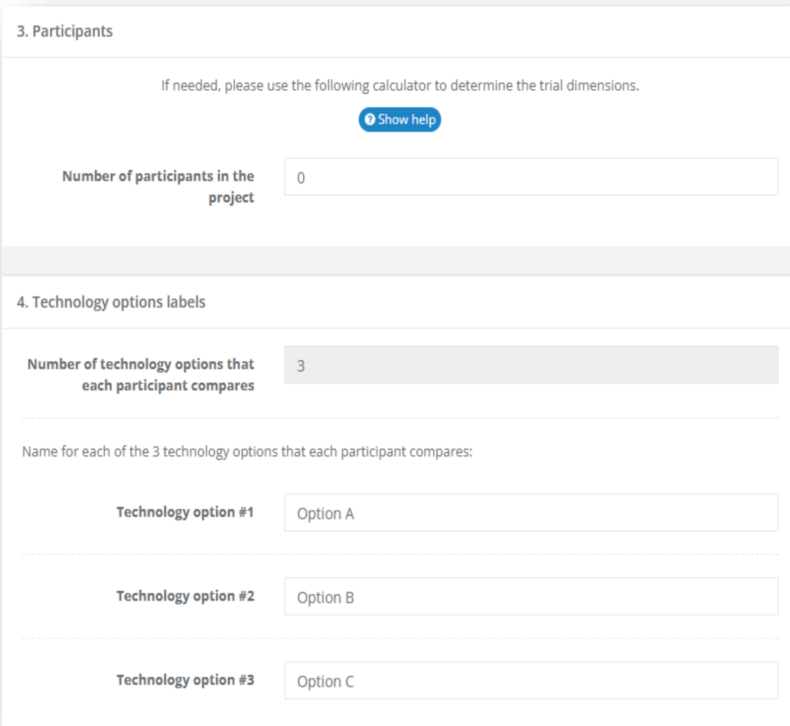


Figure 11. General and geographic information of the project

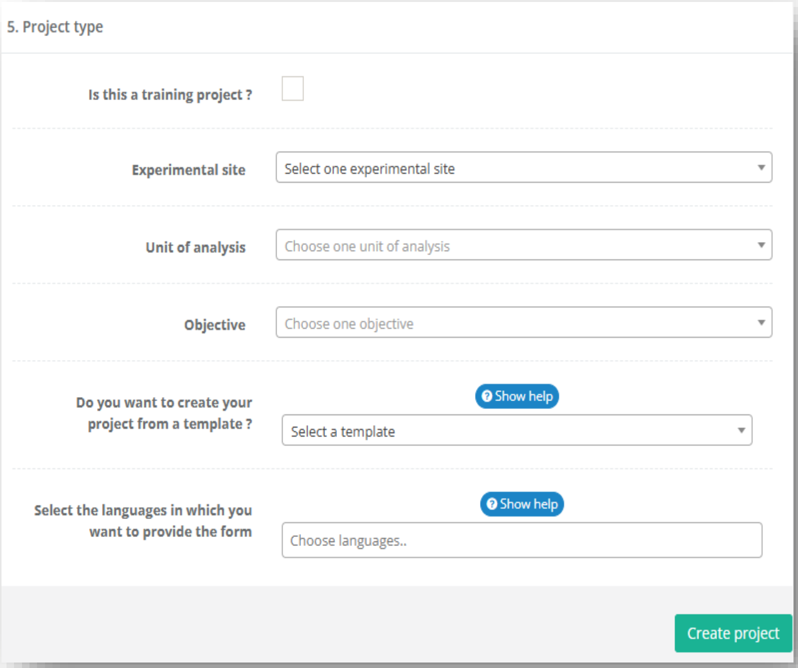


3. Participants

- ✓ Number of participants: Estimate the number of farmers who will join (e.g., 200).

4. Technology options labels

- ✓ Items each participant compares: This is pre-set to 3.
- ✓ Name for each item: Default is "Option A, B, C".



5. Project type:

✓ Choose between *on-farm testing* or *consumer marketing testing*, depending on your focus.

✓ Unit of analysis: agricultural input, crop management practice, genotype,...

✓ Objective: On farm verification, variety recommendation, variety release

Figure 12. Main project information to create a new project in CLIMMOB

6. Template use:

✓ If applicable, select an existing template to start with.

Step 4: Main dashboard (Project definition)

To use the main dashboard as a hub for defining all aspects of your tricot experiment.

Instructions:

✓ Determine the nature of your testing (on-farm or consumer). Consumer testing involves both registration and data collection in a single form.

✓ On-farm testing requires two forms: one for registration and another for data collection.

Setup procedures:

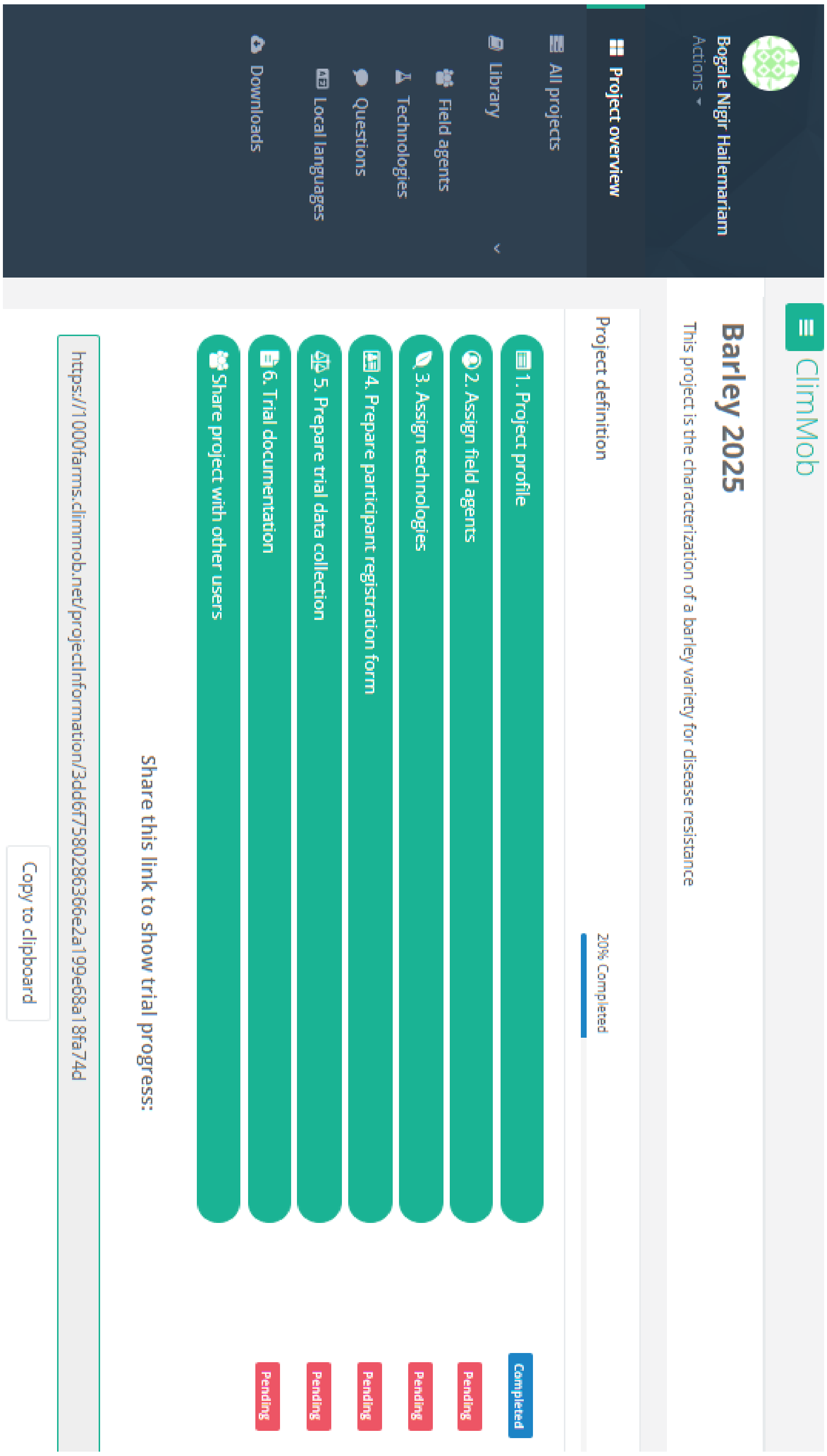
1. Define field agents:

Identify the individuals who will assist with the project.

Specify technology options:

✓ Select the technologies that participants will compare.

2. Registration questions:



3. Create a set of administrative questions for participant registration.

4. Comparison questions:

✓ Add questions that field agents will use during data collection.

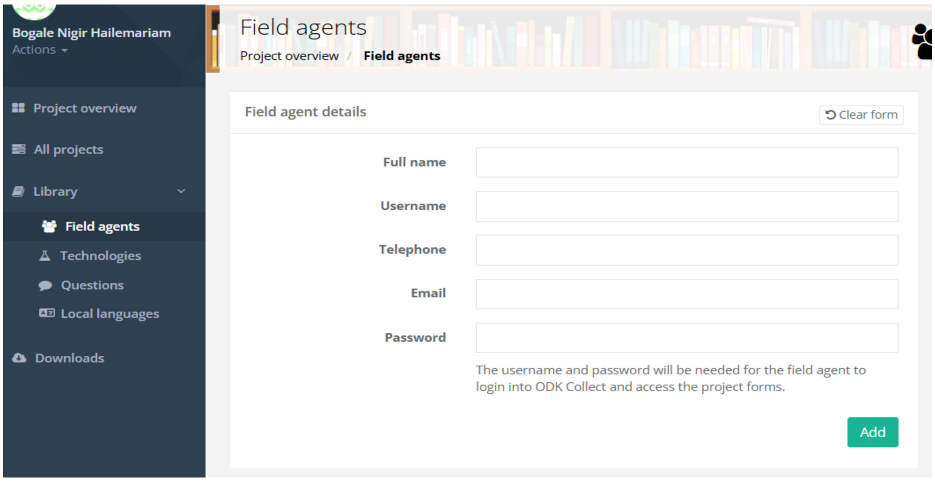
5. Share your project:

✓ Make the project visible and accessible to other users in the system.

Figure 13. Central hub of the project in the CLIMMOB

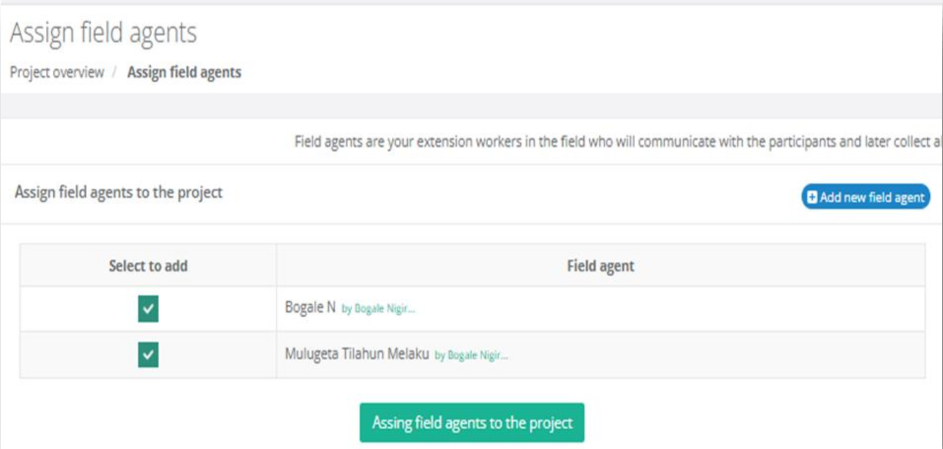
Step 5: Assign field agents

To designate individuals who will interact with participants and collect data during the trials.



Instructions:

1. Click on assign field agents from the main menu.
2. Select agents from the list provided.
3. If additional agents are required, click +Add new field agent to add them.



*Note that the field agent password and user name are necessary for ODK Collect.

Figure 13. Steps to assign field agent

Step 6: Select technology options

To establish the technology options that participants will test in your project.

Instructions:

1. Click on select technology options in the main menu.
2. Browse through the list available and select the technologies that you wish to include in your testing.

Aim of this section: Here you can specify the technology options you want to compare in your tricot experiment.

How-to:

- ✓ On the main menu click on green button Select technology options
- ✓ You will access the list of available technologies in the platform. If the technology, you are interested in is there just click on it and access the different options (e.g. varieties)
- ✓ If the technology you are interested in is not there click on + add new technology. This action will redirect you to the library, where you can create new technologies.

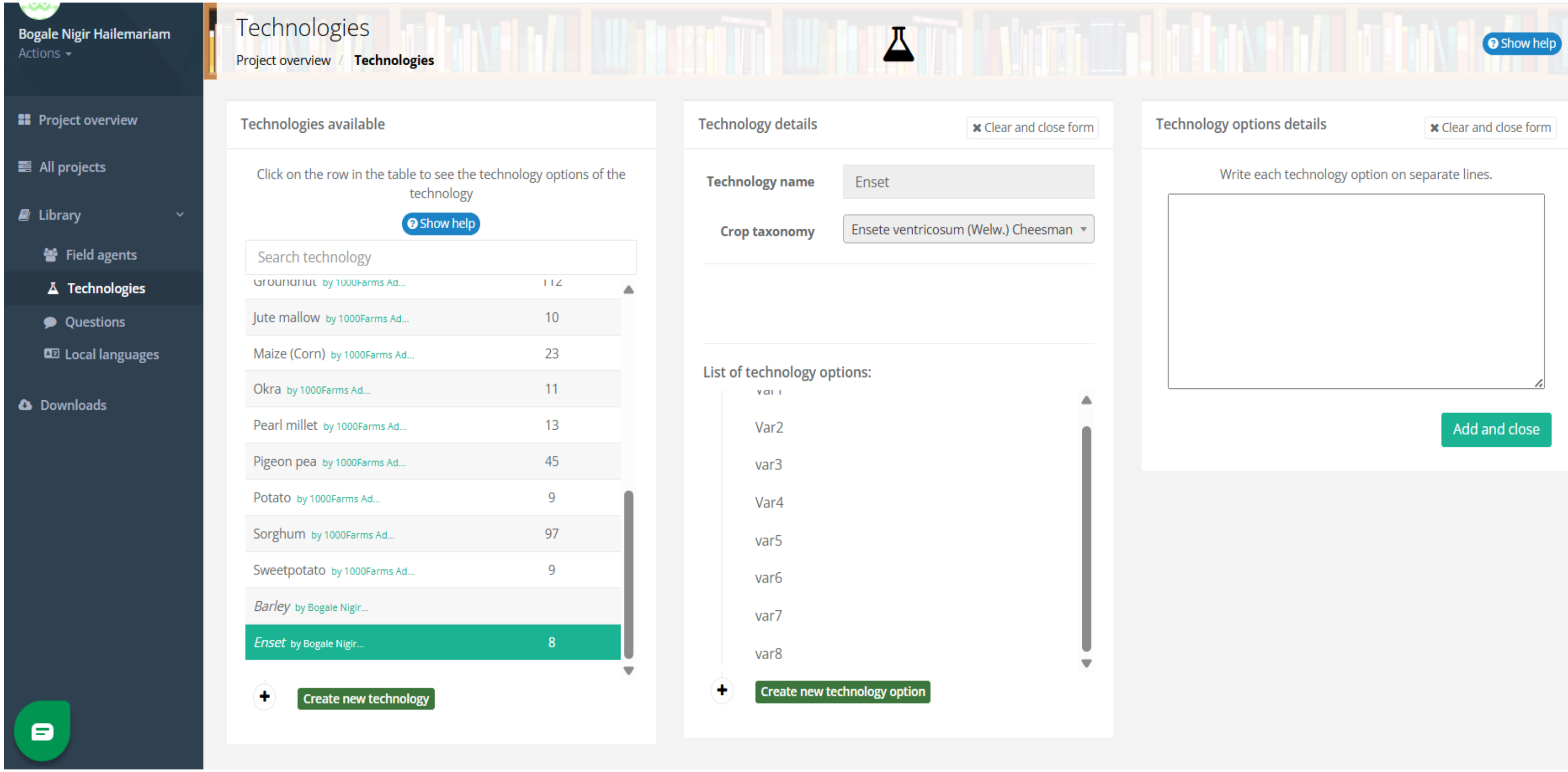


Figure 14. Steps to create new technology and create new technology options

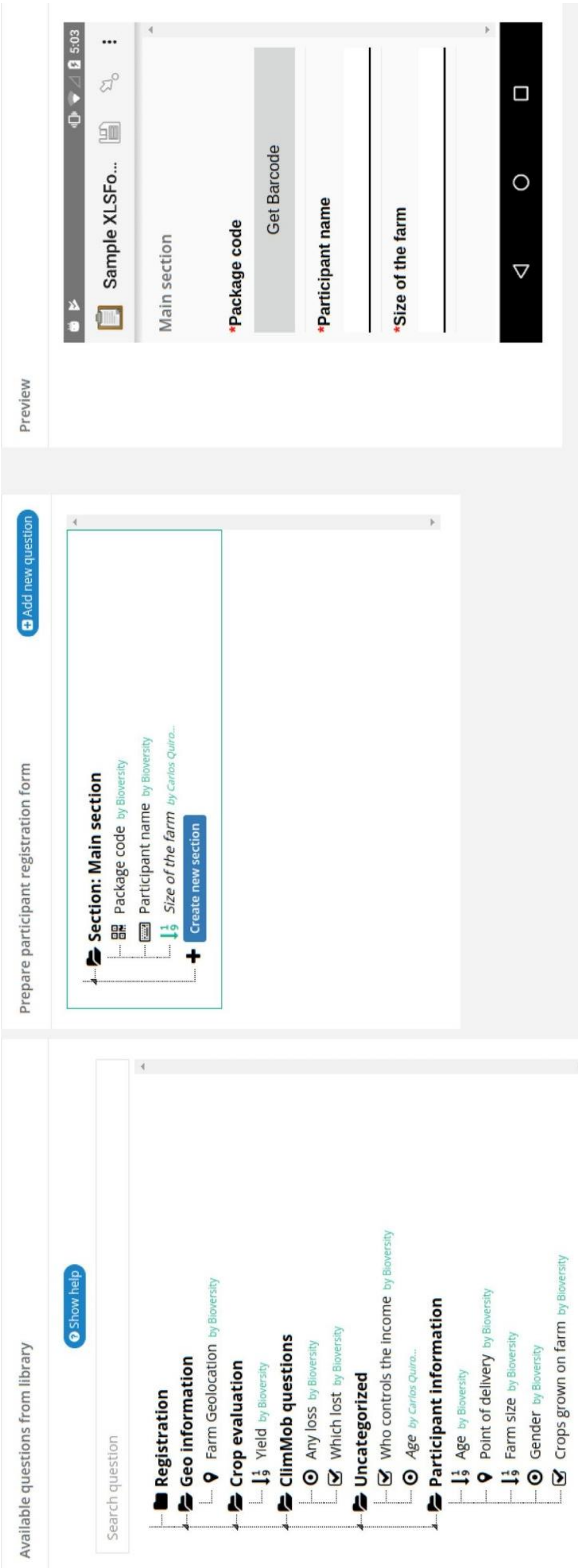


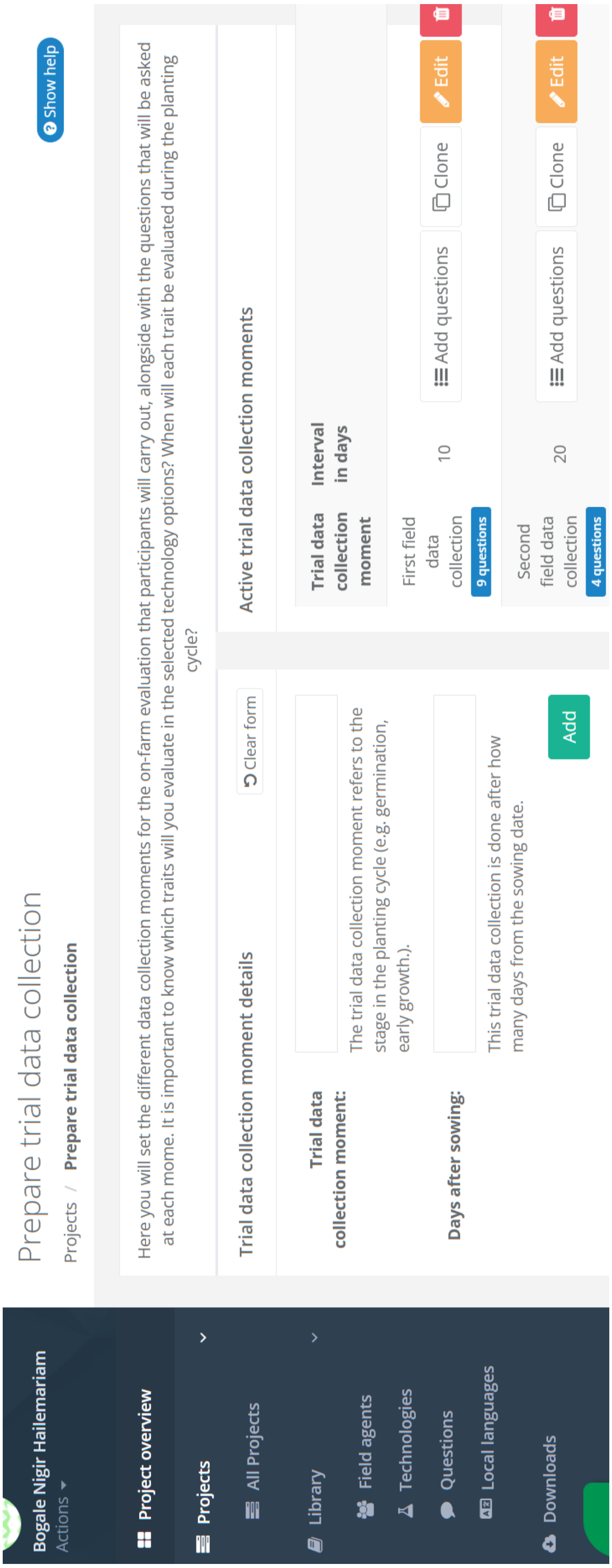
Figure 15. Steps to prepare participant registration form and overview

Step 7: Prepare participant registration form

To create and manage the questions and information required for registering participants.

Instructions:

1. Click on prepare participant registration form.
2. Drag questions from the library into the registration form.
3. If you need additional questions, create new ones as necessary.



Step 8: Prepare data collection form

To define the specific moments and questions for data collection after the trial begins.

Instructions:

1. Click on prepare data collection from the main menu.
2. Add various data collection moments and associate them with questions from the library.
3. Drag the questions that available in the library, you would like to have from the section in the left (available questions from library) and drop them in the section in the middle (assessment form): you can have a preview of the questions you have selected on your right (preview), scroll down to see all of them
4. If the question you would like to ask is not in the database (library): click on add new question and create a new question under the section you think is relevant.

Figure 16. Steps to add data collection moment and new question to be assessed

Step 9: Technology randomization

Once you have added all your data collection moments with their correspondent questions it is time to create the test packages through technology randomization.

How-to: The randomization is done automatically by the **ClimMob software**

- ✓ On the main menu, on the right side of the screen, click on **Generate packages with technology options and open the registration form of participants.**
- ✓ Review packages and CONFIRM. If the list of packages is not confirmed, you will lose it and you will need to do the randomization again.
- ✓ The randomization documents are now available in the downloads section.

◦ ***List of packages with QR for the registration form:*** This is the document you will need to prepare test packages

◦***List with randomized trial packages:*** Excel document that shows you which combination of technology options is found on each package. This document can be very helpful while preparing the test packages. DO NOT EDIT!

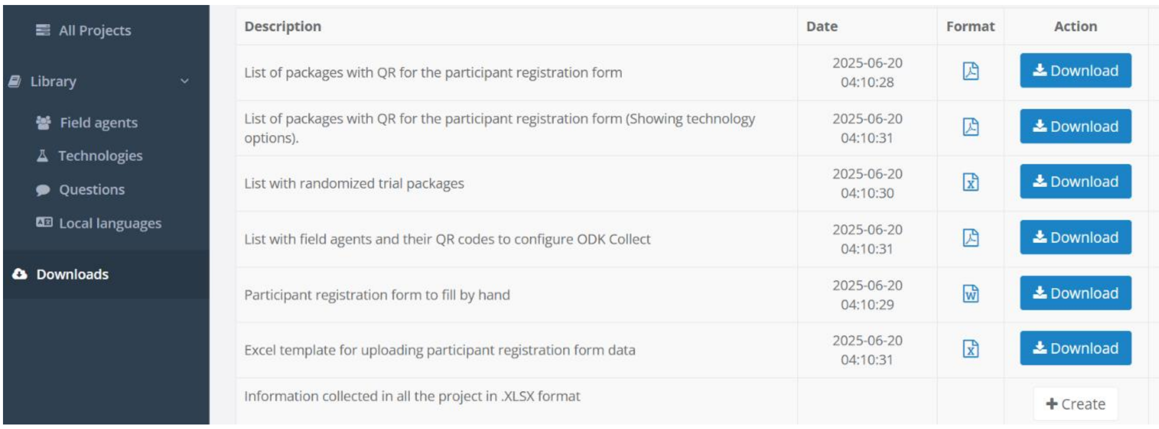


Figure 17. Generated randomization and packages to prepare physical test packages

Step 10: Prepare test packages

To create physical packages that will be distributed to participants for testing.

Instructions:

1. Compile the technology options you have selected for testing.

2. Gather necessary documentation from the download section and label each package accordingly.

Download the following:

- ➢ List of packages with QR for the participant registration form
- ➢ List with randomized trial packages

Package code	Option A	Option B	Option C
	Barley	Barley	Barley
Package #1	Barley11	Barley22	Barley44
Package #2	Barley22	Barley44	Barley33
Package #3	Barley33	Barley11	Barley22
Package #4	Barley44	Barley33	Barley11
Package #5	Barley22	Barley33	Barley44
Package #6	Barley11	Barley22	Barley33
Package #7	Barley33	Barley44	Barley11
Package #8	Barley44	Barley11	Barley22
Package #9	Barley11	Barley22	Barley44
Package #10	Barley33	Barley44	Barley11
Package #11	Barley22	Barley11	Barley33
Package #12	Barley44	Barley33	Barley22
Package #13	Barley11	Barley22	Barley33
Package #14	Barley22	Barley11	Barley44
Package #15	Barley33	Barley44	Barley11

Figure 18. Generated package code with their randomized technologies and corresponding bar codes

- ➢ Once you have randomized your technologies it is time to create the physical packages that farmers will use for the blind testing.
- ➢ Create packages containing the three technology options and their correspondent package number including their unique QR code.
- ➢ Stick to each package its correspondent label, which you are going to cut from the document list of packages with QR code for the participant registration form.

Step 11: Connect CLIMMOB with ODK Collect

To collect data in your project in an efficient and easy way you can link your project to ODK Collect.

- ✓ ODK Collect is used in digital data collection using a mobile phone or a tablet.
  - ✓ It is designed to work offline and can be connected to a cellular network / Wi-Fi for data submission after the data collection exercise.

Why use ODK Collect app?

✓ It is open source, therefore its free

✓ It can work offline

✓ Improved data quality since data is collected digitally

To install ODK Collect on your Android phone, please go to the Google Play store.

Remark:

- Each field agent downloads ODK Collect on their phone or table.
- Please note that ODK Collect is only available for Android devices.

Instructions to link your project with ODK Collect for data collection by field agents

1. Field agents should download the ODK Collect app from the Google Play Store.
2. Use the provided QR codes to set up ODK Collect on each field agent's device, integrating it with your project.

Steps:

- **Link ClimMob with ODK** collect in the phones of each of your field agents:
- Once **field agents** have been registered you will get a form with **QR code for each of them**.
- Each field agent opens ODK Collect, click the three dots (right up corner) and clicks in configure via QR code scanning their correspondent QR code or manually.

  *Note that you might need to give to the app access to your phone camera.

- Open the forms: click in get blank form and ODK Collect will open the form.

List of field agents for the project:ENS2025

To manually configure the ODK Collect server, use the URL of the user to which it belongs and use the corresponding field agent user and password.

User-owned field agents: **bogale1984**

Name	Username	Password	QR
Bogale N	boni2025	boni2025	

Figure 19. Enumerator user access for ODK connection to access project questionnaires

Manually using the following link:

- UR: https://1000farms.climmob.net/project owner
- Username:
- password:

Overview of ODK steps

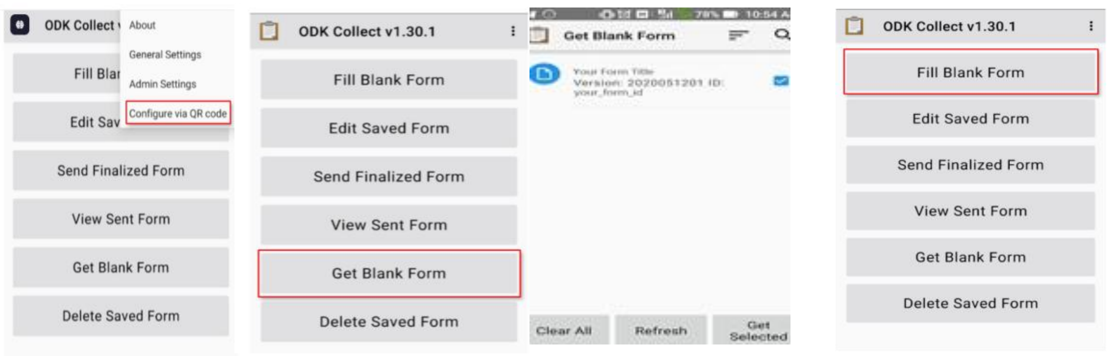


Figure 21. Overview of steps to access questionnaires in ODK

Step 12: Register participants and distribute packages

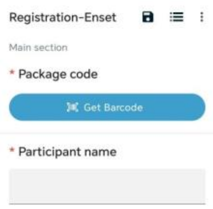
Objective:

To officially register participants for the project and distribute technology packages.

Instructions:

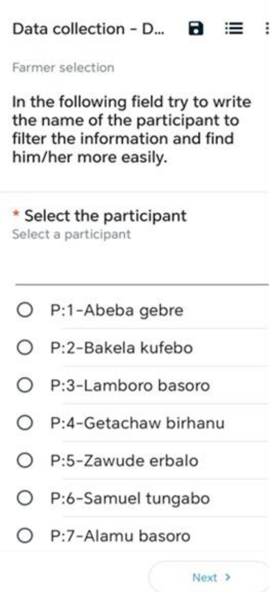
1. Use the ODK Collect app to register participants by filling in their details.
2. During registration, scan the QR code associated with each package.

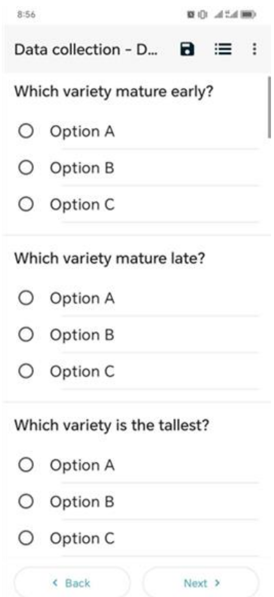
1. Once you are with the participant open ODK Collect and get the blank registration form.
2. Fill the form with the data from participants. The first step is to **scan the QR code** attached to the package with the three technology options that the participant is getting, to link that package to their individual profile.



3. Once the forms have been filled send them to the server.

Step 13: Start an assessment and collect data





- ➢ To launch the trials on-farm and begin collecting the necessary data.
- ➢ Once you have registered all the participants, on the main menu, bottom left side, select from the drop-down menu the data collection moment you would like to assess and click on start assessment
- ➢ For each data collection moment, a specific form with specific questions will be generated.

Step 14: Trial data follow up

- ✓ To understand the process for effectively collecting trial data during the project.

Instructions:

1. Field agents submit data using the ODK Collect app, ensuring that all relevant information is captured.
2. Admins should regularly review and confirm the collected data on the CLIMMOB platform to ensure accuracy.

Step 15: Data Analysis

To analyse the data gathered through the trials using CLIMMOB's analytical tools.

Instructions:

1. From the main menu, select the variables you want to analyse from your collected data.
2. Once the analysis is complete, download the final report to review the outcomes of your project.
   - ✓ Run complete Plackett-Luce models
   - ✓ Visualization: Generate maps and charts
   - ✓ Data Export: Download clean datasets for further analysis

Interpreting outputs: Show key outputs and their interpretation

5.9 Troubleshooting and best practices for digital implementation

Table 3. Common challenges and solutions:

Challenge	Solution	Prevention
Incomplete data	Automated reminders, enumerator incentives	Clear protocols, farmer compensation
Poor data quality	Validation rules, back-checks	Better training, simplified forms
Technical issues	Help desk, offline capabilities	Equipment testing, backup plans
Farmer dropout	Regular engagement, community support	Clear expectations, manageable plot size

Best practices for digital success:

1. Start simple: Begin with basic traits before adding complexity
2. Pilot test: Run small-scale tests to refine protocols
3. Build capacity: Invest in enumerator and farmer training

4. Ensure connectivity: Have backup plans for areas with poor internet
5. Maintain engagement: Regular feedback to participants on results

This elaborated manual provides both the theoretical foundation and practical implementation guidance needed to design, execute, and scale participatory crop improvement programs that are scientifically rigorous, farmer-centric, and impactful at scale.

5.9. Data analysis and feedback workshop

This section is adopted from Mengistu et al. 2023 Manual.

The approval or disproval of any hypothesis and generation of linked information greatly depends on the accurate analysis of collected data. Data analysis using scientifically proven statistical software is a prerequisite for the validation and acceptance of presented results, inferred conclusions and drawn recommendations. Data collected from farmers from crowdsourcing trials can be analyzed by CLIMMOB software which ranks varieties grown by each farmer for the various traits and produces and overall ranking of varieties tested in the target area for the varieties' traits. This ranking data is used to make decision on which varieties to promote and which to drop.

To analyze collected data using ClimMob, the project should be designed using the same software. Project creation and other procedures of ClimMob is not the concern of this Manual. Refer to ClimMob training Manuals[1] for further information.

The analysis of results is done for individual farmers and the performance ranking of the tested varieties is presented at the end of each farmer's report. Consider the following example for clarification:

- Farmer: Tsigab Yebyo
- Village: Hadnet
- District: Degua Tembien

[1] http://genecampaign.org/wp-content/uploads/2015/03/Annexure-7.-ClimMobUserManual.pdf

This farmer grew three barley (*Hordeum vulgare*) varieties under his own management conditions and evaluated the varieties for their performance. The enumerators have collected his evaluation data which was analyzed to discriminate the varieties. The CLIMMOB software was used to analyze the performance of the varieties for the considered traits and make the ranking.

Table 4 details the barley varieties given to this farmer with the respective code of A, B or C.

Table 4. Code and name of three varieties given to a farmer for crowdsourcing trial

Variety code	Name
Variety A	Adona
Variety B	Felamit
Variety C	HB

The farmer has evaluated these varieties as best, better (second position) and worst for the various traits (Table 5):

Table 5. Performance of three varieties grown by a farmer for agronomic traits

Characteristic	Best	Second	Worst
Plant architecture(height)	Felamit	HB	Adona
Yield	HB	Felamit	Adona
Straw_Yield	Felamit	HB	Adona
Seed Size	Felamit	HB	Adona
Overall performance	Felamit	HB	Adona

According to this farmer, variety Felamit is the most preferred for four of the five traits and second for grain yield after HB. On the other hand, variety Adona was perceived as the worst performer for all the traits. Because the performance of varieties is affected by farmers management conditions as well as micro-climate conditions, the ranking a variety by various farmers in the same locality may vary.

Based on the ranking of 125 crowdsourcing farmers in the same district variety Felamit ranked as the second best, next to HB, and Adona was ranked as the least-preferred. This implies that farmers evaluate varieties very closely even if they do the evaluation and ranking independently. For grain yield, the ranking position of the eight barley varieties based on the evaluation of 125 farmers in Degua Tembien district is articulated in Table 6.

Table 6. Overall ranking of varieties tested through crowdsourcing at a given place

Positions (Rank)	Varieties
Position 1	HB
Position 2	Felamit
Position 3	Fetina
Position 4	Welelay
Position 5	Hirity
Position 6	Elala 2
Position 7	Elala 1
Position 8	Adona

The farmers confirm that HB, Felamit and Fetina are the top three performing varieties while Elala 1 and Adona are the poorest performing varieties.

After data analysis is completed, a final workshop is held to inform participant farmers about the overall performance of varieties and discuss any possible future dissemination of identified varieties.

During the feedback workshop, the research group:

1. Presents the final results of the varieties‘ performance
2. Distributes personal information sheets and encourages discussion among farmers
3. Discusses practical lessons derived from the study (incentive for attendaning in the project)

At the same time participants evaluate the project success based on the following 5 recommended indicators.

1. ***Rate of completed trials***: - from the total participants, how many of them completed the trial successfully. For instance, in our previous durum wheat crowdsourcing trials, the completion or success rate was about 83%.
2. ***Gender ratio of participants***: - ensuring gender disaggregated participation is a key concern of participatory crop improvement approaches. In crowdsourcing participation of female-headed households is not an option. In our various crowdsourcing trials, 30 – 50 % female headed households’ participation was ensured.
3. ***Rate participants’ willingness to continue growing the varieties***: - if farmers grow the distributed varieties only during the project period, the impact will not be sustainable. It is

therefore important to secure sustained commitment among the participants to continue growing the preferred varieties and to disseminate them amongst other farmers.

4. ***Changes in seed choice***: - observe the perceptions of participant farmers considering whether the selected varieties are their seed choice or not. Experience shows that farmers tend to grow varieties they choose themselves over varieties introduced through any formal extension system. This was proved in Ethiopia.
5. **Willingness for scaling-up the top selected varieties through farmer-to-farmer seed exchange and use**: - try to observe farmers' willingness to scale-up the production of top selected varieties by disseminating to other farmers and continuing to use them themselves. We have observed that the rate of sharing seed with other farmers during the first few years is slow, as the primary participant farmers want to maintain selected varieties for their own use.

Some Suggested Readings

Alliance Bioversity-CIAT and MrBot Software Solutions. https://climmob.net/blog

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Annex 1. Data collection sheet for evolutionary plant breeding and participatory varietal selection (PVS) trials

No.	Planting date	Heading date	Maturity date	Plant height (cm)						No. of tillers per plant						No. of spikelets per spike						spike length						No. of Seed per spike						Biomass	Grain yield
				1	2	3	4	5	Av	1	2	3	4	5	Av	1	2	3	4	5	Av	1	2	3	4	5	Av	1	2	3	4	5	Av		
1																																			
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Anex 2. Participatory varietal ranking sheet: Farmer assessments of traits by plot (Male and Female groups) (Five farmers in each group)

Plot No.	Tillering capacity (Rank, 1- 5)					Disease resistance (Rank, 1-5)					Yield potential (Rank, 1-5)					Value in the market					Overall performance				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1																									
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List respondent farmer's name

1.___________________________________

4.___________________________________

2___________________________________

5.___________________________________

3.___________________________________

Anex 3. Sample farmer preference assessment questionnaires on crop varieties (CliMMob/ODK)

Which variety mature early?
Which variety mature late?
Which variety is the tallest?
Which variety is the shortest?
Which variety is more resistant to logging?
Which variety is more susceptible to logging?
Which variety gave you more number of tillers?
Which variety gave you less number of tillers?
Which variety has a very good spike quality?
Which variety has a poor spike quality?
Which variety has better biomass yield?
Which variety has less biomass yield?
Which variety gave you more yield?
Which variety gave you less yield?
Which variety is best for its price in the market??
Which variety is worst for its price in the market??
Overall which option was the best?
Overall which option was the worst?
Overall is A better or worse than what you usually use?
Overall is B better or worse than what you usually use?
Overall is C better or worse than what you usually use?