PROJECT REPORT ON:

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Building Capacity in Plant Breeding and Biotechnology Education and Research through Partnership Program (BREEDTECH)

Submitted by BREEDTECH Project team
This document has been developed by
[1]Matteo Dell'Acqua, [2]Ramesh Vetukuri, [1]Mercy Wairimu Macharia, [1]Afewerki Yohannes Kiros

[1]Scuola Superiore Sant'Anna, Pisa, Italy, [2]Swedish University of Agricultural Sciences

1.0 Executive Summary

The Building Capacity in Plant Breeding and Biotechnology Education and Research through Partnership Program (BREEDTECH) is committed to advancing research and innovation that address the challenges of sustainable agriculture and climate resilience across Africa and the Middle East. This report details the training initiatives undertaken for staff from Higher Education Institutes (HEIs), specifically outlining sessions held at the Swedish Agricultural University (SLU) in Sweden and Scuola Superiore Sant'Anna (SSSA) in Pisa, Italy. These workshops were structured to equip academic and research personnel with critical competencies in state-of-the-art breeding technologies and interdisciplinary research methodologies. The initial workshop took place at SLU from June 23rd to 27th, 2025, followed by a second session at SSSA from September 22nd to 26th, 2025. These events aimed to equip participants with skills for integrating biotech and genetic tools into sustainable crop improvement efforts. Beyond lectures and hands-on activities, the workshops included case studies, field excursions, and management meetings designed to promote collaboration and facilitate enduring partnerships among the institutions involved. Collectively, these workshops enhanced participants' technical knowledge, systems thinking, and ability to collaborate in developing innovative training programs. The trainings were informed by the needs assessment outlined in D2.1.

This document reports in detail the SLU and SSSA training outcomes, and concludes with a reflection on lessons learned, proposing actions to improve the impact of future training interventions.

2.0 SLU training

The training course “Advanced Molecular Breeding and Plant Protection Technologies”, held at SLU from 23–27 June 2025, brought together 12 in-person participants from Kenya and Ethiopia, alongside additional attendees joining via Zoom from various institutions, including SLU students and staff. The program aimed to strengthen capacity in advanced molecular breeding and plant protection technologies, with a focus on Spray-Induced Gene Silencing (SIGS), CRISPR-based genome editing, phenomics, genomic selection, nanocarrier technologies, and plant resilience assessment. Owing to border closures and ongoing unrest in Palestine, participants from the country were not able to attend in person. The geopolitical global situation also hampered travels from other partners, which required connection flights in the middle east.

Over five days, the course combined theoretical lectures, hands-on laboratory sessions, and a field visit to Borgeby Fältdagar, providing participants with exposure to state-of-the-art agricultural innovations, demonstration trial fields, and ongoing research at universities, breeding companies, and technology providers. Practical sessions included SIGS experimental setups in potato, nanoparticle encapsulation techniques, CRISPR protoplast transformation, mutant screening, and physiological measurements for stress resilience. Evaluation results indicated a high level of satisfaction with the course content, delivery, and relevance, with participants highlighting the value of the practical sessions, networking opportunities, and exposure to cutting-edge research. The course successfully facilitated knowledge exchange between HEIs in Africa and Europe, fostering opportunities for future collaborations in sustainable agriculture and crop improvement (Fig. 1)

Fig. 1. Course participants on SLU grounds

The course covered a comprehensive range of topics relevant to modern plant breeding, with a particular emphasis on cutting-edge molecular biology methods and their integration into breeding programs. This included:

- Spray-Induced Gene Silencing (SIGS): principles, mechanisms, risk assessment, formulation strategies, and practical application for disease control.
- CRISPR-based genome editing: theoretical foundations, sgRNA design, gene targeting strategies, protoplast isolation and transformation, mutant screening, and validation.
- Phenomics: advanced plant phenotyping tools for stress tolerance and disease resistance screening.
- Genomic selection: models, statistical methods, and data integration for predictive breeding.
- Nanocarrier technologies: encapsulation and delivery systems for RNA molecules and other bioactive compounds.
- Plant resilience assessment: measurement of physiological responses under biotic and abiotic stresses.

2.1 Structure of the course

Monday began with a welcome session, coffee, and essential administrative tasks, including access card and Wi-Fi ID setup. The training then moved into a session on Phenomics, delivered by Dr. Aakash Chawade, covering advanced plant phenotyping technologies and their application in breeding for disease resistance and stress tolerance. Following lunch, Dr. Katie Stevens introduced Spray-Induced Gene Silencing (SIGS), providing a broad overview of the technology, mechanisms of RNAi, and risk assessment considerations. She also highlighted its role in sustainable crop protection and demonstrated practical examples, including potato late blight control. The afternoon concluded with Dr. Alexandre Aono's lecture on Genomic Selection, presenting key models, statistical methods, and perspectives on its integration into modern breeding programs.

Tuesday began with a SIGS mechanisms recap and open discussion led by Dr. Katie Stevens, reinforcing core concepts from the previous day and addressing participant questions. This was followed by Dr. Bekele Gelena Kelbessa's SIGS Theory & Lab session, where participants learned about dsRNA synthesis, nanoparticle encapsulation strategies, and delivery methods for plant-pathogen systems and lab sessions. After lunch, Dr. Alexandre Aono continued his training on genomic selection, focusing on model refinement and data integration. The day ended with an extended SIGS laboratory session, where participants gained hands-on experience with RNAi experiments in potato, including preparation, application, spraying, and observation of effects.

On Wednesday, participants attended Borgeby Fältdagar, a major agricultural innovation field event. They explored demonstration trial fields from breeding companies, technology providers, and universities, observing the latest developments in crop improvement, agricultural machinery, and digital farming tools. This visit provided real-world exposure to applied innovations and networking opportunities with industry stakeholders.

On Thursday,the day began with Dr. Naga Charan's session on Nanocarriers: From Theory to Practice, exploring the design, characterization, and application of nanocarriers for agricultural purposes, particularly for improving SIGS efficiency.

This was followed by Dr. Awais Zahid's lecture on Quantifying Plant Resilience under both biotic and abiotic stresses, including physiological measurement techniques and lab session. After lunch, Dr. Selvaraju Kanagarajan led a two-part CRISPR training, beginning with CRISPR Theory, including sgRNA design and gene-editing strategies. This was followed by a hands-on lab, where participants performed protoplast isolation and transfection, mutant screening, and molecular validation techniques, based on the provided CRISPR lab protocols.

Friday continued with Dr. Kanagarajan's Advanced CRISPR Theory & Lab. Participants deepened their knowledge of multiplex gene editing, off-target analysis, and advanced screening workflows. Practical sessions allowed them to apply techniques learned earlier in the week, consolidating skills in plant molecular biology and genome editing. The course concluded with a closing session, followed by a networking dinner, allowing participants and trainers to exchange experiences and discuss future collaborations.

The evaluation of the training activity was conducted through a post-course questionnaire, completed by 12 participants. Respondents were asked to score various aspects of the course on a scale from 0 (very poor) to 10 (excellent). The questions covered organisational aspects, course content, training delivery, and perceived relevance to their work. The results are summarised in Fig. 2.

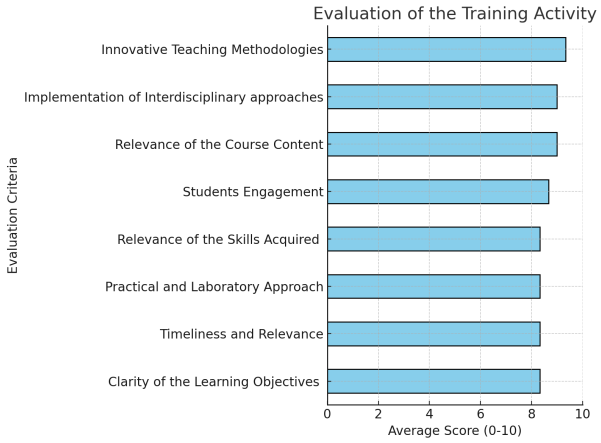

Fig. 2. Evaluation of the Training Activity. Average scores given by participants (0 = very poor; 10 = excellent) for different aspects of the course.

The analysis of the survey results reveals a highly positive evaluation of the training course. Most indicators scored between 8.5 and 10, demonstrating that the programme met or exceeded participant expectations. The training successfully met its objectives, providing participants with both theoretical knowledge and practical skills in advanced plant science and biotechnology. The mix of lectures, laboratory sessions, and field visits ensured a well-rounded learning experience. Feedback from participants was overwhelmingly positive, highlighting the value of interactive teaching, practical application, and networking opportunities.

2.2 SSSA training

The SSSA training titled “Data-Driven Innovation in Breeding Programs for Local Adaptation” was designed to engage academicians and researchers from HEIs in Kenya, Ethiopia, and Palestine. Participants were selected based on their academic and research backgrounds which aligns with the overall objectives of the training. A total of 15 staff members attended the workshop, representing a broad spectrum of expertise encompassing plant breeding, crop science, crop protection, and biotechnological applications in agriculture (Fig. 3). Initially, 19 participants were expected to take part, however participation was affected by unforeseen circumstances. Owing to border closures and ongoing unrest in Palestine, four participants from An-Najah University were unable to travel to Italy. In addition, we had planned to include Ethiopian students who had been unable to participate in the earlier student-focused BREEDTECH workshop due to visa denials. Unfortunately, their second visa applications were also rejected, preventing their participation in the current workshop session.

Fig. 3. Course participants on SSSA grounds

The training program was organized over five consecutive days, following a logical and progressive framework that moved from fundamental concepts to advanced applications. The structure was designed to build sequentially, beginning with core topics in genetics, agrobiodiversity, and climate science, and advancing toward hands-on data analysis and applied genomics. Most days integrated theoretical lectures, and interactive discussions with a thematic focus to reinforce learning objectives.

2.3 Structure of the course

Monday opened with participant registration, followed by formal welcoming remarks and introductory presentations. Representatives from the ISP introduced the organizing institutions, the training team, and presented the main objectives and expected outcomes of the workshop. Subsequent sessions featured a series of lectures dedicated to the advanced principles of genetics, organized into three thematic modules designed to progressively strengthen participants' conceptual understanding: (i) the uniqueness of the genetic approach, (ii) the link between genotype and phenotype and the molecular role of DNA, and (iii) the application of genetic markers and genetic mapping. These lectures were delivered throughout the day, with the final component partially postponed to the following morning to allow sufficient time for in-depth discussion and comprehension By the end of Day 1, participants had established a strong foundational understanding of key genetic concepts, which set the stage for the more specialized topics to be covered in the subsequent days.

On Tuesday the program seen continuation of lectures from the previous day, focusing on mapping populations and their application in identifying genetic factors associated with plant stress responses. A practical demonstration showcased the use of a maize multi-parental mapping population to investigate genetic determinants influencing cuticle-mediated permeability and stomatal density, serving as proxy traits for drought tolerance. Following this, participants were introduced to the principles of agricultural meteorology, emphasizing the influence of weather and climate on crop production and their integration into modelling frameworks to support data-driven agricultural decision-making. Key topics included climate–crop modelling, soil water balance assessment using the AquaBEHER tool, and methods for defining the wet season calendar. A hands-on case study demonstrated the use of AquaBEHER for seasonal forecasting and planting decision support, illustrating the practical value of these modelling tools in optimizing crop management. Subsequent sessions addressed genetic variation, agrobiodiversity, and agroecology, with discussions centred on leveraging biodiversity to enhance the economic, social, and environmental sustainability of agricultural systems. This module was complemented by two applied case studies: (i) a holistic breeding approach to address agroecological complexity through plant and environment interactions, and (ii) the use of chickpea cultivar mixtures to improve yield stability under variable environmental conditions. The day concluded with a seminar on the application of crop models for agrobiodiversity analysis, reinforcing the integration of modelling approaches into biodiversity research.

On Wednesday lectures provided an in-depth exploration of plant genomics, examining the organization and structural characteristics of nuclear and organelle genomes. Key genomic elements such as protein-coding genes, repetitive DNA sequences, and transposable elements were discussed in the context of their functional significance in plant genomes. In the second part of the morning, the focus shifted to transcriptomics, emphasizing the roles of coding and non-coding RNAs in gene regulation and cellular function. Following the theoretical lectures, a hands-on bioinformatics practical session was conducted to consolidate and apply the genomic and transcriptomic concepts introduced. Participants were trained in key computational workflows, including sequence data quality assessment, alignment of sequencing reads to reference genomes, and DNA variant calling. To complement these exercises, two applied case studies "*From Genomes to Pangenomes*" and "*Environmental DNA Typing*" were presented, illustrating how bioinformatics tools are utilized to address real-world research questions in genomics.

On Thursday participants were guided in the field of trait–genotype association analysis through a blend of theory and intensive practice. The morning began with an in-depth overview of the theoretical foundations and biological relevance of identifying genetic markers linked to phenotypic traits. Key methodologies were introduced, particularly Genome-Wide Association Studies (GWAS) and Quantitative Trait Loci (QTL) mapping, to explain how genetic variation can be statistically associated with observable traits. These conceptual foundations prepared participants for a practical, hands-on exercise using the TASSEL software platform to perform association mapping. In the hands-on module, trainers guided participants through a full GWAS workflow. This included installing and configuring the TASSEL software, performing quality control checks on genotype datasets, and conducting relatedness analyses such as computing kinship matrices, performing principal component analysis (PCA), and generating multidimensional scaling (MDS) plots to account for population structure. The session concluded in executing a GWAS within TASSEL, where participants ran analyses to identify DNA markers associated with specific traits from a sample dataset.

On Friday, lectures focused on exploring the future of genomics-based breeding, integrating the concepts and skills developed throughout the week into a forward-looking perspective on modern crop improvement. Building upon the analytical frameworks introduced in the previous sessions, the morning began with discussions on how GWAS, genomic prediction, and genome editing can be strategically applied to accelerate genetic gains and address emerging agricultural challenges. The session emphasized how these advanced genomic tools, when appropriately adapted, can enhance crop resilience, yield stability, and resource-use efficiency, particularly within smallholder and resource-limited farming systems.

Participants rated eight aspects of the course on a 1–10 Likert scale (Fig. 4). the Relevance of the Course Content received the highest mean score, approaching 9.5. This indicates participants perceived the content a highly pertinent to their professional needs. Training course structure, Consistency with existing needs, and Usability of the acquired skills each averaged above 9, reflecting strong satisfaction with the course's organisation and the immediate applicability of the knowledge gained. The Competences of the trainers, Effectiveness in improving participants' skills, and Trainers' ability to transfer knowledge dimensions all scored around 9, highlighting the perceived expertise and teaching quality of the instructors. The only dimension with a lower, though still positive, mean was Quality of practical sessions, which averaged slightly above 8; this suggests that hands-on elements were appreciated but may not have fully met participants' expectations.

Fig. 4. Average Staff Training Evaluation Scores. Each coloured marker represents the mean rating for one of the eight dimensions evaluated by participants. The concentric circles mark the scale from 2 to 10.

2.4 Concluding remarks

The BREEDTECH Staff Training Workshop was effective in achieving its objectives of capacity building and facilitating knowledge exchange in advanced plant breeding and biotechnology, as evidenced by participant evaluations (see Fig. 2 and Fig. 4). Notably, a significant number of attendees expressed keen interest in sustaining long-term engagement and pursuing research collaborations beyond the workshop itself. This outcome suggests the event played a pivotal role in fostering an international network of researchers dedicated to applying new knowledge to address real-world challenges within their respective countries. Despite these successes, the workshop faced several challenges. Attendance was impacted by travel restrictions, which prevented some invited delegates from participating in person, thereby limiting the diversity of perspectives represented. Additionally, budgetary constraints—exacerbated by ongoing currency devaluation in Ethiopia—posed significant difficulties. Fluctuating exchange rates and reduced purchasing power complicated the ability to cover essential costs such as travel, accommodation, and subsistence for Ethiopian participants, affecting overall attendance and inclusivity. Visa denials for several Ethiopian students presented another major obstacle. Although extensive preparations were made and supporting documentation provided, a number of qualified candidates were unable to obtain travel authorization. This not only reduced Ethiopian representation but also constrained capacity-building efforts in a key target country. Finally, there were instances where participant selection did not fully align with the specific content of the workshop. In certain cases, some attendees' professional backgrounds or areas of expertise did not match the specialized topics addressed, potentially affecting the immediate relevance and applicability of select sessions. Addressing these participant alignment and selection issues will be essential for maximizing the impact and relevance of future workshops.

2.5 Way forward

To address the challenges encountered with participation, particularly those arising from travel restrictions and visa issues, we have organized a new training workshop, not originally planned, to be held in Sweden in 2026. The training will be open to all HEIs and will be contributed by all EU partners of BREEDTECH. This upcoming event is designed to bring together both students and staff, and organize a blended training that is designed to provide a valuable opportunity for the two groups to interact, share perspectives, and collaborate directly. By fostering dialogue and cooperation between participants, the training aims to strengthen collective efforts toward achieving the broader objectives of the project and to promote sustained engagement across diverse backgrounds.