CGIAR project on

Roots, Tubers and Banana Breeding: A Consolidated Investment

Annual Technical Report 2024

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CGIAR Technical Reporting 2024

CGIAR Technical Reporting has been developed in alignment with CGIAR's Technical Reporting Arrangement. This annual report ("Type 1" Report) constitutes part of the broader CGIAR Technical Report. Each CGIAR Research Initiative/Impact Platform/Science Group Project (SGP) submits an annual "Type 1" Report, which provides assurance on progress towards end of Initiative/Impact Platform/SGP outcomes.

As 2024 marks the final year of this CGIAR Portfolio and the 2022-24 business cycle, this Type 1 Report takes a dual approach to its analysis and reporting. Alongside highlighting key achievements for 2024, the report also provides a cumulative overview of the 2022-24 business cycle, where relevant. This perspective captures the evolution of efforts over the three-year period. By presenting both annual and multi-year insights, the report underscores the cumulative impact of CGIAR's work and sets the stage for the transition to the 2025-30 Portfolio.

The 2024 CGIAR Technical Report comprises:

- **Type 1 Initiative, Impact Platform, and SGP Reports:** These annual reports present progress towards end of Initiative/Impact Platform/SGP outcomes and provide quality-assured results accessible via the CGIAR Results Dashboard.
- **Type 3 CGIAR Portfolio Practice Change Report:** This report provides insights into CGIAR's progress in Performance Management and Project Coordination.
- **Portfolio Narrative:** Drawing on the Type 1 and Type 3 reports, as well as data from the CGIAR Results Dashboard, the Portfolio Narrative synthesizes insights to provide an overall view of Portfolio coherence. It highlights synergies, partnerships, country and regional engagement, and collective progress.
- **Type 2 CGIAR Contributions to Impact in Agrifood Systems: evidence and learnings from 2022 to 2024:** This report offers a high-level summary of CGIAR's contributions to its impact targets and Science Group outcomes, aligned with the Sustainable Development Goals (SDGs), for the three-year business cycle.

The Portfolio Narrative informs the 2024 CGIAR Annual Report – a comprehensive summary of the organization's collective achievements, impacts, and strategic outlook.

Elements of the Type 2 report are integrated into the CGIAR Flagship Report, released in April 2025 at CGIAR Science Week. The Flagship Report synthesizes CGIAR research in an accessible format designed specifically to provide policy- and decision-makers at national, regional, and global levels with the evidence they require to formulate, develop, and negotiate evidence-based policies and investments.

The diagram below illustrates these relationships.

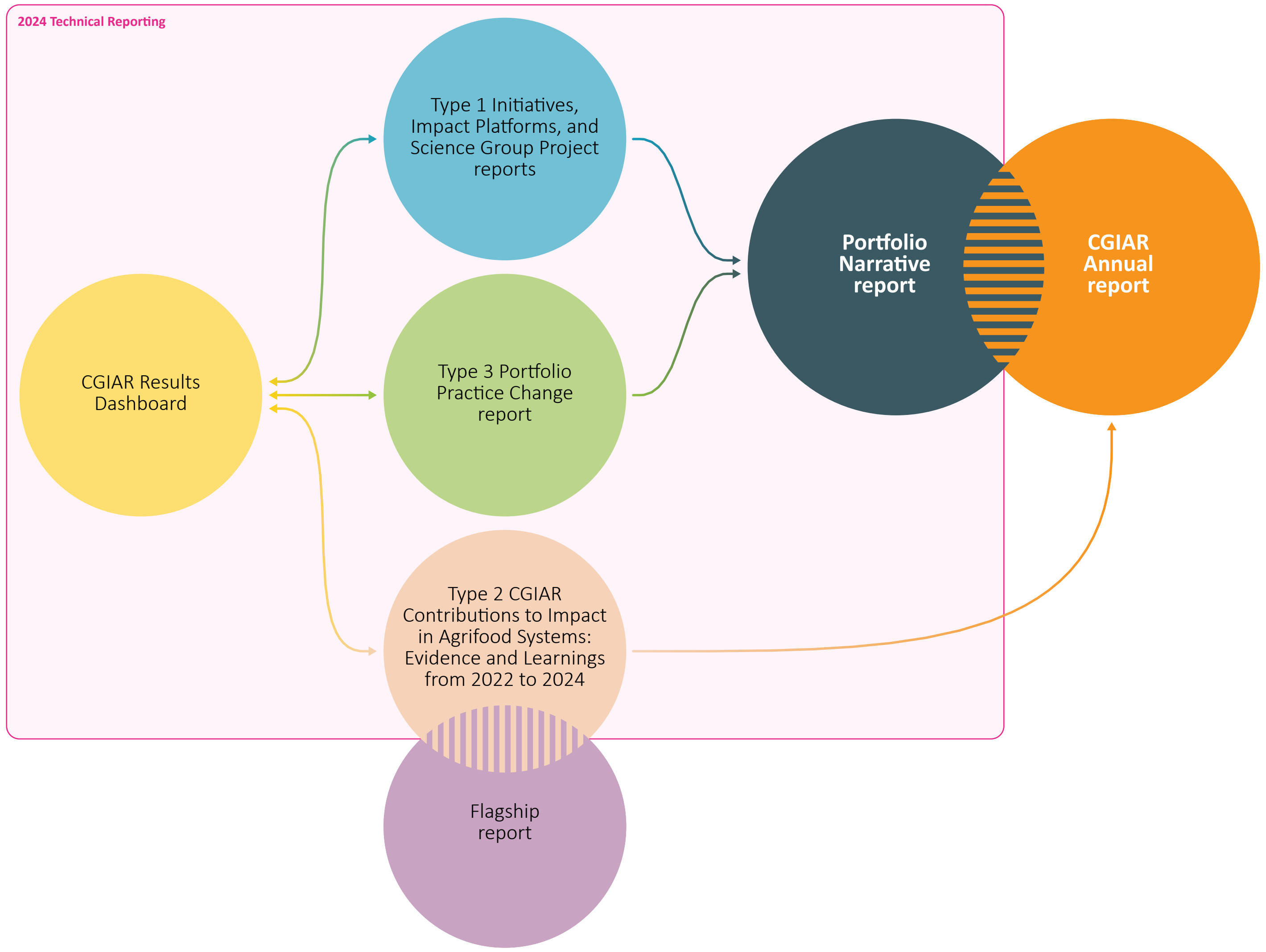


Figure 1. CGIAR's 2024 Technical Reporting components and their integration with other CGIAR reporting products.

Section 1: **Fact sheet, executive summary and budget**

Science Group Project name	Roots, Tubers and Banana Breeding: A Consolidated Investment
SGP name	RTB Breeding
Science Group Project Lead	Hugo Campos (h.campos@cgiar.org)
Science Group	Genetic Innovation
Start – end date	1 February 2023 – 31 May 2025
Geographic scope	**Regions** East and Southern Africa · West and Central Africa **Countries** Cameroon · Colombia · Côte d'Ivoire · Ethiopia · Ghana · Kenya · Malawi · Mozambique · Nigeria · Peru · Rwanda · Sierra Leone · Tanzania · United Republic · The Democratic Republic of the Congo · Uganda · Zambia
Links to webpage	https://rtbbreeding.cgiar.org/

EXECUTIVE SUMMARY

CGIAR's Science Group Project (SGP) on Roots, Tubers and Banana (RTB) Breeding made significant strides in transforming breeding systems for RTB (root, tuber, and banana) crops, namely banana, cassava, potato, sweetpotato, and yam, with a particular focus on sub-Saharan Africa. Central to these advancements has been increasing interactions among these breeding programs so that they share learnings, good practices, and pitfalls rather than focusing solely on the crop they are mandated to research. Breeding endeavors were also made more inclusive, efficient, and market-driven, and better aligned with the needs of farmers, especially women, and responding to both current challenges and future opportunities.

A core achievement was a shift toward farmer- and market-oriented breeding, with an emphasis on gender-responsive target product profiles (TPPs) and market segments (MSs). These profiles prioritize important quality traits such as taste, nutritional value, shelf life, and appearance traits that are particularly valued by women and marginalized groups. This focus on end-user preferences helped develop several varieties with high acceptance with different end-user groups. Experimental auctions and consumer preference assessments across several countries, especially in Nigeria and Uganda, strengthened the demand-driven breeding approach, further enhancing inclusivity and market responsiveness.

On the operational front, RTB Breeding implemented a standardized product development framework to streamline breeding processes. The adoption of harmonized breeding stages and the clarification of team roles improved collaboration across regions. Additionally, human resource mapping and skills assessments guided targeted capacity-building efforts. These improvements enhanced collaboration between CGIAR Centers and National Agricultural Research and Extension Systems (NARES), laying the foundation for scalable breeding programs. RTB Breeding also prioritized the creation of inclusive breeding networks targeting West/Central Africa and Eastern/Southern Africa by empowering national research partners with customized capacity-building programs and strategic support, particularly in gender inclusion and decision-making. These efforts fostered stronger collaboration across national and regional boundaries, aligning breeding efforts with local agricultural priorities and improving the scalability of innovations across sub-Saharan Africa.

RTB Breeding made significant breakthroughs by integrating molecular tools and genomics, which significantly improved breeding precision and efficiency. Marker-assisted selection techniques have enabled faster breeding by selecting traits such as disease resistance and nutritional content. In banana, cassava, yam, and sweetpotato, genomic studies helped identify genomic regions linked with key traits, improving the targeting of breeding efforts. For example, large-scale genomic studies in cassava enhanced the ability to select desired traits, further advancing breeding outcomes. Innovations such as the Semi-Autotrophic Hydroponics (SAH) method accelerated early-generation seed production, improving variety testing and commercialization timelines.

RTB Breeding also embraced data-driven tools like BreedBase and Bioflow analytics, which enhanced digital data management and decision-making across breeding pipelines. The development of over 45 crop-specific Standard Operating Procedures (SOPs) improved data quality and standardization, optimizing breeding pipelines across CGIAR Centers and NARES. Breeding cost estimation workshops and efforts to track cost drivers enhanced financial planning, ensuring that resources are used efficiently for maximum impact. These advancements led to substantial progress in genetic gains. Key successes included integrating food quality preferences into breeding pipelines, developing predictive breeding technologies, and creating pangenomes for crops such as banana, yam, and sweetpotato. The pangenome approach represents a significant milestone, as it offers a more comprehensive understanding of genetic variation and ensures precision breeding through better exploitation of haplotypes.

The RTB Breeding Innovation & Integration Fund played a major role in accelerating knowledge exchange and fostering collaboration among research organizations. By supporting learning from both successes and challenges, the Fund ensured that the RTB Breeding community continued to innovate and to invest in the professional development of younger breeders and scientists, particularly women. In its latest round, three proposals were selected to strengthen cross-crop learning and to advance integrated breeding approaches.

The RTB Breeding Network, launched in October 2024, brings together 18 NARES, universities, and CGIAR Centers to accelerate genetic gains in RTB crops such as banana, cassava, sweetpotato, potato, and yam. By fostering regional collaboration through subregional hubs in West & Central Africa and Eastern & Southern Africa, the network aligns with CGIAR's Accelerated Breeding Initiative. The latter works to harmonize breeding standards, share data, and leverage collective expertise to develop climate-resilient, farmer-preferred varieties that improve food security and enhance the livelihoods of smallholder farmers.

These collective efforts positioned RTB Breeding at the forefront of crop improvement efforts, helping to make breeding systems more efficient, inclusive, and responsive to the needs of farmers.

	2023	**2024**
APPROVED BUDGET	$13.16M	**$16.51M**

High yielding cassava roots. Photo credit: Ismail Rabbi

Section 2: **Progress towards End of Project outcomes**

Science Group Project-level theory of change diagram

This is a simple, linear, and static representation of a complex, non-linear, and dynamic reality. Feedback loops and connections between this Project and other Initiatives' theories of change are excluded for clarity.

SPHERE OF **CONTROL**

Work Packages

Work Package 1
ReFOCUS Aligning breeding teams and breeding objectives with farmers' needs.

Work Package 2
ReORGANIZE breeding teams to drive efficiency gains.

Work Package 3
Smarter Use of More Data.

Work Package 4
DISCOVER: Trait Discovery and Deployment.

Work Package 5
Performance Management of Consistent, Connected Operations.

Work Package 6
TRANSFORM towards inclusive, impactful CGIAR-NARES-SME breeding networks.

Work Package 7
ACCELERATE population improvement and variety identification.

Work Package 8
Cost-effective Shared Services.

SPHERE OF **INFLUENCE**

End-of-Initiative Outcomes

End-of-Initiative Outcome 1
1 ▶ ABI-CGIAR-NARES-SME networks use market segments, product profiles and pipeline investment cases to orient variety development and deployment towards those that provide larger scale benefits across the 5 Impact Areas.

End-of-Initiative Outcome 2
2 ▶ ABI-CGIAR and NARES using a revised organizational framework for their breeding pipelines providing gender diverse, multidisciplinary teams with clear roles and decision power.

End-of-Initiative Outcome 3
6 ▶ ABI-CGIAR-Multidisciplinary and gender aware breeding networks implement stronger partnership models where NARES and Small and Medium-sized Enterprises (SMEs) have clear roles and decision rights, and an increased contribution to the breeding process.

End-of-Initiative Outcome 4
4 ▶ ABI-CGIAR and NARES supporting breeding pipelines with Trait Discovery and Deployment programs that deliver high impact traits within elite parental lines.

End-of-Initiative Outcome 5
7 ▶ ABI-CGIAR-National and private seed company breeding programs accelerate the development of varieties that provide larger scale benefits across the 5 Impact Areas.

End-of-Initiative Outcome 6
8 ▶ BRI-CGIAR and NARES breeding teams use shared services, facilities and operations that have been improved for greater throughput, accuracy and safety, at lower unit costs.

End-of-Initiative Outcome 7
5 ▶ BRI-CGIAR and NARES breeding teams have up-to date knowledge and capacities to design and operate shared services, facilities and operations.

End-of-Initiative Outcome 8
3 ▶ BRI-CGIAR and NARES breeding teams use state of the art data management systems.

Action Area Outcomes

Genetic Innovation

1 ▶ 3 ▶ 4 ▶ **1** • CGIAR partners develop and scale innovations that contribute to the empowerment of women and other social groups in food, land, and water systems.

2 ▶ 3 ▶ 5 ▶ 6 ▶ 7 ▶ 8 ▶ **2** • National and private seed company breeding programs accelerate the development of varieties that provide larger scale benefits across the 5 Impact Areas.

2 ▶ 3 ▶ **3** • National and local multi-stakeholder platforms are strengthened to become more effective and sustainable, addressing development trade-offs and generating strategies for effective food, land, and water systems transformation.

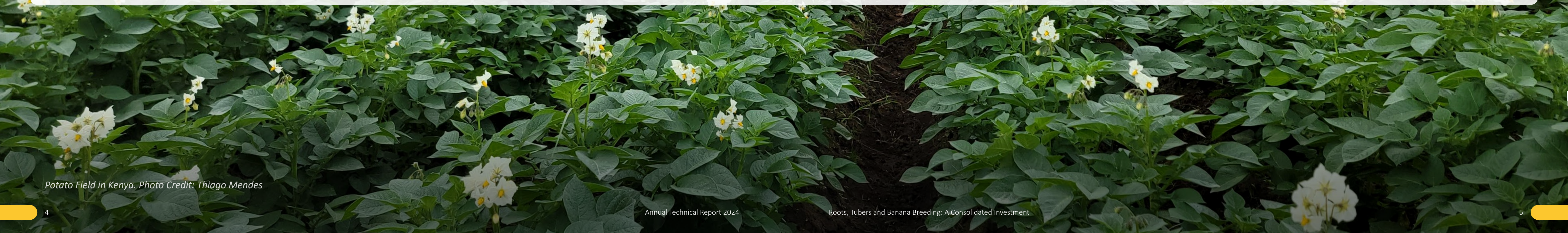
SPHERE OF **INTEREST**

Impact Areas

Nutrition, Health & Food Security
1 ▶ 2 ▶ • End hunger for all and enable affordable health diets for the 3 billion people who do not currently have access to safe and nutritious food.

Poverty Reduction, Livelihoods & Jobs
1 ▶ 2 ▶ • Lift at least 500 million people living in rural areas above the extreme poverty line of US $1.90 per day (2011 PPP).

Gender Equality, Youth & Social Inclusion
3 ▶ • Close the gender gap in rights to economic resources on, access to ownership of, and control over land and natural resources, for more than 500 million women who work in food, land, and water systems.



Potato Field in Kenya. Photo Credit: Thiago Mendes

Summary of progress against the theory of change

The main aim of CGIAR's RTB Breeding was to re-focus breeding programs on farmer and market needs, especially the needs of women, through well-defined product profiles, efficient breeding pipelines, and, particularly, by shifting mindsets away from a previous focus on the breeding of a single crop. It also developed effective and efficient CGIAR-NARES breeding networks across Africa and leveraged partners on other continents. RTB Breeding's research approach focused on defining breeding objectives attending to farmers' needs and using TPPs. It developed breeding strategies by reorganizing breeding teams and establishing inclusive and impactful breeding networks of CGIAR, NARES, and small and medium enterprises (SMEs). It also enhanced trait discovery and deployment in order to accelerate population improvement and variety identification. RTB also leveraged the strategies of CGIAR's Breeding Resources Initiative, such as smarter use of more data and cost-effective shared services to achieve desired outcomes. This was accomplished by relying on high-quality research from all the different RTB crops and food-quality components.

RTB Breeding's research activities were conducted in 25 countries and covered banana, cassava, potato, sweetpotato, yam, and food quality. Four activities were conducted in Southern Africa, five in East Africa, two in Central Africa, five in West Africa, three in South America, one in East Asia, and four in Europe and the USA. All of these countries contributed to the results this project reported in CGIAR's Performance and Results Management System (PRMS). These results are presented in Work Packages by crops and cross-cutting work, but their implementation cut across Work Packages in a matrix formation, as indicated in the Theory of Change (TOC) and results framework. This interconnectivity was central to achieving the project's goal. From 2023 to 2024, this SGP planned and executed research activities that led to achieving 169 results. Of these, 167 results were research outputs produced across the project's eight Work Packages and two results were project outcomes. Approximately 17 percent of the outputs produced were knowledge products, 19 percent involved innovation development, 24 percent focused on capacity sharing for development, and 40 percent represented other outputs. The project outcomes focused on innovation use and other outcomes. These research outputs and outcomes contributed to the eight measurable end-of-project outcomes, three action areas, and three impact areas by 2025.

During this two-year reporting period, the project collaborated with several CGIAR Initiatives — originally with Genetic Innovation and then with Breeding for Tomorrow, Accelerated Breeding, Market Intelligence, and Breeding Resources —with three CGIAR Centers contributing to producing the results. The project established 33 formal partnerships with national, international, and advanced research institutions and development agencies. It also established two strong regional breeding networks led by representatives chosen by national programs in West & Central and in East & Southern RTB Breeding Networks.

Some of the notable changes occurring in the breeding networks within the two-year period under review include defining and endorsing more than 40 TPPs and MSs and embedding traits relating to social inclusion, food quality, and environmental resilience. A common framework was established, integrating a RACI matrix (responsible, accountable, consulted, informed) and a RAPID model (recommend, agree, perform, input, decide), to streamline responsibilities and enhance inclusive decision-making. This enabled stakeholder selection for product advancement meetings (PAMs) and product design team (PDT) meetings, which improved coordination as supported by stakeholder engagement best practices. Marker-assisted selection is now routinely implemented in CGIAR-NARES breeding networks for traits such as virus resistance, high carotenoid content, dry matter, and low cyanogenic potential. NARES breeding networks assisted in the release of more than 13 varieties that have met farmers' needs and preferences, which accelerated the cultivation and adoption of those varieties.

CGIAR and NARES breeding teams improved their operations by adopting the innovative phenotyping tools and platforms needed for quick, accurate, and cost-effective evaluation of breeding materials. More than 45 SOPs, which standardized critical breeding processes across multiple institutions, were produced, significantly enhancing shared operational knowledge, staff capacity, and data quality. Breeding operational costing improved understanding of key cost drivers and enabled more efficient budget planning, which fostered transparency and accountability in breeding operations. By mid-2025, there were more than 2,400 registered users of the three BreedBases from more than 27 breeding programs informing breeding decisions and leading to improved outcomes of breeding programs. These notable outcomes aim to contribute to the three Action Areas and the three Impact Areas in the project's TOC.

This body of interconnected results represented significant progress toward end-of-project outcomes (EOPOs). It enabled higher genetic gains to be translated into superior varieties and greater adoption rates at the farm-gate.

Emmanuel Habimana, a farmer in Rwanda showcasing freshly harvested sweet potatoes. Photo Credit: Donata Kiiza

Progress against End of Project Outcomes

This infographic provides a concise summary of the project's progress toward achieving its Theory of Change End-of-Project outcomes for 2024 period. By drawing on reported results, it offers a comprehensive synthesis of progress made against the established outcome targets, highlighting the project's overall impact and key achievements at the conclusion of 2024.

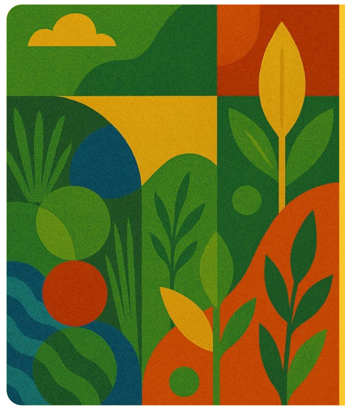
EOPO 1

ABI-CGIAR-NARES-SME networks use market segments, product profiles and pipeline investment cases to orient variety development and deployment towards those that provide larger scale benefits across the 5 Impact Areas.

Over the project's two years of operation, substantial progress was made toward the SGP's TOC and end-of-project outcomes (EOPOs), particularly in aligning breeding pipelines with market demands and user preferences for root, tuber, and banana crops. Research efforts across 13+ countries enabled the development and institutionalization of demand-led and inclusive breeding processes. Through regional training and multistakeholder product design team meetings, more than 40 TPPs and MSs were defined and endorsed, with traits embedded to social inclusion, food quality, and environmental resilience.

Notably, in 2024, TPPs for sweetpotato and cassava incorporated weevil resistance, micronutrient traits, and gender-differentiated preferences, while consumer auctions guided trait prioritization across key countries. These efforts addressed key research questions of this SGP around how breeding programs can become more gender-responsive, better aligned with market needs, and effective in enhancing varietal adoption.

By institutionalizing inclusive TPPs and leveraging breeding program assessments, the SGP created a replicable model for market-oriented varietal development. The shift from trait-based to product-based breeding, underpinned by user-preference data, represented a significant scientific and operational advancement, positioning national and CGIAR breeding programs to deliver greater impact for food security and livelihoods in the Global South.



EOPO 2

ABI-CGIAR and NARES using a revised organizational framework for their breeding pipelines providing gender diverse, multidisciplinary teams with clear roles and decision power.

During the project's 2023–2024 operations, it developed a revised organizational framework to optimize breeding pipelines, fostering gender-diverse, multidisciplinary teams with clear roles and decision-making. A common framework was established, integrating the RACI matrix and RAPID model to streamline responsibilities and enhance inclusive decision-making. This enabled stakeholder selection for product advancement and product design team meetings, improving coordination, as supported by stakeholder engagement best practices. Key performance indicators were developed to measure breeding program performance, with scalable dashboards in progress, aligning with data-driven monitoring and evaluation approaches. Skillset and gap analyses provided evidence for optimizing human resource allocation across crops and Centers, fostering collaboration within the breeding teams. Targeted trainings addressed identified knowledge gaps, enhancing team capacity, consistent with capacity-building strategies. These outcomes strengthened breeding pipelines through structured, inclusive, and evidence-based approaches, ensuring that the teams delivered impactful results. The framework and tools laid a foundation for sustained improvements in efficiency, inclusivity, and performance, contributing to CGIAR and NARES' goals of advancing agricultural innovation and food security.

EOPO 3

ABI-CGIAR-Multidisciplinary and gender aware breeding networks implement stronger partnership models where NARES and Small and Medium-sized Enterprises (SMEs) have clear roles and decision rights, and an increased contribution to the breeding process.

During the 2023–2024 period, substantial progress was made toward EOPO 3 by embedding inclusive and structured partnership models in the design and implementation of regional breeding networks across West, Central, East, and Southern Africa. Product design team and product advancement meetings brought together multidisciplinary teams including NARES, CGIAR scientists, private-sector actors, and user representatives to co-define market segments, co-develop TPPs, and jointly evaluate late-stage varieties.

These platforms clearly assigned roles and decision rights to national partners, elevating their leadership in trait prioritization, varietal evaluation, and strategic alignment. Notably, gender and social inclusion were systematically integrated, ensuring that TPPs captured the needs of women and marginalized groups. The product design teams served as decision-making bodies where NARES and national stakeholders exercised ownership over breeding investments, a marked shift from past CGIAR-led models.

Additionally, capacity strengthening through regional workshops enabled NARES to lead pipeline reviews and product design, solidifying their role in steering breeding agendas. Overall, the Work Package's efforts catalyzed a shift to locally owned, gender-responsive, and impact-oriented breeding partnerships well aligned with EOPO targets.

EOPO 4

ABI-CGIAR and NARES supporting breeding pipelines with TD&D programs that deliver high impact traits within elite parental lines.

Significant progress was made in 2023 and 2024 within CGIAR and NARES breeding networks and across RTB crops by integrating molecular tools and genomics into the RTB breeding pipelines, enhancing precision and efficiency. Marker-assisted selection is now routinely implemented in CGIAR-NARES breeding networks for traits such as virus resistance, high carotenoid content, dry matter, and low cyanogenic potential. Work done so far represents important steps toward increasing genetic gains by more efficient breeding cycles and improved varietal development aligned with product profiles.

Within the two years under review, over 3,000 early-generation genotypes were selected using marker-assisted selection in yam. A total of 14 key agronomic and yam tuber quality traits were targeted for marker-trait association, leading to the validation of single-nucleotide polymorphism (SNP) markers for nine traits and the integration of seven into the breeding program through KASP-PCR (Kompetitive Allele Specific-Polymerase Chain Reaction) assays. In addition, a refined SNP panel improved selection accuracy in breeding effort in the crop. A large-scale genome-wide association study involving over 5,100 genotypes and 100,000 SNP markers identified 41 genomic regions influencing 14 critical traits spanning biotic stress, quality, and plant architecture in cassava. In sweetpotato, a co-infection assay was developed using a double-grafting method to support breeding virus-resistant varieties. These tools and approaches will support the development of superior varieties for RTB crops.

Progress against End of Project Outcomes

This infographic provides a concise summary of the project's progress toward achieving its Theory of Change End-of-Project outcomes for 2024 period. By drawing on reported results, it offers a comprehensive synthesis of progress made against the established outcome targets, highlighting the project's overall impact and key achievements at the conclusion of 2024.

EOPO 5

ABI-CGIAR-National and private seed company breeding programs accelerate the development of varieties that provide larger scale benefits across the 5 Impact Areas.

Over the project's two years, the integration of genomics-supported recurrent selection schemes and optimized breeding pipelines proved effective in accelerating population improvement and variety identification. The participatory approaches and focus on gender-related traits ensured that the selected varieties meet farmers' needs and preferences, promoting successful adoption and cultivation.

As a result, the NARES breeding networks assisted in releasing varieties that met farmers' needs and preferences and accelerated the cultivation and adoption of those varieties. A new matooke hybrid banana variety, NARITA 17, was developed for Uganda. This variety features high yield and favorable sensory attributes. In addition, 12 new sweetpotato varieties were proposed for release in 2024 across Uganda, Mozambique, and Rwanda in collaboration with the project's NARES partners in those countries.

In 2024, private seed companies such as GoSeed and Umudike Seeds conducted Demand Creation Trials (DCTs) with cassava varieties that engaged farmers and processors. They collected data to align the breeding with user needs and selected the best varieties for the different market segments. In addition, over 1,000 farmers were involved in testing released yam varieties in 37 locations in Nigeria.

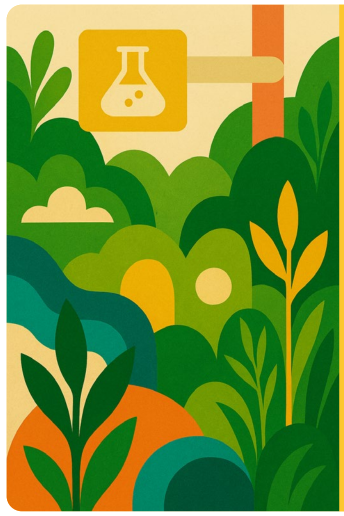
NARES breeding programs and seed companies adopted the use of the Semi-Autotrophic Hydroponics (SAH), a rapid and high-ratio clonal propagation method, to produce a significant number of plantlets, establishing hectares of early-generation seed. These methods enhanced the efficiency and scale of breeding programs and seed companies, ensuring the availability of quality planting materials for trials and commercialization. All these efforts supported the calculation of genetic gain.

EOPO 6

BRI-CGIAR and NARES breeding teams use shared services, facilities and operations that have been improved for greater throughput, accuracy and safety, at lower unit costs.

CGIAR and NARES breeding teams have improved their operations by developing innovative phenotyping tools and platforms that are needed for quick, accurate, and cost-effective evaluation of breeding materials. This enhances shared services and operations to all breeding programs of RTB crops achieving higher throughput, accuracy, and safety at reduced costs. Phenotyping has long been a bottleneck in breeding programs for root, tuber, and banana crops, The development and adoption of advanced phenotyping technologies, such as near-infrared spectroscopy and hyperspectral imaging, are critical for forecasting key quality attributes that drive consumer acceptance of RTB crop products. These technologies, supported by SOPs, enable consistent execution of operational activities and facilitate data sharing across breeding programs and RTB Centers. Training was conducted on these phenotyping technologies to strengthen the capacity of breeding network partners, ensuring uniformity and reliability in their application.

Significant genomic resources are now available for most RTB crops, with several accessions having their genomes sequenced and assembled. These resources enhance the use of genomic information for marker-assisted selection, genomic selection, and prediction of cross-performance, thereby accelerating molecular breeding efforts. The integration of these cutting-edge phenotyping tools, which provide rapid and high-throughput phenotyping, with the available genomic resources is poised to fast-track the development of improved RTB varieties that meet end-user expectations at reduced costs. Continuous refinement and improvement of these models and tools are essential to enhance their robustness and ensure long-term success in breeding programs.



EOPO 7

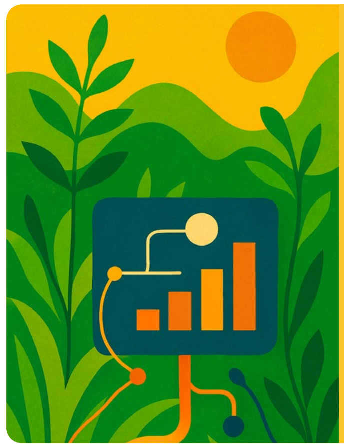
BRI-CGIAR and NARES breeding teams have up-to date knowledge and capacities to design and operate shared services, facilities and operations.

During the 2023–2024 period, the RTB Breeding community made targeted investments to strengthen the technical capacity and operational effectiveness of CGIAR and NARES breeding teams. Two key initiatives were development and deployment of SOPs and systematic estimation of breeding operational costs directly contributed to this EOPO.

Through close collaboration with NARES, a total of 46 SOPs were developed and validated (11 for yam, 14 for cassava, and 21 for banana/plantain). These SOPs standardized critical breeding processes across multiple institutions, significantly enhancing shared operational knowledge, staff capacity, and data quality. Their implementation laid the groundwork for cross-crop digital integration and harmonized trial management systems.

Additionally, operational costing workshops conducted in partnership with CGIAR's Accelerated Breeding Initiative team, including one at Nigeria's National Root Crops Research Institute, empowered CGIAR and NARES teams to systematically estimate and document breeding costs. This process improved understanding of key cost drivers, which enabled more efficient budget planning, and fostered transparency and accountability in the use of shared breeding infrastructure.

Together, these efforts built the technical foundation and collaborative momentum needed for CGIAR and NARES breeding programs to co-manage modern, data-driven operations and shared services aligned with CGIAR's mission of delivering high-impact, climate-resilient varieties.



EOPO 8

BRI-CGIAR and NARES breeding teams use state of the art data management systems.

CGIAR and NARES breeding teams leveraged BreedBase, a state-of-the-art data management system, to streamline their breeding efforts. BreedBase serves as a digital ecosystem, used throughout the entire breeding cycle, providing a comprehensive platform for the collection, analysis, and dissemination of information. Increased adoption in BreedBase is primarily attributed to two factors: extensive capacity building provided in over 15 training courses and the continuous updating of BreedBase features. Most features on BreedBase are crop agnostic, so improvements requested by one crop also benefit other RTB crops and CGIAR and NARES breeding networks.

One addition to the data management system is Bioflow, which currently offers an extensive set of modules, able to carry out the most crucial analytical procedures to take breeding decisions using state-of-the-art methodology. The drive for adoption is a combination of capacity building and the availability of an easy-to-use analytical pipeline. These advancements facilitate more informed breeding decisions, ultimately leading to improved outcomes in breeding programs.

Currently, CassavaBase boasts 2,100 registered users across 27 breeding programs. In contrast, YamBase has 340 registered users participating in 11 breeding programs, while MusaBase has 300 registered users, also across 11 breeding programs. This information highlights the differing levels of user participation within these breeding programs, indicating their respective scope and outreach.

Section 3: **Work Package progress**

WP1: ReFOCUS

Work Package 1

Outputs

1 · Portfolio of distinct, achievable target product profiles.

2 · Strategic approach for advancing traits on Product Profiles.

End-of-Initiative Outcome 1

1 ▶ 2 ▶ ABI-CGIAR-NARES-SME networks use market segments, product profiles and pipeline investment cases to orient variety development and deployment towards those that provide larger scale benefits across the 5 Impact Areas.

Work Package 1 progress against the theory of change

Over the past two years, significant advancements were made in developing and aligning TPPs and MSs for key RTB crops across sub-Saharan Africa. Regional training workshops on TPP development for yam were conducted, strengthening the capacity of NARES in Nigeria, Ghana, Côte d'Ivoire, Benin, Uganda, Ethiopia, and the Democratic Republic of the Congo. Special emphasis was placed on integrating social, gender, and quality traits into breeding priorities. Additionally, the West Africa Yam Product Advancement Meeting enhanced cross-country collaboration by aligning breeding pipelines to consumer preferences, focusing on traits like early maturity, shelf life, and disease resistance.

Extensive reviews and endorsements of MSs and TPPs were undertaken for potato in Rwanda, Kenya, and Ethiopia, with gender analyses informing breeding priorities. Product design team meetings across 10 countries led to the definition and formal signing of TPPs and MSs, and comprehensive breeding program assessments were completed to guide improvements. For sweetpotato, TPPs focusing on white, orange, and purple-fleshed types were finalized across six countries, enabling better resource targeting and regional clone sharing.

Efforts to strengthen demand-led breeding continued through experimental auctions that identified consumer preferences in Uganda, Nigeria, and Côte d'Ivoire for cassava, plantain, and sweetpotato products. Research showed the importance of prioritizing taste, appearance, and nutritional quality to boost adoption. Key thresholds for essential food quality traits were established for yam, plantain, matooke, cassava, and sweetpotato, providing measurable standards to guide variety selection.

Social inclusion and gender equity were systematically integrated into cassava and yam TPPs, emphasizing traits that empower women and marginalized groups. Gender-responsive breeding for sweetpotato in Uganda and Mozambique highlighted significant differences in trait preferences between men and women, leading to revised product profiles that reflect end-user needs more accurately.

Additional work on sweetpotato breeding identified key morphological indicators for sweetpotato weevil resistance and further incorporated nutritional traits, such as iron and zinc content, into selection pipelines. Finally, enhanced TPPs for potato in East Africa now incorporate the needs and preferences of different social groups, ensuring more inclusive product development.

Overall, these initiatives reinforce a shift toward more inclusive, demand-driven, and market-responsive breeding strategies across the RTB crops, improving the prospects for variety adoption, resilience, and food security in the targeted regions.

Potato harvesting in Kenya. Photo Credit: Michael Major

WP2: ReOrganize

Work Package 2

Outputs

3 · Pipeline specific stages gates, hand over criteria and RACI documented for CGIAR-NARES breeding teams. (Scalable Crop Product Pipeline Management).

4 · Capacity building of men and women researchers including gender intentional demand led breeding. (Banana, Cassava, Potato, Sweetpotato,Yam, Quality).

End-of-Initiative Outcome 2

3 ▶ 4 ▶ 1 ▶ ABI-CGIAR and NARES using a revised organizational framework for their breeding pipelines providing gender diverse, multidisciplinary teams with clear roles and decision power.

Work Package 2 progress against the theory of change

WP2, ReOrganize developed a common organizational framework within the product development process, which included a common stage plan and stage definition for managing and advancing products. Breeding programs adopted the harmonized stage-gate terminology with intent for full adoption and implementation. Critical competencies required to drive product development were identified and their roles and responsibilities delineated. Knowledge of available skill sets and skill gaps provided clear evidence on needs and strengths and are fostering the pooling of human resources across crops and Centers. The mapping of human resources and competencies can assist in identifying areas where capacity building is needed.

The RACI matrix was used by some teams to establish team responsibility, while others used the RAPID model to clearly delineate responsibilities in terms of decision-making to ensure effectiveness and inclusiveness of decisions made. A key performance indicator framework for measuring performance of breeding programs and teams was established and is being translated into scalable dashboards. These tools will increase the transparency of breeding schemes, facilitate inter-program communication and scientific exchange across breeding programs and partners, and ultimately improve the effectiveness and efficiency of the breeding efforts. Small-scale farmers and customers are the targeted winners in the revised and improved breeding process organization. Success is realized as increased rates of genetic gain, improved efficiency of process, and timely commercialization of market-leading products that farmers recognize as improvements for their farms and families.

Capacity was built over the specified period. This capacity building work included assessment of consumers-preferred traits, breeding pipeline optimization using modern tools, descriptive sensory analysis and consumers testing, use of molecular markers for fingerprinting as a quality assurance and quality control measure, training on seed systems and seed delivery, and the adoption and dissemination of new technologies. Developing, strengthening, and enhancing individual skills and competencies is critical for effective and efficient product development. Building capacity benefits RTB breeding programs overall. Programs that provide such growth opportunities attract and retain talent.

WP3: TRANSFORM

Work Package 3

Outputs

- **5** · Breedbase contents and features updated.
- **6** · Capacity building for CGIAR and NARs breeding networks in the use of breeding data management tools and systems/bioinformatics/biometrics.
- **7** · Trials analyzed highlighting changes in biometric procedures to improve analysis and predictive capacity from breeding operations.
- **8** · Digital tools developed for data collection for Sweetpotatobase update, and bioinformatics.

5 ▶ 6 ▶ 7 ▶ 8 ▶

End-of-Initiative Outcome 8

BRI-CGIAR and NARES breeding teams use state of the art data management systems.

Work Package 3 progress against the theory of change

Strengthening NARES and Stakeholder Capacity through Regional Breeding Networks in WCA and ESA

Significant strides were made in strengthening the capacity of NARES and relevant other stakeholders to actively participate in regional breeding networks across West and Central Africa and East and Southern Africa. For Cassava, regional workshops in both regions brought together NARES from Nigeria, Ghana, Benin, DR Congo, Uganda, Tanzania, Kenya, and others to define priority market segments and jointly develop harmonized TPPs. These sessions enhanced technical skills in market segmentation, inclusive trait prioritization, and product profiling, leading to more demand-driven breeding efforts.

Similarly, for yam, a coordinated regional approach across both regions engaged partners from Nigeria, Ghana, Côte d'Ivoire, Benin, Uganda, Ethiopia, and DR Congo. Through expert-led sessions and participatory workshops, NARES and allied institutions refined Early, Intermediate, and Water Yam segment TPPs. The focus on integrating social, gender, and quality traits empowered participants to align breeding pipelines with user needs and market demands.

In East Africa, the banana network supported NARES-led product design team meetings in Tanzania, Uganda, Burundi, Rwanda, Kenya, and DR Congo. These interactions enabled partners to identify priority MSs and draft regionally aligned TPPs, laying the foundation for structured breeding strategies. For plantain, product design team processes were initiated in Ghana and Nigeria, marking the beginning of regional coordination for this crop.

Additionally, similar efforts were undertaken for potato and sweetpotato in East and Southern Africa, engaging national partners to define key MSs and co-develop crop-specific TPPs that reflect regional production and consumer needs.

WP4: DISCOVER

Work Package 4

Outputs

- **9** · Marker-trait associations for key grower and consumer traits identified and documented.
- **10** · Pre-breeding pipeline(s) for transferring needed novel alleles into elite, adapted genetic backgrounds.
- **11** · Genomic prediction testing is initiated in 2x parental improvement.
- **12** · Founders and advanced clones screened for Begomo virus resistance.
- **13** · Value established trait investment case for yam Trait Discovery and Deployment pipeline developed.

9 ▶ 10 ▶ 11 ▶ 12 ▶ 13 ▶

Outcomes

- **1** · Breeding networks prioritize targeted CGIAR Trait Discovery and Deployment projects.
- **2** · CGIAR and NARES mainstream best practices in breeding pipelines for development of prioritized donor germplasm.

1 ▶ 2 ▶

End-of-Initiative Outcome 4

ABI-CGIAR and NARES supporting breeding pipelines with TD&D programs that deliver high impact traits within elite parental lines.

Work Package 4 progress against the theory of change

Significant progress was made in 2023 and 2024 across RTB crops through the integration of molecular tools and genomics into the RTB Breeding pipelines, enhancing precision and efficiency. In banana, molecular markers associated with fruit filling were deployed to allow early selection of hybrids with edible fruits at the nursery stage to shorten the breeding cycle and reduce cost. In 2024, markers linked to resistance against banana bacterial wilt and pro-vitamin A content were also identified. Additionally, the planned launch of separate diploid (2x) and tetraploid (4x) breeding pipelines enabled the application of genomic selection to enhance genetic gains. In sweetpotato, efforts to breed virus-resistant varieties advanced through innovative phenotyping techniques.

A focus on resistance to sweet potato leaf curl virus and sweet potato chlorotic stunt virus led to the development of a co-infection assay using a double-grafting method. In yam breeding work reported in 2023 and 2024, 14 key agronomic and tuber quality traits were targeted for marker-trait association, leading to the validation of SNP markers for nine traits and the integration of seven into the breeding program through KASP-PCR assays. By 2024, over 3,000 early-generation genotypes were selected using marker-assisted selection. A refined SNP panel improved selection accuracy and a haplotype-based reference genome will expand the genetic base and support the development of superior varieties. In cassava, a large-scale genome-wide association study involving over 5,100 genotypes and 100,000 SNP markers identified 41 genomic regions influencing 14 critical traits spanning biotic stress, quality, and plant architecture. Marker-assisted selection is now routinely implemented in CGIAR-NARES breeding networks for traits such as virus resistance, high carotenoid content, dry matter, and low cyanogenic potential. Across the RTB crops, the advancements reported represent important steps toward increasing genetic gains via more efficient breeding cycles and improved varietal development aligned with product profiles.

Cassava field in the early growing phase, Nigeria. Photo Credit: Chiedozie Egesi/NRCRI

WP5: ACCELERATE

Work Package 5

Outputs

14 • Breeding cost structure developed for RTB crops.

15 • SOPs developed/updated for RTB breeding operations and breeding process management.

14 ▶ **Outcomes**

3 • CGIAR RTB breeding networks awareness of costing and costing structure.

15 ▶ 3 ▶ **End-of-Initiative Outcome 7**

BRI-CGIAR and NARES breeding teams have up-to date knowledge and capacities to design and operate shared services, facilities and operations.

Work Package 5 progress against the theory of change

Over the past two years, the banana, cassava, yam, and sweetpotato breeding programs have made significant progress through the integration of genomics, strengthened partnerships with NARES, and participatory approaches that prioritize end-user needs. These coordinated efforts have focused on accelerating genetic gains, enhancing the efficiency of breeding pipelines, and ensuring that newly developed varieties are well aligned with market demands and farmer preferences.

Banana breeding has advanced through robust collaborations with six East and three West African NARES partners. Together, they have tested 12 NARITA hybrids across five countries, employing both multilocational and on-farm trials. Uganda notably conducted its first TRICOT (Triadic Comparison of Technologies) testing, engaging farmers in the evaluation process. A key milestone was the release of NARITA 17 in Uganda in 2025 — a matooke hybrid that combines high yield with strong consumer acceptance. In addition, Uganda's National Agricultural Research Organisation (NARO) has taken on a leadership role as chair of the matooke product advancement meeting. In Tanzania, commercial adoption has also progressed, with a small enterprise successfully multiplying and marketing TARIBAN, a matooke hybrid released in 2021.

Technically, banana breeding has achieved several pioneering milestones, with 21 SOPs developed to guide breeding and phenotyping activities. For the first time, full-scale parental breeding was launched for both diploid and tetraploid banana lines, and the first backcrossed diploid plants reached the flowering stage. Comprehensive mapping of genetic diversity and population structure across the breeding pipelines was completed alongside the identification of additive and non-additive genetic effects in diploids. Karyotyping was introduced to inform breeding decisions, while improved statistical models allowed for selection immediately after the first harvest cycle.

The program has developed best linear unbiased predictors using both pedigree and genomic data (SNPs) as well as a hybrid model that combines the two. Quality control and assurance measures were embedded throughout the breeding pipeline. Marker-assisted selection was successfully applied to improve pulp diameter, allowing the early elimination of 33 percent of underperforming entries before field testing. Importantly, resistance loci were identified for key diseases such as Banana Xanthomonas Wilt and Fusarium wilt Tropical Race 4 (TR4), further enhancing breeding outcomes. In collaboration with the Salk Institute for Biological Studies, the first banana pangenome was developed, comprising 20 diploid genomes that directly feed into the breeding program. High-throughput phenotyping facilities became operational for key pests and diseases, and the first digital tool for screening banana weevil resistance was also deployed, marking a shift toward scalable, tech-driven selection methods.

In parallel, genomics-supported recurrent selection was also implemented in cassava, yam, and sweetpotato breeding programs. In sweetpotato, a Genomic Prediction Cross-Performance pipeline was developed to optimize parent selection and improve predictive accuracy. Yam breeding integrated similar genomic tools into YamBase, enabling more refined parent selection and targeted crossing strategies. These advances were supported by the revision of MSs and breeding priorities across countries, including Uganda, Malawi, Mozambique, and Zambia. Breeding pipeline assessments, cost evaluations, and improvement plans were completed, leading to the development of breeding manuals and the calculation of genetic gains.

Variety testing and selection efforts were increasingly participatory and gender responsive. Late-stage breeding lines were assessed under farmers' field conditions for agronomic and post-harvest traits. In Uganda, five matooke hybrids were evaluated for potential release, while consumer preferences for sweetpotato and cassava were studied across Uganda, Mozambique, and Nigeria. TRICOT testing has become a widely adopted approach, involving hundreds of farmers in variety validation and ensuring that new varieties meet practical needs.

To facilitate scale-up and seed delivery, the SAH method developed by the International Institute of Tropical Agriculture (IITA) and the International Center for Tropical Agriculture (CIAT) was deployed to produce large volumes of quality plantlets. This rapid and cost-effective clonal propagation technique enabled early-generation seed production and improved access to planting materials for trials and commercial distribution. In 2024, demand creation trials for cassava engaged farmers and processors to align breeding outputs with user needs. In Nigeria, improved yam varieties were tested across 37 locations with participation from over 1,000 farmers, leading to the identification of five high-yielding varieties with dry matter content of up to 35.5 percent. In addition, twelve sweetpotato varieties with high yield potential and stress tolerance were proposed for release in 2024 across Uganda, Mozambique, and Rwanda.

Across all four crops, the integration of genomics-supported recurrent selection and optimized breeding pipelines proved effective in accelerating both population improvement and variety release. The consistent application of participatory methods and attention to gender-related traits ensured that breeding outputs were not only scientifically robust but also socially relevant and widely adoptable.

These outcomes affirm the core assumptions of the Work Package 5 TOC, demonstrating that genomics, data-driven breeding, and stakeholder engagement can together deliver impactful innovations in crop improvement across sub-Saharan Africa.

WP6: Cost-effective Shared Services

Work Package 6

Outputs

16 • Breeding pipeline human capacity (NARES).

17 • Mechanism developed/streamlined for NARs partners to co-create and for decision making.

18 • Guidelines on gender diversity, and clear roles and decision rights for CGIAR, NARES and appropriate stakeholders.

17 ▶ 18 ▶ 1 ▶ **End-of-Initiative Outcome 3**

ABI-CGIAR-Multidisciplinary and gender aware breeding networks implement stronger partnership models where National Agricultural Research and Extensions Systems (NARES) and Small and Medium-sized Enterprises (SMEs) have clear roles and decision rights, and an increased contribution to the breeding process.

Work Package 6 progress against the theory of change

High-quality phenotyping is a challenge in most breeding programs. Innovative phenotyping tools and platforms are needed for quick, accurate, and cost-effective evaluation of large numbers of breeding lines. Several phenotyping technologies were explored for RTB crops. The potential of near-infrared spectroscopy and hyperspectral imaging for forecasting key driving quality attributes such as texture, starch, sugar, and amylose content were investigated and models developed. The capacity of digital imaging systems to rapidly and effectively assess characteristics including color, mealiness, illnesses, and postharvest features was evaluated, and models were developed using a variety of machine learning techniques. Development of toolkits such as YamSCoP facilitated analysis of yam shape and color. Smart Grader Readers were used to increase the phenotyping accuracy of yield-related traits. The developed models need to be either refined, validated, or mainstreamed into breeding programs. Training on phenotyping technologies was carried out to strengthen the capacity of our breeding network partners and SOPs were established to ensure consistency and the correct execution of operational activities.

Significant genomic resources are now available for most RTB crops. Several accessions have had their genomes sequenced and assembled; these resources facilitate the use of genomic information for marker-assisted selection, genomic selection, and genomic prediction of cross performance. Pan-genomes are available for cassava, yam, bananas and plantains. The cassava Practical Haplotype Graph (PHG), a powerful tool, is available and enabled us to bridge genotype information from different markers on panel. The development of pan-genome for yam enabled us to capture missing information, such as transposable elements. Such resources are critical for variant discovery and help to answer important biological questions.

An IITA farm officer Anetor Omonuwa holds cassava variety undergoing field testing for high-yield-potential in IITA's-Ikenne research station in-Nigeria.
Photo Credit: Ismail Rabbi

WP7: Performance Management of Consistent, Connected Operations

Work Package 7

Outputs

19 · Genomics-supported RSS schemes developed to facilitate genomic-assisted breeding and population improvements.

20 · Optimized breeding pipelines, pipeline structure and germplasm sharing strategy developed and updated.

21 · Optimized variety selection-Variety testing and selection at CGIAR and NARES partners considering farmer's representative conditions and gender-related traits.

22 · Farmer-and market-relevant variety identification schemes- Participatory ranking and adoption data on agronomic and post harvest performance of late-stage breeding lines considering farmer's representative conditions, consumer and gender-related traits.

23 · On-farm testing approaches- System for multi stakeholder variety validation established considering farmer's representative conditions and gender-related traits.

24 · Genotypes selected for nutritional quality traits such as iron, zinc, beta-carotene, and polyphenols content.

25 · CGIAR and NARES crop candidate varieties meeting target product profiles specifications.

26 · Demand Creation Trials conducted targeting main stakeholders and considering social and gender aspects.

27 · Rapid and high ratio clonal propagation methods used in breeding programs to scale testing of late-stage materials for MET trials across TPE considering farmer's representative conditions and gender-related traits. (Banana, Cassava, Potato, Sweetpotato,Yam).

Outcomes

21 22 23 24 ▶ **4** · CGIAR-NARES test advanced lines under farmer-representative conditions and market segments considering social and gender aspects.

25 26 27 ▶ **5** · Stakeholders demand for and access to CGIAR-NARES-developed varieties carrying traits preferred by both men and women farmers and other value chain actors.

End-of-Initiative Outcome 5

19 20 4 5 ▶ ABI-National and private seed company breeding programs accelerate the development of varieties that provide larger scale benefits across the 5 Impact Areas.

Work Package 7 progress against the theory of change

Over 2023–2024, the RTB Breeding community made major strides in strengthening and modernizing its breeding programs. Two of the most impactful initiatives were the development and deployment of SOPs and the systematic estimation of breeding operational costs, both aimed at enhancing program efficiency, transparency, and accountability.

Through close collaboration with the NARES across all RTB crops, a significant number of SOPs were developed, validated, and deployed. Specifically, 11 SOPs were developed and validated for yam, 14 SOPs for cassava, and 21 SOPs for banana/plantain. These SOPs cover critical breeding phases, from crossing block management to field evaluations and post-harvest assessments. Their implementation improved data quality, standardized breeding practices, strengthened staff capacity, and created the foundation for digital integration in trial management.

In parallel, considerable progress was made in the estimation of breeding operational costs. Historically, breeding programs have operated with limited insight into their true costs. In collaboration with CGIAR's Accelerated Breeding Initiative team, a costing workshop was organized at the National Root Crops Research Institute, in Umudike, Nigeria, where operational costs were systematically estimated for yam, cassava, and sweetpotato breeding programs. For example, the IITA-yam breeding program's operational cost was estimated to be around USD 2.7 million. Also, during the 2024 cropping season, the IITA-cassava breeding program underwent a costing exercise and a full document was developed. This exercise helped breeding teams to better understand key cost drivers, to optimize resource use, and to improve budget planning and advocacy efforts. Furthermore, it laid the groundwork for assessing the cost-efficiency of breeding pipelines and designing more cost-effective strategies.

Estimations of breeding costs for other national breeding programs across the RTB network are planned for 2025 to ensure comprehensive understanding of investment needs across the entire breeding system.

Together, the deployment of SOPs and the costing exercises significantly enhanced the scientific rigor, financial transparency, and operational sustainability of RTB Breeding efforts. These initiatives align with the broader CGIAR mission of accelerating the development and delivery of breakthrough product varieties with at least 25 percent productivity or income advantage over current cultivars and also that are climate-resilient and meet market and farmer demands.

Moving forward, the RTB community remains committed to refining SOPs, completing full costing across the breeding network, and integrating digital tools to modernize and future-proof breeding operations across Africa, Asia, and Latin America.

WP8: Smarter Use of More Data

Work Package 8

Outputs

28 · Whole genome sequence database available for a subset of landraces and superior parents.

29 · Whole genome long read sequence database available (Practical Haplotype Graph, PHG) for cassava assembled for imputation and improved genomic prediction.

30 · Protocols for use of high throughput phenotyping tools applied to specific high priority traits.

31 · Decision making options based on routine phenotyping of post harvest quality traits.

32 · New and emerging phenotyping tools and platforms for agronomic/food quality traits developed and validated for adapting in breeding programs.

Outcomes

28 29 30 31 32 ▶ **6** · CGIAR RTB breeding networks have shared services approaches available to accelerate RTB variety development documented.

End-of-Initiative Outcome 6

6 ▶ BRI-CGIAR and NARES breeding teams use shared services, facilities and operations that have been improved for greater throughput, accuracy and safety, at lower unit costs.

Work Package 8 progress against the theory of change

During 2023 and 2024, substantial progress was made by CGIAR and NARES breeding teams working on RTB crops on the use of state-of-the-art data management and analysis systems. The adoption of BreedBase as a digital ecosystem, used throughout the entire breeding cycle, was increased by two main drivers. First, intensive capacity building was provided by all RTB Centers and the Boyce Thompson Institute to the CGIAR-NARES breeding networks, through both in-person workshops and online sessions, to increase knowledge on the use of BreedBase and the integrated digital data collection tools like FieldBook App. In total, more than 15 training courses were conducted across RTB crops during the project's two years. Second, BreedBase features and contents were updated. Most features are crop agnostic, so improvements requested by one crop also benefit the other RTB crops. Ontology is an exception to this rule, so ontologies, especially quality traits, were further maintained and updated in the BreedBases for all RTB crops separately. Other highlights of recent BreedBase improvements were: (i) improved handling of repeated measurements; (ii) implementation of a data quality verification system; (iii) improved management of access privileges; (iv) integration of an ordering system for seeds, plants, and other items; and (v) increased ability to store high dimensionality phenotypes such as NIRS (near-infrared spectroscopy) data, transcript data, and proteomic data. The increased adoption of BreedBase is illustrated by the increasing number of datapoints available in the databases.

Some analytical features were also improved in BreedBase, but under CGIAR's Genetic Innovation Science Group the initiative was taken to develop a database agnostic analytics tool, called Bioflow, to support data-driven decision-making in CGIAR-NARES breeding programs. This suite of analytical modules was developed by the CGIAR Breeding Analytics team and has served as the platform of preference to analyze breeding data since its release in October 2024. Bioflow currently offers an extensive set of modules, able to carry out the most crucial analytical procedures to take breeding decisions using state-of-the-art methodology, with further development for improvement and amplification ongoing. The RTB biometrics community committed to collaborating on this development and adoption of Bioflow by RTB breeding programs. Several of the 2024 training courses on data management mentioned above already included an analytics component building capacity on using Bioflow to analyze breeding data.

The TOC assumptions for Work Package 8 were valid. The combination of capacity building and an improved digital ecosystem increased the adoption of BreedBase and digital tools, while the combination of capacity building and the availability of an easy-to-use analytical pipeline drove the adoption of Bioflow and the corresponding state-of-the-art biometric procedures.

Work Package progress rating summary

WORK PACKAGE	PROGRESS RATING & RATIONALE
1	On track Over the past two years, significant progress was made by Work Package 1 in developing and aligning MSs and TPPs for RTB crops across Level 1 and Level 2 countries through inclusive stakeholder engagements. Regional workshops and product design team meetings strengthened NARES capacities and led to formal endorsement of TPPs in over 10 countries. Gender and social inclusion were integrated into breeding priorities and consumer preferences informed trait selection through experimental auctions. Key food quality thresholds were established for yam, cassava, sweetpotato, and banana/plantain, ensuring breeding pipelines are more targeted, inclusive, and responsive to diverse user needs across regions.
2	On track Work Package 2 delivered committed outputs and Work Packages as per the TOC with the allocated budget. The framework of reorganizational changes was developed and disseminated using defined management tools for process definition and communication. Additional coaching and oversight were required for full implementation. A system for process monitoring and evaluation/assessment/learning was developed, with further dissemination and continuous implementation needed. The capacity of men and women researchers, extension agents, and farmers was built over the period, giving them the skills they need to optimize their contribution to the process of product development and delivery.
3	On track Work Package 3 successfully delivered committed outputs and work packages as per the TOC within the allocated budget across both Level 1 and Level 2 countries. Through inclusive stakeholder engagement, we co-developed market segments and TPPs, ensuring alignment with user needs and priorities. A system for process monitoring, evaluation, assessment, and learning was established, with further dissemination and continuous implementation needed.
4	On track Work Package 4 is on track, with strong progress made in 2023–2024 across RTB crops through the integration of genomics and molecular tools. Marker-assisted selection, genomic selection, and innovative phenotyping accelerated breeding cycles, improved precision, and supported the development of superior, market-aligned varieties in banana, cassava, yam, and sweetpotato.

WORK PACKAGE	PROGRESS RATING & RATIONALE
5	On track Work Package 5 is on track, with significant progress made in implementing genomics-supported recurrent selection in cassava, yam, and sweetpotato. Tools like the Genomic Prediction Cross-Performance pipeline and integration into YamBase enhanced breeding efficiency. Farmer-centered testing, participatory approaches, and the release of high-performing varieties confirmed strong alignment with user needs and project goals.
6	On track Work Package 6 delivered committed outputs within the allocated budget. Innovative phenotyping technologies were explored, models were developed for key traits, and some were validated. A significant emphasis was put on quality traits that drive consumer acceptance of the final product. SOPs are in place and will facilitate data sharing across the different breeding programs. An increased number of genomics tools are available that contribute to genomic research and molecular breeding in RTB crops. The combination of cutting-edge phenotyping technologies that provide rapid, accurate, and high-throughput phenotyping with the available genomic resources will fast track the development of improved varieties and increase genetic gains that satisfy end-user expectations. Continuous refinement and improvement are needed to make the models and tools more robust.
7	On track Under Work Package 7, a series of breeding optimization activities were undertaken through collaborative efforts between CGIAR and the NARES. Significant progress was achieved during the 2024 cropping season, notably the development and implementation of SOPs and the completion of a comprehensive breeding cost analysis, both representing major milestones. Moving forward, what's needed is to advance the development and deployment of high-throughput phenotyping technologies and systematically document breeding costs across NARES. These efforts will enhance breeding efficiency and support the development of high-performing product profiles aligned with target environments and market needs.
8	On track The four outputs under Work Package 8 were all achieved or significant progress was made, as explained in the narrative and shown in the PRMS.

Definitions

On track	Delayed	Off track
Progress largely aligns with Plan of Results and Budget and Work Package theory of change.	Progress slightly falls behind Plan of Results and Budget and Work Package theory of change in key areas.	Progress clearly falls behind Plan of Results and Budget and Work Package theory of change in most/all areas.
Can include small deviations/issues/delays/risks that do not jeopardize success of Work Package.	Deviations/issues/delays/risks could jeopardize success of Work Package if not managed appropriately.	Deviations/issues/delays/risks do jeopardize success of Work Package.

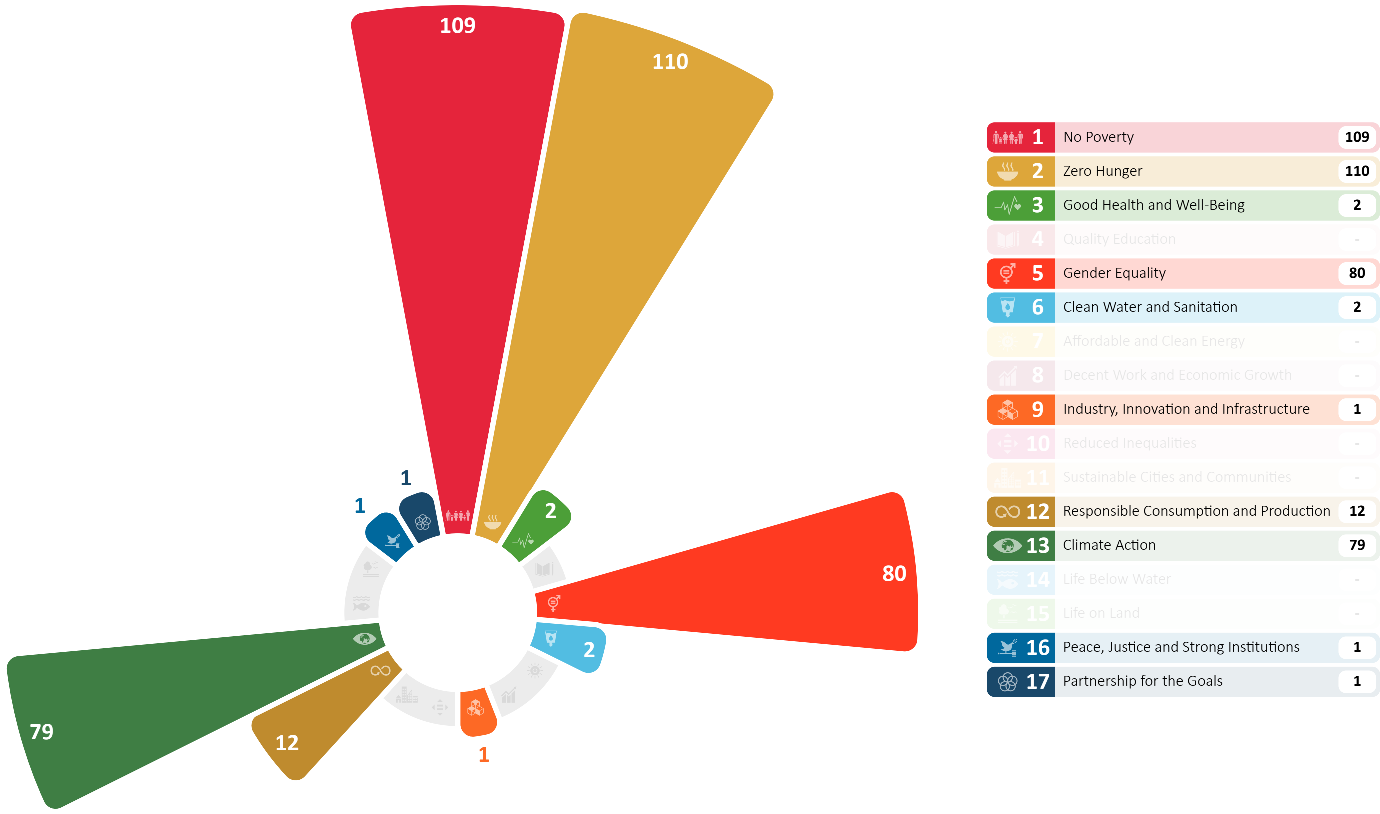
Section 4: **Quantitative overview of key results**

This section provides an overview of 2022–2024 results reported by RTB Breeding Investment. These results align with the CGIAR Results Framework and RTB Breeding's Investment theory of change. Further information on these results is available through the CGIAR Results Dashboard.

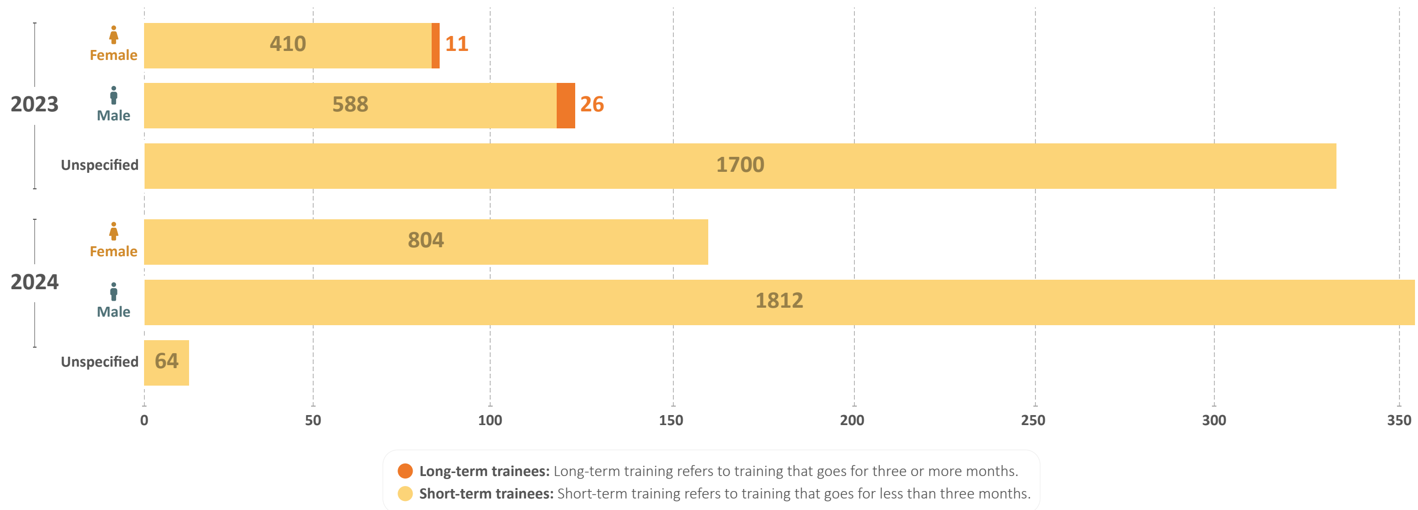
The data used to create the graphics in this section were sourced from the CGIAR Results Dashboard as of May 5, 2025. These results are accurate as of this date and may differ from those in previous Technical Reports. Such differences may be due to data updates throughout the reporting year, revisions to previously reported results, or updates to the theory of change.

Overview of results per category

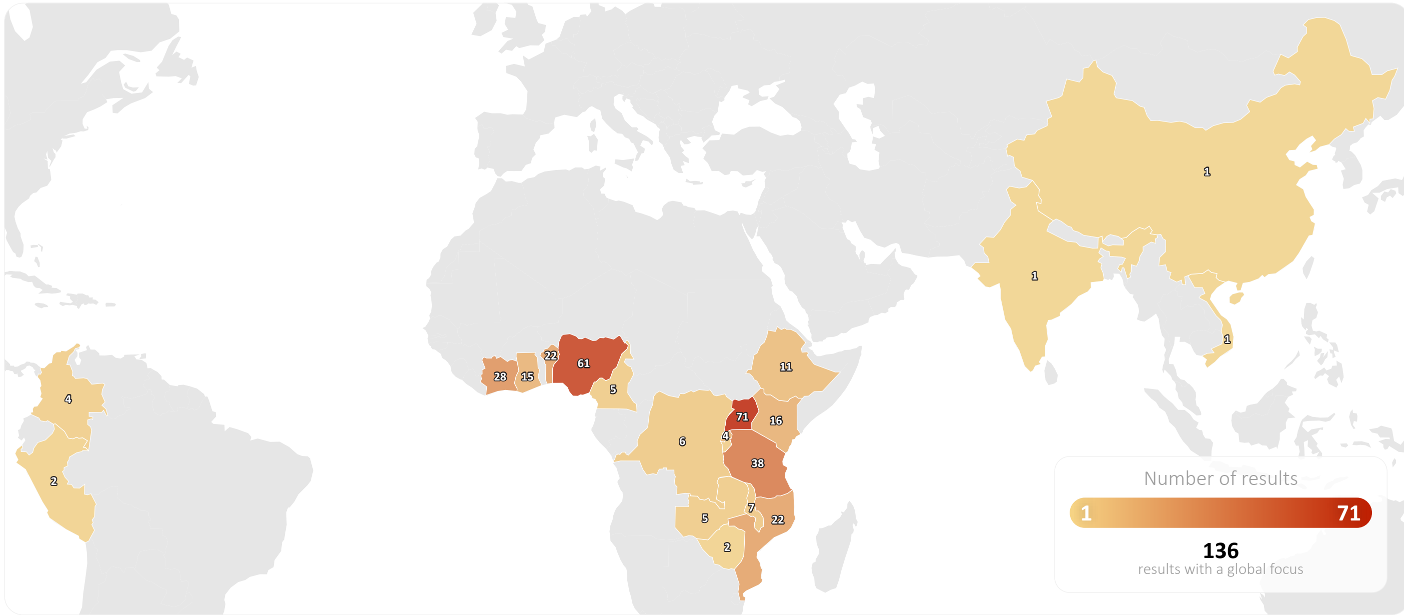
Contribution to the UN Sustainable Development Goals



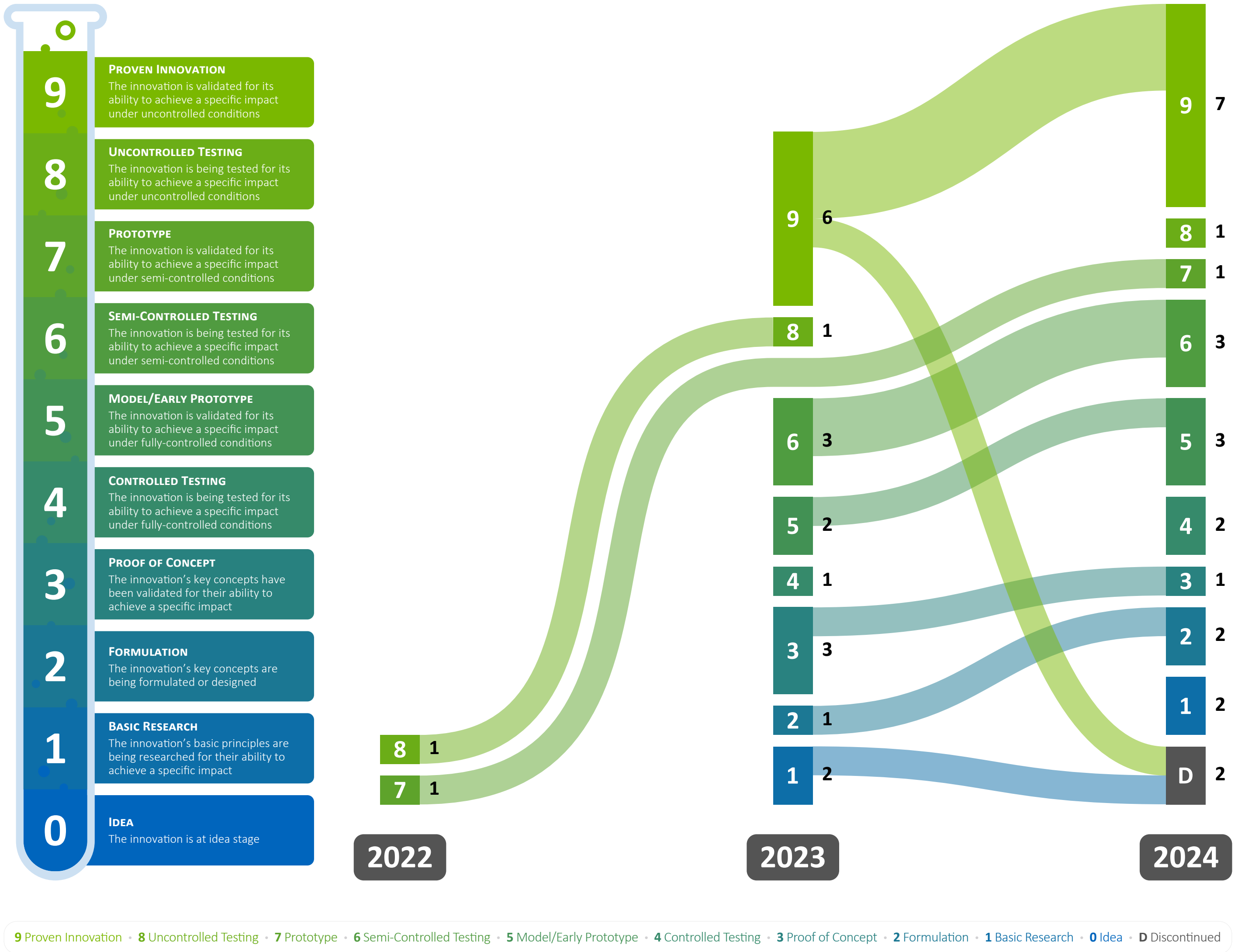
Number of individuals trained by RTB



Geographic distribution of reported results

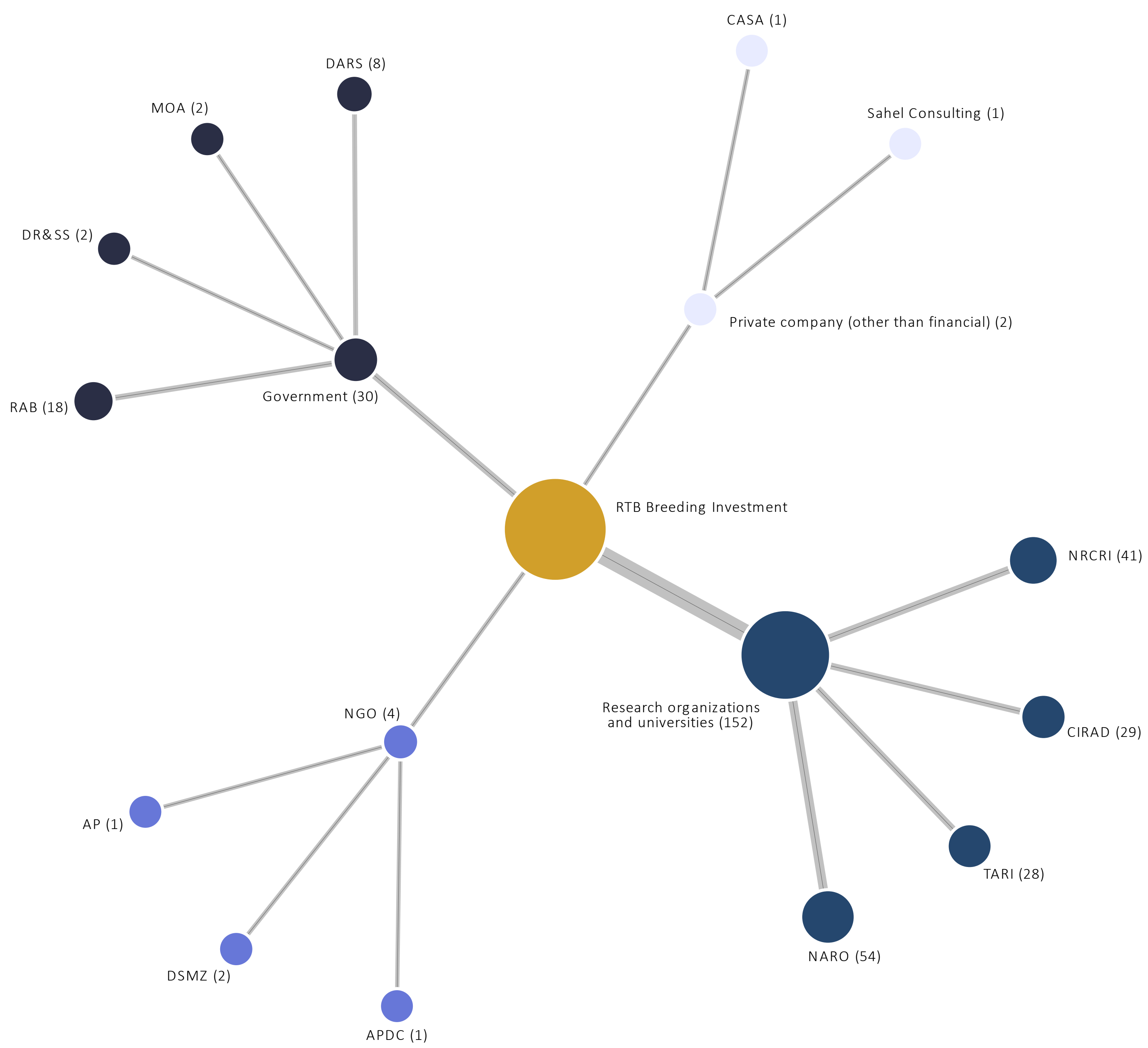


Progress of innovation readiness levels over the three years (2022 – 2024)



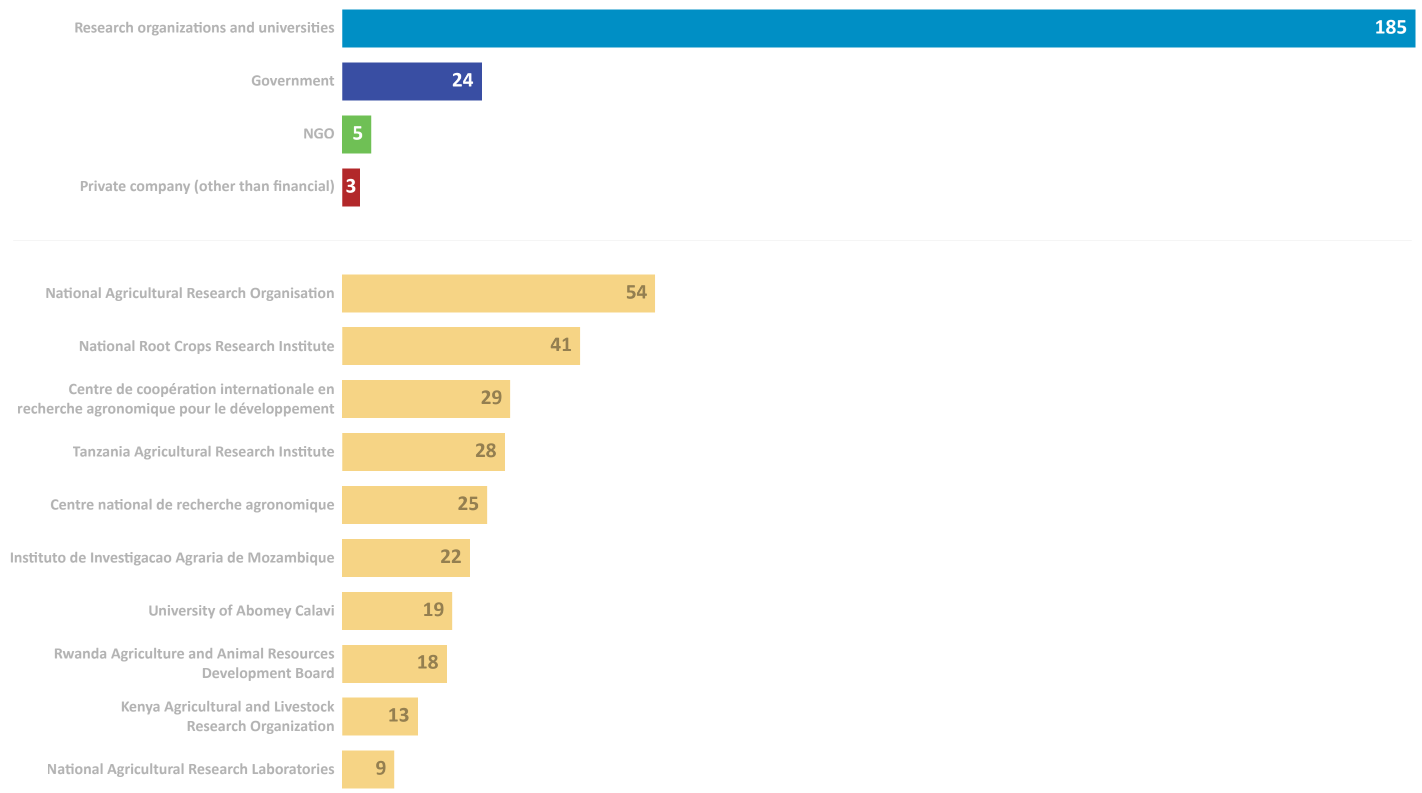
Section 5: **Partnerships**

Roots, Tubers and Banana Breeding: A Consolidated Investment's external partners



The diagram maps the key external partners of RTB Breeding project, organized by partner type. The numbers in brackets represent the number of results each partner has contributed to, reflecting the scale and diversity of collaborations. To allow for a clearer view, a maximum threshold of four partners was applied for each typology. The list of partner acronyms is available here. Data sourced from CGIAR Results Dashboard, on 15 June 2025.

Top 10 partners that contributed to delivering 2022–2024 results



Total number of results by partner type and by the top 10 contributing partners.

The ability of RTB Breeding to build efficient and effective partnerships, particularly with national programs, remained a key comparative advantage. Over its two years of operation, RTB Breeding deepened collaborations with more than 15 national programs and multiple advanced research institutions across Africa, Latin America, and Europe. These partnerships significantly contributed to progress across all of the project's Work Packages through shared capacity, innovation, and joint knowledge generation.

Collaborations continue to focus on streamlining breeding processes, modernizing operations, and strengthening demand-led, inclusive breeding strategies. This was achieved through the co-development and formalization of TPPs and MSs across key RTB crops. Regional training workshops and multi-country consultations supported the development of TPPs for cassava, yam, sweetpotato, banana/plantain, and potato, with a strong emphasis on integrating social inclusion, gender, and quality traits. Notably, product design team meetings across 10 countries formalized TPPs, while experimental auctions and participatory consumer research helped define trait priorities.

Under ReFOCUS Work Package 1, aligned TPPs and MSs were finalized across Eastern, Western, and Central Africa, guiding national breeding programs to deliver varieties aligned with farmer and consumer preferences. For example, gender-responsive breeding approaches in Uganda and Mozambique led to revised sweetpotato profiles that better reflect differences in trait preferences between men and women. In parallel, research on quality trait thresholds and morphological indicators for pest resistance strengthened the targeting of high-impact traits.

This project's ReOrganize Work Package 2 efforts continued to modernize organizational structures within RTB breeding programs. All RTB crop teams adopted harmonized stage-gate processes and critical competencies were mapped across institutions using RACI and RAPID tools to clarify decision-making roles. Key performance indicators were defined and embedded into scalable dashboards to monitor breeding program efficiency. These frameworks improved internal communication, accountability, and transparency across CGIAR and NARES partners.

Through the project's TRANSFORM Work Package 3, capacity sharing intensified, with more than 15 training events conducted to build expertise in genomic tools, consumer testing, seed systems, and digital breeding tools such as BreedBase and Bioflow. Participating national programs in Nigeria, Ghana, Côte d'Ivoire, and Uganda strengthened breeding competencies while engaging in regional forums and cross-country product advancement initiatives .

The project's ACCELERATE Work Package 5 drove field-level impact by enhancing variety testing, validation, and demand creation. Participatory evaluations and on-farm trials such as TRICOT were implemented across multiple countries. In Uganda, over 1,000 farmers were engaged in multi-location yam trials, while cassava and sweetpotato adoption research informed the release of farmer-preferred hybrids. The SAH method also scaled production of high-quality early-generation seed, supporting variety dissemination.

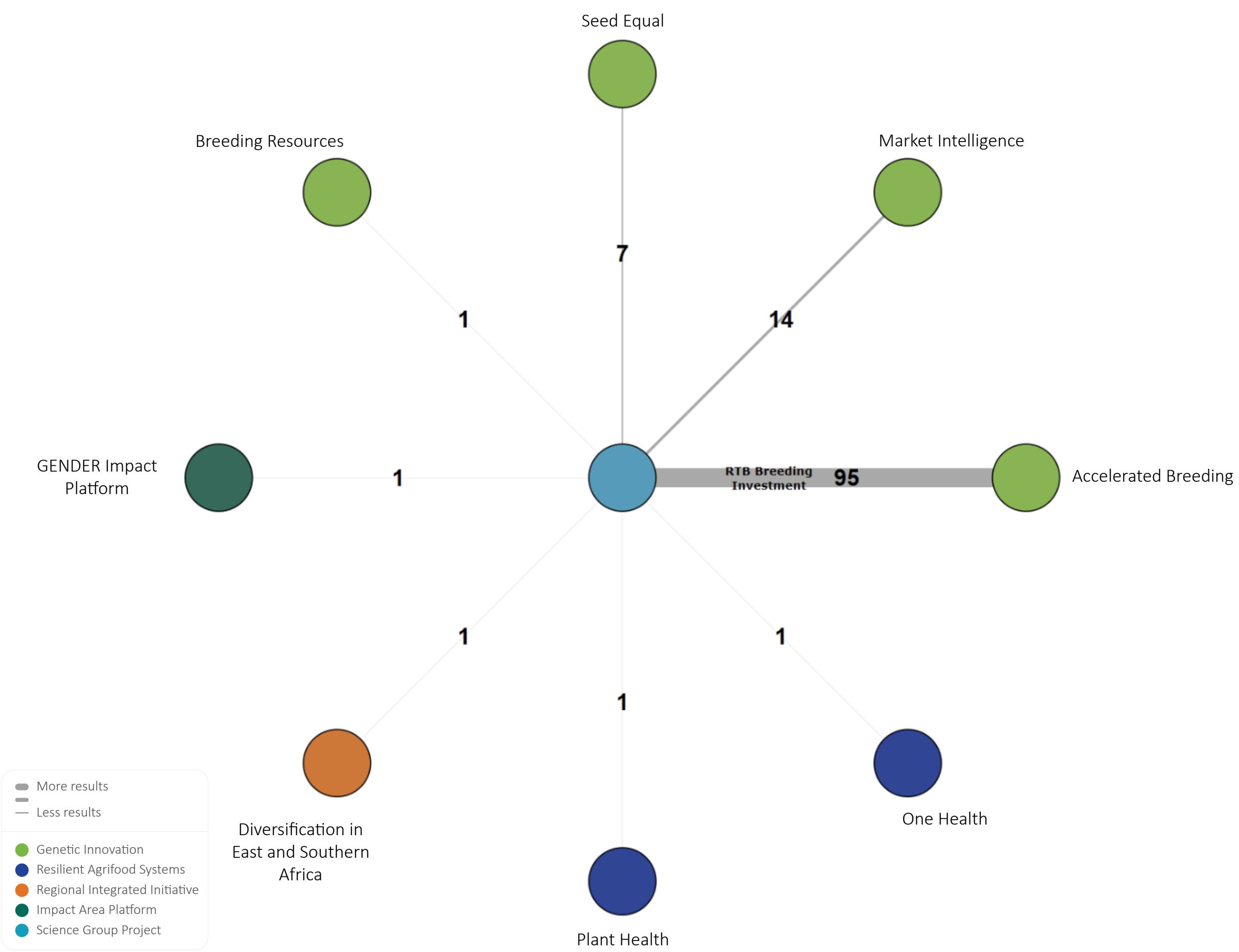
Efficiency gains were further captured under Work Package 7, Performance Management of Consistent, Connected Operations, where 46 SOPs were developed and validated across cassava, yam, and banana pipelines. Costing exercises carried out with the Accelerated Breeding Initiative team in Nigeria, for example, provided accurate estimates of breeding operations, guiding better resource use and financial planning. Full costing exercises are planned for additional national programs in 2025.

Adoption of digital tools like BreedBase and Bioflow increased significantly. Over 15 training courses supported digital transformation, while updates to BreedBase improved data verification, access control, and integration of high-dimensional phenotypic data. Bioflow, released in 2024, became the preferred analytics platform across RTB crops, facilitating data-driven breeding decisions.

Together, these initiatives marked a strong, cohesive shift toward inclusive, efficient, and market-responsive breeding, underpinned by robust partnerships that bridge research, capacity development, and impact on smallholder farms.

Section 6: **CGIAR Portfolio linkages**

Roots, Tubers and Banana Breeding: A Consolidated Investment's internal network of collaborations



The diagram presents the internal collaborations of RTB project with other CGIAR Initiatives and Impact Area Platforms. Connections are sized according to the number of shared reported results, highlighting the depth of collaboration across the CGIAR Portfolio. Thicker lines represent stronger collaborative links based on a higher number of shared results. Data sourced from CGIAR Results Dashboard, on 15 June 2025.

RTB Breeding made substantial strides over two years in transforming RTB breeding systems across sub-Saharan Africa and other regions. The overarching goal was to re-focus breeding programs on farmer and market needs, especially those of women, through well-defined product profiles and robust, efficient breeding pipelines. This was operationalized through interconnected Work Packages aligned with the Genetic Innovation Science Group. Each of the Work Packages links to shared objectives, such as inclusivity, efficiency, innovation, and scalability of breeding programs through national and regional collaborations.

ReFOCUS: The RTB Breeding ReFOCUS Work Package prioritized the alignment of TPPs and MSs across RTB crops. Major achievements included capacity-building workshops in several African countries to develop gender-responsive TPPs for crops such as yam, sweetpotato, cassava, and banana/plantain. Breeding teams now explicitly consider quality traits like taste, appearance, nutritional value, and shelf-life attributes that are especially valued by women and marginalized groups. The integration of social and gender research led to revised breeding objectives that better reflect end-user preferences. Experimental auctions and consumer preference assessments in countries like Nigeria and Uganda strengthened demand-led breeding approaches. These tools guided the selection of varieties more likely to be adopted, reinforcing the shift toward market-demanded, inclusive breeding outputs.

ReORGANIZE: The ReORGANIZE Work Package focused on operational efficiency through adoption of a standardized product development framework. Breeding teams implemented harmonized stage gates and defined roles using models such as RACI and RAPID. These tools clarified team responsibilities and improved decision-making transparency. Importantly, key performance indicators were introduced to evaluate breeding program performance and are now being integrated into scalable dashboards. Human resource mapping and skills assessments provided insights for targeted capacity building, while improved organization and resource pooling among CGIAR Centers and NARES partners laid the foundation for more effective collaboration. Enhanced organizational clarity and shared processes worked to ensure timely commercialization of improved varieties, directly benefiting smallholder farmers.

TRANSFORM: The TRANSFORM Work Package emphasized the formation of inclusive breeding networks by empowering partners, particularly NARES, through customized capacity building and strategic division of labor. Although specific progress under this Work Package 3 is not elaborated in detail, its theoretical foundation was reflected across the other Work Packages through cross-cutting themes such as shared decision-making, gender inclusion, and alignment with national agricultural priorities.

DISCOVER: Major advancements were achieved in RTB Breeding in the DISCOVER Work Package through the integration of molecular tools and genomics, significantly enhancing precision and efficiency. In banana, markers for fruit filling, disease resistance, and nutrition were identified, while diploid and tetraploid pipelines supported genomic selection. Sweetpotato breeding progressed with innovative virus-resistance screening methods, and yam programs validated SNP markers for key traits, integrating them into selection protocols. Cassava saw breakthroughs through large-scale genomic studies, identifying key trait-associated regions and enabling routine marker-assisted selection. Overall, these innovations streamlined breeding cycles and improved the development of superior, market-ready varieties.

ACCELERATE: RTB Breeding Work Package 5, ACCELERATE, played a central role in modernizing and speeding up breeding processes through genomics-supported recurrent selection. For example, cassava and yam breeding programs now use predictive models to optimize parent selection. These tools have led to improved genetic gains and reduced breeding cycle times. CIP and its partners have revised breeding pipelines in multiple countries, focusing on traits prioritized by farmers and processors. Participatory testing, such as TRICOT, has become standard practice, increasing the likelihood that released varieties will meet farmer expectations. Examples include the identification of five high-yielding yam varieties in Nigeria and 12 new sweetpotato varieties proposed for release across Uganda, Mozambique, and Rwanda. Moreover, innovations such as the Semi-Autotrophic Hydroponics (SAH) method have significantly enhanced early-generation seed production, improving the scale and efficiency of propagation and variety testing.

Cross-Cutting Enablers: Work Package 6, Cost-effective Shared Services, and Work Package 7, Performance Management of Consistent, Connected Operations, bolstered the effectiveness of breeding through cost tracking and operational standardization. The development and implementation of over 45 crop-specific SOPs improved breeding data quality and process standardization. Cost estimation workshops, like those held at the National Root Crops Research Institute, in Nigeria, enabled teams to identify key cost drivers and improve financial planning. Work Package 8, Smarter Use of More Data, enhanced data-driven decision-making. Increased adoption of BreedBase and introduction of the Bioflow analytics tool improved digital data management and analysis. More than 15 training sessions built local capacity, enabling breeding programs to harness high-dimensional data such as NIRS and proteomics. This contributed to better selection accuracy and pipeline optimization across crops.

The collective progress of the RTB Breeding investment demonstrates a highly integrated approach to rethinking crop breeding for the 21st century. By aligning breeding objectives with end-user needs, especially those of women, and by improving the organization, efficiency, and scientific rigor of breeding programs, CGIAR and its partners are transforming RTB crop development. These advancements position the system to deliver high-impact, market-demanded varieties with greater speed, inclusivity, and value for money invested.

Yam seedling nursery. Photo Credit: Asrat Amele

Section 7: **Key result story**

A step change in banana breeding: How NARITA 17 and the RTB Breeding Network are empowering African farmers, boosting yields and fighting disease

NARITA 17 boosts banana yields by 25 kg per bunch and resists disease, improving food security for millions in sub-Saharan Africa.

NARITA 17 / NAROBAN 6 (L), NAROBAN5 (M) and Mbwazirume Landrace (R) during the Variety Release Committee meeting at NARL Kawanda, Uganda. Photo Credit: Michael Batte

Primary Impact Area

Other relevant Impact Areas targeted

Contributing Initiative

Accelerated Breeding

Contributing Centers

CIP · IITA

Contributing external partners

National Agricultural Research Organisation (Uganda)

Geographic scope

Countries:
Uganda

In a significant stride toward enhancing food security and agricultural resilience in sub-Saharan Africa, the CGIAR's International Institute of Tropical Agriculture (IITA) and Uganda's National Agricultural Research Organisation (NARO) have released NARITA 17, a high-yielding, disease-resistant matooke banana variety.

NARITA 17 is a product of a collaborative breeding program between IITA and NARO, designed to address the challenges faced by banana farmers, including low yields and susceptibility to diseases like Black Sigatoka. This triploid hybrid was developed through a meticulous breeding process involving the East African Highland banana cultivar "Entukura", a disease-resistant tetraploid (1438K-1), and an improved diploid (9719-7).

Extensive field trials conducted in Uganda demonstrated that NARITA 17 exhibits significant heterobeltiosis, with bunch weights averaging 25 kg, surpassing both its parents and grandparents. This variety not only offers higher yields but also shows enhanced resistance to Black Sigatoka, a major fungal disease affecting banana crops. Based on data from our network of fields trials, NARITA 17 yields 70 tons/hectare whereas the benchmark Mbwazirume it aims to replace in the market achieves just 12 tons/ha.

The release of NARITA 17 aligns with the objectives of the [RTB Breeding Network], a collaborative effort involving 18 national agricultural research and extension systems (NARES) and universities. Launched in October 2024, the Network aims to accelerate the development and dissemination of improved varieties of key staple crops, including banana/plantain, cassava, potato, sweetpotato, and yam.

By consolidating resources, adopting standardized breeding protocols, and sharing data and genetic materials, the RTB Breeding Network seeks to deliver new, climate-resilient crop varieties that meet the specific needs of smallholder farmers. The Network is structured in two subregional groups, West & Central Africa and Eastern & Southern Africa, to address the unique agricultural challenges of each region.

The introduction of NARITA 17 and the establishment of the RTB Breeding Network are poised to significantly impact food security and livelihoods in sub-Saharan Africa. Bananas are a staple food for millions in the region, and improved varieties like NARITA 17 can lead to increased productivity and income for smallholder farmers.

Moreover, the RTB Breeding Network's collaborative model fosters capacity building among national research institutions, enabling them to effectively participate in breeding programs and contribute to the development of crop varieties tailored to local conditions and preferences.

The success of NARITA 17 underscores the potential for collaborative breeding programs to address agricultural challenges in sub-Saharan Africa. As the RTB Breeding Network continues to expand and strengthen its partnerships, it is expected to play a pivotal role in delivering improved crop varieties that enhance resilience, productivity, and food security for smallholder farmers across the region.

By leveraging collective expertise and resources, initiatives like the RTB Breeding Network exemplify the power of collaboration in driving agricultural innovation and transforming livelihoods in sub-Saharan Africa.

> NARITA 17, a top-performing, disease-resistant banana hybrid, boosts yields and food security for millions of people in sub-Saharan Africa. This new variety is resistant to the primary pathogens causing Fusarium wilt in bananas (FOC-TR4 and FOC-R1), to the burrowing nematode Radopholus similis, and to banana weevils, and meets consumer requirements. NARITA 17 is among our best-bet hybrids of matooke, developed jointly by NARO and IITA.
>
> Rony Swennen, IITA Banana Breeding Program Leader

CGIAR

Women farmers in Kenya proudly display freshly harvested potatoes. Photo credit: Michael Major