Innovea Global Coffee Breeding Network

Rwanda Arabica Breeding: Current Progress, Challenges, and Goals

I.   Report Overview & Objectives

The annual report for Rwanda chapter of the Innovea Global Arabica Coffee Breeding Network details the progress made in the collaborative, science-driven effort to revolutionize coffee breeding. The network, coordinated by World Coffee Research (WCR) and executed by a collaboration of national partners (like the Rwanda Agriculture and Animal Resources Development Board, RAB), focuses on accelerating the development and delivery of climate-resilient, high-performing coffee varieties. The report provides a standardized framework to track activities across multiple global sites, focusing on data collection (phenotyping and genotyping), and meeting established metrics for genetic gain to create a sustainable and innovative pipeline for the future of Arabica coffee.

- **Project Title:** Innovea Global Coffee Breeding Network—Arabica
- **Reporting Period: 2023-2025**
- **Partner Institution & Location:**

Rwanda Agriculture and Animal Resources Development Board (RAB)| Directorate of Agricultural Development| Department of Crop Innovation and Tech Transfer | Traditional Export Crops Program

- **Date of Report:** November 4th, 2025
- **Alignment with Core Objectives:**

The Rwanda Agriculture and Animal Resources Development Board (RAB) plays an outstanding, on-the-ground role in the World Coffee Research (WCR) Innovea Global Arabica Coffee Breeding Network. With the Innovea initiative, RAB successfully installed the first field trials of the Innovea Global Arabica Breeding Network back in March 2024. The trials involve performance evaluation of genetically diverse breeding materials (bi and multi-parental crosses), and materials represent new genetic combinations from diverse high-performing Arabica varieties across Africa, Asia, and the Americas. During the current performance period, RAB Scientists are responsible for phenotyping by collecting comprehensive data on the performance of each individual tree for the last two years. Apart from phenotypic data, RAB is also involved in genotypic data collection using mid-density SNPs panels. This data is fed back into the WCR's global database to accelerate the breeding cycle.

Table 1: Overview of the alignment of Innovea activities under RAB with WCR Innovea global objectives

WCR Innovea Global Objective	RAB key Activities	Alignment with Innovea Objectives
1. Develop a collaborative network of partners to increase genetic gain in coffee breeding.	Host Multi-Location Field Trials: RAB hosts, standardized field trial site for the Innovea network, planting and managing diverse, WCR-sourced breeding material from multi-parental crosses.	RAB is one of nine key global partners (including the US, India, and Kenya), making Rwanda an active partner in the collaborative network for multi-environment testing (MET).
2. Improve populations from which national coffee institutes can continuously select high-performing coffee varieties.	Rigorous Phenotyping and Genotyping: RAB scientists collect comprehensive phenotypic data (observable traits like yield and disease resistance) and genotypic data (molecular data using SNP panels) on every single tree.	This high-quality data is fed back into the WCR's global database to power Genomic Selection. This accelerates the development of new, superior breeding populations, which are then delivered back to national institutes like RAB.

| WCR Innovea Global Objective	RAB key Activities	Alignment with Innovea Objectives
3. Enhance national breeding and research capacity to effectively implement product-focused research.	Apply Modern Breeding Techniques: Under the guidance of WCR, RAB is set to utilize and is trained in modern, data-driven breeding approaches, including facilitating the exploitation of genomic selection and using SNP panels.	RAB actively demonstrates the ability to implement and utilize cutting-edge breeding tools and methodologies, directly enhancing its internal capacity and supporting product-focused research that is faster and more efficient.
4. Contribute to the development of national varieties that respond to both the international export market and farmer demands.	Testing Diverse Genetics under Local Conditions: RAB tests unique genetic crosses from Africa, Asia, and the Americas, exposing them to Rwanda's specific agroecological challenges (e.g., Coffee Berry Disease) and environmental pressures.	By rigorously testing and selecting the best-performing lines in Rwanda, RAB ensures the eventual varieties released are locally adapted for high yield and disease resistance, meeting farmer needs, while also possessing the required quality traits for the export market.

II. Overall Progress
Executive Summary of Achievements
Phenotyping and genotyping at RAB

RAB's key role in the WCR Innovea network is the resource-intensive process of phenotyping (measuring plant traits) in the field. Phenotyping is crucial because it links a plant's genetic code (genotype) to its real-world performance (phenotype) under Rwandan conditions. Current measurement activities focus on vegetative traits like plant height, stem diameter, and resistance to coffee leaf rust and coffee berry disease. These recorded traits are expected to determine the plants' yield, quality attributes, and ultimate climate resilience. Phenotypic data for growth and disease scores were collected in September 2023, March 2025, and September 2025. Initial yield data collection began in October 2025 with the first, small harvest, and samples are now being prepared for coffee cupping.

RAB's role is vital for data input to the centralized WCR "breeding factory" by applying modern genomic tools. The primary activity involves collecting leaf DNA samples from trial plants and shipping them to external genotyping labs (like Intertek, Sweden, and DArT Canberra, Australia). This data is used for hybridity testing before field planting and for developing mid-density SNP panels for quality control. Along with Innovea partners, RAB utilizes these genotyping principles for crucial, early-stage quality control of the breeding material. By facilitating sample collection and shipping (e.g., in 2024 and 2025), RAB contributes essential genetic material and expertise to the global database for genomic selection.
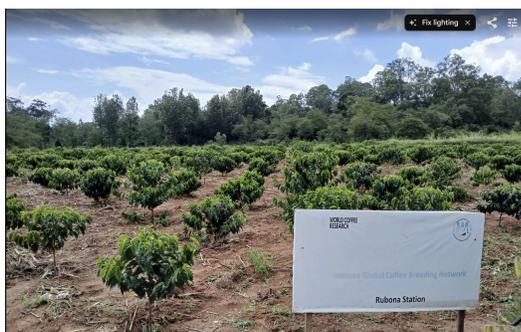
A. **Project Implementation & Milestones nursery development:**
The table below highlights key activities within the project implementation phases

| Key activity and the project implementation stages	Description of activities	Alignment with Innovea Goals
Seed Receipt & Germination	In **August 2023**, Rwanda (RAB) was among the first seven partner countries to receive the first wave of **genetically unique seeds** (around 800-900 seeds) developed from new crosses made by WCR's centralized breeding factory (even if the crosses were made in Rwanda).	Marks the initiation of the trial phase, introducing **unprecedented genetic diversity** from across the globe into Rwanda (even if crosses were made in Rwanda).
Nursery Establishment	From August 2023 to March 2024 RAB established a specialized nursery at one of its key research stations (**Rubona**, which is a main site for coffee research) to handle these precious, multi-parental seeds. The seeds were germinated and raised in a controlled environment to ensure maximum survival and proper identification (see the photo).	Provides a **controlled environment** for the vulnerable first stage of growth and ensures every plant is tracked and handled according to strict WCR protocols.
Genotyping/Hybridity Check	While in the nursery phase, leaf samples were collected from the young seedlings assigned with Unique Identifier code (UIC). This is a crucial quality control step where the DNA of the seedlings is tested (genotyped) to confirm their pedigree and hybridity (that they are indeed the product of the intended cross).	**Quality assurance** using modern molecular tools; prevents mislabeling and ensures the genetic integrity of the field trial population.
Transplanting to Field	After successfully passing the quality checks in the nursery, the seedlings were ready for the next phase. RAB scientists began selecting and transplanting these small trees from the nursery into established experimental **field trial sites** by **early 2024** (March 2024).	Signifies the end of the nursery phase and the start of the **phenotyping** (performance evaluation) phase, where the plants will grow and produce data over the next 5-6 years.

B. The field performance evaluation phase

The performance evaluation of the WCR Innovea breeding materials in the field is the core purpose of the field trials hosted by RAB .This phase, also known as phenotyping, is a long-term, rigorous, and highly standardized process crucial for advancing the entire global breeding network. The performance evaluation phase began when RAB, along with other partners, transplanted the genetically unique seedlings from the Innovea nursery into designated experimental field sites, a process that commenced in early 2024, and the 1st phase of field evaluation will end in 2028. The key activities for field performance evaluation focus on

1. Field Establishment and Management, including Transplanting and Trial Installation: RAB successfully transplanted the first wave of Innovea seedlings from the nursery into established **field trial plots,** and it was done in March 2024.

2. Trial Maintenance: Maintaining the plots according to strict global standards to ensure environmental factors (e.g., fertilization, pruning) and erratic weather patterns do not skew the genetic performance data. (done March 2024 up to now).

3. Continuous Phenotyping (Data Collection): RAB scientists collect standardized, multi-year data on key performance indicators

Performance Indicator	Specific Phenotyping Activity	Done so far
Disease Resistance	Scoring severity and incidence of major endemic diseases, especially Coffee Leaf Rust (CLR) and Coffee Berry Disease (CBD).	Done: August 2024, March 2025, and August 2025
Plant Architecture	Measuring plant height, canopy diameter, and growth rate to inform efficient farm management.	Done September 2024, March 2025, and September 2025
Yield & Productivity	Annual measurement of cherry yield (kg/tree) and assessment of bean quality (e.g., screen size).	Started in October 2025
Cup Quality	Collecting, processing, and standardizing green coffee samples for sensory analysis (cupping) by WCR's quality evaluation partners.	TBD upon sufficient sample size
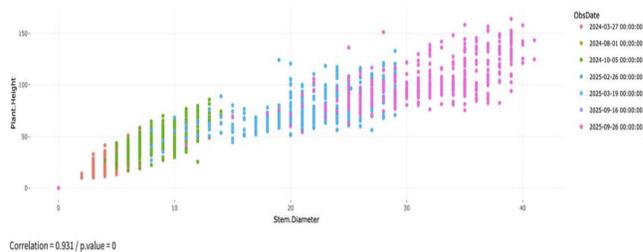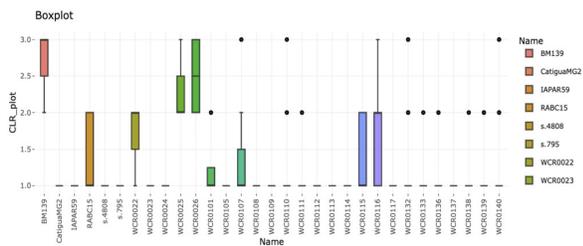
III. Challenges and Limitations

A.   **Establishment & Agronomic Challenges: The most important challenge is the current obvious weather variability.** The challenges associated with unpredictable weather patterns in Rwanda's coffee-growing regions include (1) Erratic Rainfall Patterns: Fluctuations in the timing, intensity, and distribution of rainfall are common; (2) Drought/Insufficient Rain: Causes stress on young plants in the trials, inhibits proper flowering, or leads to fruit abortion, resulting in lower and unreliable yield data for the tested varieties.

B. **Research & Analysis Limitations:** Limited skills in genomic data analysis, which are expected to be mitigated by the WCR scientific team.

IV. Next Steps and Future Goals

A. **Addressing Research Limitations.** RAB will continue to attend the capacity building program at WCR to address the current and future limitations

B. **Future Data Collection & Analysis:** Continued phenotyping process with more breeding traits addition to the stem diameter, plant height, rust scores, and yield, according to predefined descriptors (cfr phenome).

C. **Contribution to Long-Term Objectives:** *The table below summarizes how the upcoming activities will contribute to identifying and selecting new high-performing, climate-resilient coffee varieties for the nation's coffee sector*

Upcoming/Ongoing Activity	Contribution to Selection	Outcome for Rwanda Coffee Sector
Phenotyping: Continued measurement of growth, disease, and yield.	**Identifies Stability:** Pinpoints crosses that show stable, superior yield and disease resistance specifically under Rwandan conditions.	**Adaptation and Profitability:** Farmers receive varieties proven to yield well and resist key diseases, increasing profitability and production stability.
Cupping/Quality Analysis: Evaluating the harvested coffee samples.	**Verifies Market Suitability:** Ensures high yield and resilience are matched with the high-quality cup profiles demanded by the international export market.	**Market Access:** Maintains Rwanda's reputation for premium quality, securing better prices for farmers.
Genotyping: Contributing samples and applying molecular quality control.	**Accelerates Selection:** Powers **Genomic Selection** and confirms plant identity, drastically reducing the time required to select a finished variety (from ~25 years to potentially <10 years).	**Speed of Innovation:** Provides Rwandan farmers with new, climate-resilient varieties *faster* than ever before, addressing the urgent threat of climate change.

D. Plan for Improved Materials from RAB Sites

RAB's plan follows the established WCR model, where the global network develops the initial superior breeding populations, but the final selection and release of finished varieties remain under the control of the national partner. The plan will involve the deployment of hybrid varieties and the inclusion of Innovea

materials into Rwanda's varietal development program. The Compelling Plan for Maximizing Innovea Material for Rwanda is the compelling plan is divided into three interconnected tracks designed to maximize the genetic gain from the first Innovea cycle:

Track 1: Hybrid Variety Fast-Track Selection and Release

Phase	Activity at RAB (Timeframe)	Goal for Rwanda
1. Hybrid Elite Selection	Intensive data analysis combining phenotype (yield, cup quality, rust/CBD scores) with genotype (Genomic Selection) to identify the top 1% of F1 hybrids that show stable, superior performance in Rwanda.	**Immediate Genetic Gain**: Quickly select the most productive and resilient hybrids for rapid national promotion.
2. Pre-Commercial Hybrid Trials	The selected F1 hybrids are moved into multi-location, pre-commercial trials across key Rwandan coffee zones. Focus is on confirming stable yield, quality, and disease resistance under diverse farming conditions.	**Risk Mitigation:** Verify that the high performance holds across different environments before full release, ensuring farmer success.
3. Hybrid Commercialization	Partner with private sector and NAEB to establish a robust and secure clonal propagation system for the identified elite hybrids (as F1 hybrids must be multiplied asexually). Officially release the new varieties to the sector.	**First Wave of Resilience**: Deliver the first wave of high-performing, climate-ready varieties to farmers quickly (as early as 2033).

Track 2: Inbred Line Development for Sustainability

Phase	Activity at RAB (Timeframe)	Goal for Rwanda
1. Inbred Line Initiation	Select superior F2, F3, and F4 generations derived from the Innovea crosses that are showing high genetic value. Initiate **self-pollination and subsequent selection** for uniformity and stability over several generations.	**Long-Term Seed Security:** Develop stable lines that can be multiplied by seed, making them easier and cheaper for farmers to access and propagate.
2. Line Testing and Stabilization	Conduct rigorous field trials and molecular screening on the advanced inbred lines. Only lines that consistently show **homozygosity** for key desirable traits (like CBD resistance) will be advanced.	**Seed Quality Control:** Ensure the purity and predictability of the genetic material, providing farmers with a reliable, standardized product.
3. Inbred Release & Integration	Release the stabilized inbred lines as national varieties. Integrate them into RAB's existing germplasm to serve as "parent stock" for future crosses and breeding cycles.	**Sustainable Pipeline:** Create a sustainable source of genetic diversity and superior parent stock for the next 50+ years of Rwandan coffee breeding.

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