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1. ACKNOWLEDGEMENTS

The key project partners in Africa are three regional centres of excellence specialising in plant breeding of priority food crops and the post graduate education of plant breeders in Africa, namely: African Centre for Crop Improvement (ACCI) at the University of KwaZulu Natal in southern Africa; West Africa Crop Improvement Centre (WACCI) at the University of Ghana; and the Alliance of Bioversity International and the International Centre for Tropical Agriculture and the Pan African Bean Research Alliance (CIAT/PABRA). In addition to these regional and Pan African entities, other important DLB partners include the Ethiopian Institute of Agricultural Research (EIAR) and Haramaya University, Ethiopia; the Ugandan National Agricultural Research organization (NARO) and Makerere University, Uganda; and the University of Nairobi, Kenya. The project team also works with an extensive DLB Community of Practice of more than 400 plant breeders working in national agricultural research institutes and universities throughout Africa.

The DLB project gratefully acknowledges the contributions of these African universities and Pan Africa and regional centres of excellence in plant breeding who have been the key project partners in Africa since the commencement of the DLB project in 2014. The project also values the many contributions of the cadre of plant breeders in Africa who have participated in various DLB events and are now the community of practice implementing a demand led breeding approach in their national breeding programs.

The DLB project is supported by an Alliance for Food Security, formed in 2014 by the Australian Centre for International Agricultural Research (ACIAR) and the Crawford Fund, Australia; and the Syngenta Foundation for Sustainable Agriculture (SFSA), Switzerland. The project is managed by the University of Queensland on behalf of its three co-sponsors and the many partners in Africa. The contributions of the co-sponsors in enabling the achievements of the DLB in Africa are gratefully acknowledged.

News on project activities and access to educational resources and professional development opportunities are available at: https://www.demandledbreeding.org and at: https://www.demandledbreeding.org/what-we-do, https://www.demandledbreeding.org/where-we-work https://www.demandledbreeding.org/our-approach

2. EXECUTIVE SUMMARY

The purpose of the "Demand led Breeding" (DLB) project is to contribute to the transformation of African agriculture by enabling small scale farmers to participate in local and regional markets by increasing the availability and adoption of high performing plant varieties that meet market demands and are resilient to the challenges of climate change and extreme weather events.

The DLB project does this by seeking to understand and learn from best practices in plant variety design worldwide and adapt these practices for use in varietal development in Africa. The project tests the thesis that market led product development by public and private sector R&D entities will lead to increased availability and higher uptake of new, high performing crop varieties that enhance productivity, profitability, and resilience to climate change and other environmental constraints for priority food crops in target countries and environments.

The intended research outcome is that plant breeders in Africa will adopt more demand-led approaches to plant breeding to respond both to the preferences of farmers, consumers, and others along the value chain and the need to develop more climate resilient crop varieties. A three-pronged approach has been used to reach the intended outcomes:
(i) Best practices in plant variety design: to identify and adapt best practices in plant variety design worldwide for use in plant breeding programs in Africa
(ii) Education and training: to strengthen capacity within breeding programs on demand led variety design through education and professional development opportunities for plant breeders; and
(iii) Policy and advocacy to provide evidence to support new policy development and investments in plant breeding that will help generate more high performing varieties to meet emerging market demands, with emphasis on Africa.

In the area of education and training, a DLB educators group developed a new curriculum on demand led plant breeding, now consisting of nine modules covering various aspect of DLB. These modules are all available on line via the project web site at https://demandledbreeding.org for use by individual breeders, as well as being incorporated into the post graduate education programs for plant breeders undertaking MSc and PhD programs at the Universities of KwaZulu Natal (ACCI-southern Africa), University of Nairobi, Kenya (eastern Africa), and University of Ghana, (WACCI-West Africa). The DLB curriculum was further developed into a textbook published by CABI UK, as "*The Business of Plant Breeding – Market led approaches to plant variety design in Africa (2017).* The textbook has been distributed to more than 500 plant breeders in countries in eastern, southern and West Africa, via the DLB partners in each region.

The project also developed a Product Profiling "tool kit "as a guide for plant breeders on the preparation of Product Profiles (PPs), to guide the setting of breeding objectives, that take account of farmer and consumer preferences, and the special needs of women farmers. Over 20 PPs have been developed by African plant breeders who are members of the DLB Community of Practice, covering a range of crops and countries across Africa. These crops include PPs for beans in several countries, in conjunction with bean breeders who are members of the PABRA networks in eastern and southern Africa; tomato in West Africa, in a partnership between WACCI, University of Ghana and the World Vegetable Centre, Benin; and PPs to guide breeding in other crops of importance in Africa including cassava, coffee, cowpea, green gram, groundnut, Kersting's groundnut, maize, pigeon pea rice, soybean and sorghum. Other outputs of the project include examples of business cases to encourage innovative investments to ensure more sustainable financing of plant breeding in Africa; market studies to identify traits of interest to women, such as reduced cooking time in beans. The overall intent is to demonstrate that a demand and market led approach to new varietal development is a benefit towards achieving more productive and sustainable agricultural systems in the countries of Africa. Further information is available on the project website at: www.demandledbreeding.org

3. BACKGROUND AND RATIONALE

Context

This project originated in response to a study on the adoption of new varieties of 20 crop species in 30 countries of Africa over 15 years. The CGIAR Independent Science and Partnerships Council commissioned the study in 2013. The main findings were that the average adoption rates of more than 1150 crop varieties developed by CGIAR centres and their partners in Africa between 1995-2010 was about 35% (Walker et al., 2014) **(Table 3.1).** This low adoption rate of new varieties in Africa contrasts with about 60% adoption of new crop varieties in Asia and 80% adoption in South America. The study concluded that new maize varieties had the highest adoption, being grown in 20 countries in eastern, central, southern and West Africa. New varieties of field pea, which are mainly grown in Ethiopia, had the lowest adoption (1.5%). Adoption of modern varieties was highest in Zimbabwe and lowest in Mozambique.

Variety adoption: Constraints and issues:

Many studies have been conducted to determine the reasons for the low adoption of new technologies in Africa. Most have focused on micro factors related to on-farm resources, farmer behaviour, farm to market-related factors, and variables related to access to services. Farmer preferences as factors that influence the decision to adopt new varieties have been considered in some studies.

Surprisingly, there are few studies that address specific elements of varietal design and their effects on farmer adoption of new varieties. Typically, some information is available from ex-ante impact studies investigating the benefits from development interventions. These studies demonstrate that farmer preferences for local varieties are driven by the importance of consumer-based traits over varieties with yield improvements and resistance to biotic stresses, but which lack the core consumer requirements. For example, in Kenya, farmers prefer sorghum varieties with desirable consumer attributes such as taste, brewing quality and ease of cooking and this influences new varietal adoption of sorghum in Kenya.

With this background, the Demand led Breeding project was developed in 2014 to investigate the proposition that a more demand led approach to varietal development would lead to new, high performing varieties (HPVs) that better responded to farmer needs and market demands, and hence it would be more attractive for farmers to grow these new varieties.

An Alliance for Food Security in Africa was formed in 2014 by the Australian Centre for International Agricultural Research (ACIAR) the Crawford Fund, Australia, and the Syngenta Foundation for Sustainable Agriculture (SFSA) Switzerland to support the DLB project. The Alliance joined with African, Australian, and international research institutes and universities as partners in contributing towards the transformation of African agriculture through crop improvement. The project is managed by the University of Queensland (UQ) Australia and implemented in conjunction with several African partners, including national agricultural research institutions, African universities, as well as regional and international R&D programs.

Table 1.1 *Adoption of modern varieties of food crops in Sub-Sahara Africa in 2010*

Crop	***Country observations***	***Total area (ha)***	***Adopted area (ha)***	***% Modern varieties***
Soybean	*14*	*1,185,306*	*1,041,923*	*89.7*
Maize-WCA	*11*	*9,972,479*	*6,556,762*	*65.7*
Wheat	*1*	*1,453,820*	*850,121*	*62.5*
Pigeon pea	*3*	*365,901*	*182,452*	*49.9*
Maize-ESA	*9*	*14,695,862*	*6,470,405*	*44.0*
Cassava	*17*	*11,035,995*	*4,376,237*	*39.7*
Rice	*19*	*6,787,043*	*2,582,317*	*38.0*
Potatoes	*5*	*615,737*	*211,772*	*34.4*
Barley	*2*	*970,720*	*317,597*	*32.7*
Yams	*8*	*4,673,300*	*1,409,309*	*30.2*
Groundnut	*10*	*6,356,963*	*1,854,543*	*29.2*
Bean	*9*	*2,497,209*	*723,544*	*29.0*
Sorghum	*8*	*17,965,926*	*4,927,345*	*27.4*
Cowpeas	*18*	*11,471,533*	*3,117,621*	*27.2*
Pearl millet	*5*	*14,089,940*	*2,552,121*	*18.1*
Chickpea	*3*	*249,632*	*37,438*	*15.0*
Faba bean	*2*	*614,606*	*85,806*	*14.0*
Lentils	*1*	*94,946*	*9,874*	*10.4*
Sweet potato	*5*	*1,478,086*	*102,143*	*6.9*
Banana	*1*	*915,877*	*556,784*	*6.2*
Field peas	*1*	*230,749*	*3,461*	*1.5*
Total/weighted average	***152***	***107 721 630***	***37 969 577***	***35.25***

Source: Walker et al 2014

Rationale

The **purpose** of the "Demand led Breeding" (DLB) project is to contribute to the transformation of African agriculture by enabling small scale farmers to participate in local and regional markets, by increasing the availability and adoption of high performing plant varieties that meet market demands and are resilient to the challenges of climate change and extreme weather events.

Research question: The DLB project seeks to understand and learn from best practices in plant variety design worldwide. The project tests the thesis that market led product development by public and private sector R&D entities will lead to increased availability and higher uptake of new, high performing crop varieties that enhance productivity, profitability, and resilience of priority crops in target environments.

Research outcome: The intended research outcome is that plant breeders in Africa will adopt more demand-led approaches to plant breeding to respond both to the preferences of farmers, consumers, and others along the value chain and the need to develop more climate resilient crop varieties.

Research strategy and approach

Central to the transformation of agriculture in Africa is identifying market demand and developing new products with suitable characteristics to meet market requirements. Such demand can originate from producers, processors, and/or consumers. A more customer focussed approach to plant varietal design will influence public and private sector plant breeding programs. Decisions on determining the preferred traits for adoption to breed new varieties are paramount for success. Private sector companies have considerable experience worldwide in developing new crop varieties that fit the needs of customers. This experience in plant variety design can add value to public as well as private sector breeding programs in emerging economies. As economies mature and markets expand, it can be expected that the private companies will also become increasingly involved in breeding new high performing varieties (HPVs) to meet customer requirements and market demand in emerging economies.

Public and private investments in R&D could have greater benefits for small-scale producers if market and consumer demand-led approaches are used to contribute towards priority setting and, specifically, to drive the science targets for crop improvement. This concept involves catalysing a process to define and implement demand-driven targeting for selected countries, crops, and markets.

Market drivers are defined broadly as the major factors that can influence the uptake of output products by smallholder farmers and their value chains, e.g. economic, biological, agronomic, environmental, public policy and trade considerations, social and cultural factors. Strengthening the use of market drivers to influence science programs can enable more output products to have greater 'active pull' and uptake by farmers and stakeholders in the value chain. Additional merits of advocating a new demand driven approach to R&D include more confident priority setting with greater buy-in from R&D management, national governments, regional organizations, international partners, public and private investors.

Creating dependable demand-led specifications with success criteria for genetic improvement of crops will require innovative thinking as well as improved access to and use of a broad range of specific, applicable, and quantifiable local, national and international data sources. Leveraging and combining the expertise, know-how and goodwill from a range of private and public organizations in Africa and internationally are vital ingredients for success.

A demand led approach to R&D in relation to crop improvement is illustrated in the pathways to impact illustrated in Figures 1 and 2 below. These pathways can be adapted towards the needs and seed systems appropriate for specific types of crops, such as horticultural crops, cereals, grain legumes or roots and tubers.

The Demand led breeding project aims to:

- Encourage market-led approaches to determine breeding targets within crop improvement programs, especially in Africa. This will enable research leaders to have access to and interpretation of high-quality data about a range of business drivers and views of stakeholders. These business drivers and stakeholders will influence demand and determine the rate of uptake of new technologies, specifically new varieties of crops grown for food security and/or income generation;
- Develop, communicate and disseminate a set of new decision support tools that will enable R&D programs in Africa to obtain and evaluate information about market demands and use this information to set targets and product specifications within plant breeding programs;
- Expand the use of innovative approaches to plant breeding that drive delivery of new seeds, uptake and purchasing of new varieties, technologies, and other inputs by smallholder farmers in Africa.

The project aims to understand and learn from best practices in plant variety design globally, in the private sector and in leading public research agencies with outstanding track records in uptake of their research outputs. The project tests the thesis that market-led product development by public and private sector research agencies will lead to increased availability and higher levels of uptake of new high performing crop varieties that enhance productivity and profitability in the target crops in selected countries of Africa.

Figure 1 Demand driven R&D approaches – illustrative pathway to impact

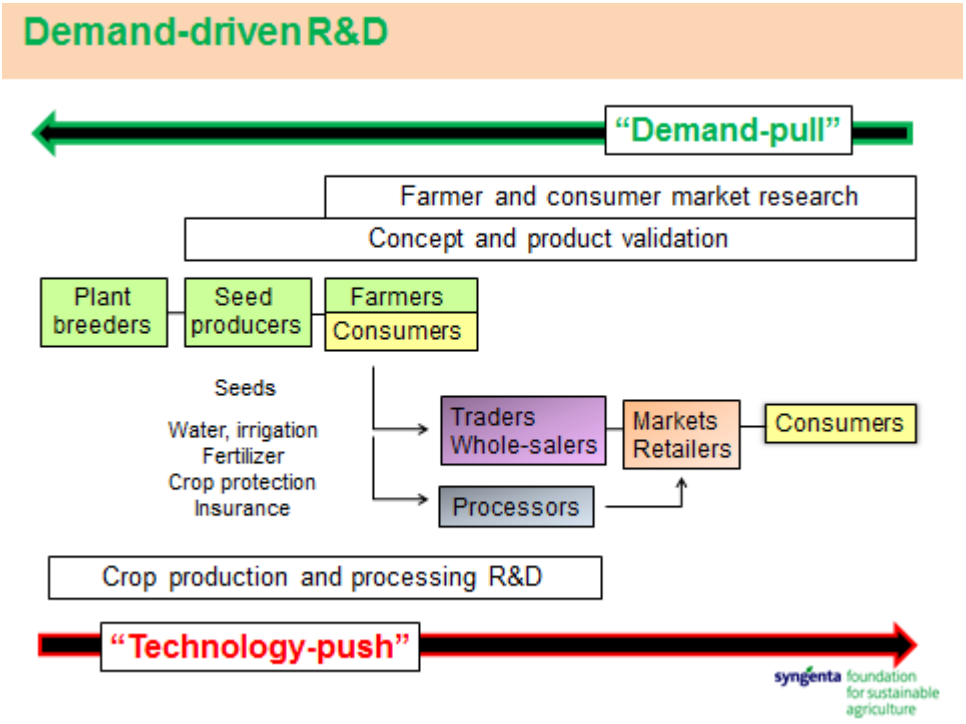
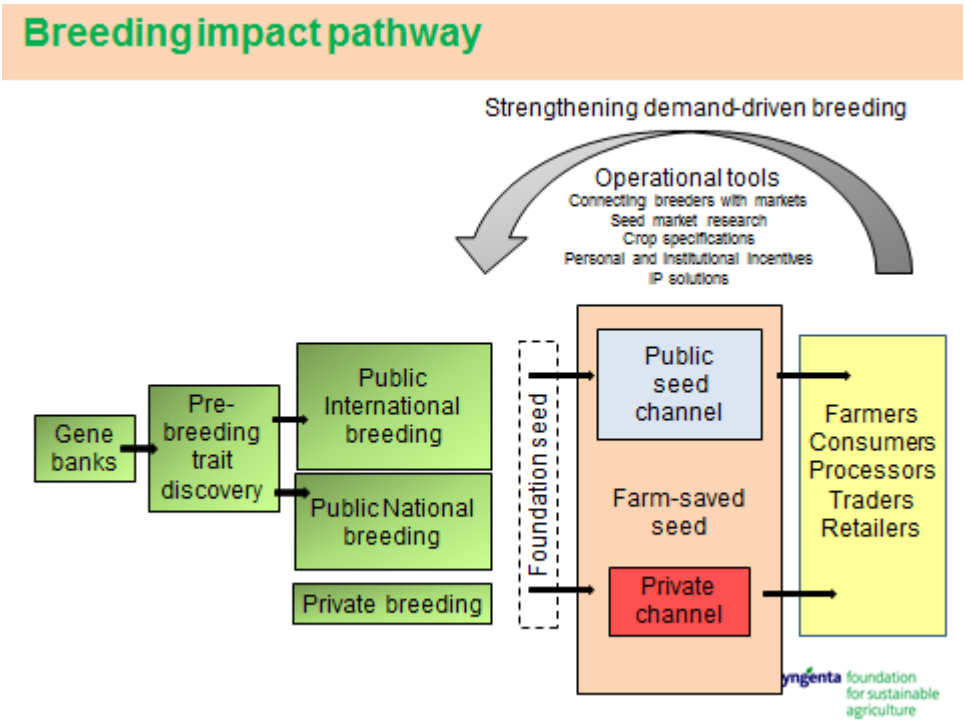


Figure 2 Plant breeding impact pathway – illustrative pathway to impact



4. OBJECTIVES

Project Goal:
To contribute to the transformation of African agriculture by enabling small scale farmers to better participate in local and regional markets, by increasing the availability and adoption of high performing plant varieties that meet market demands. The intended research outcome is that plant breeders in Africa will adopt more demand-led approaches to plant breeding that respond to the preferences of farmers, consumers, and others along the value chain.

Project Objectives: The three project objectives are:

Objective 1: Best practices in plant variety design: To enable plant breeders to develop new high performing varieties that meet customer requirements and market demand, by having increased access and capability to implement state-of-the art knowledge, methodologies, and best practices from the public and private sectors on demand led plant variety design.

Objective 2: Education and training: To build capacity within plant breeding programs on demand led variety design, through strengthening education and training programs for plant breeders, including through post graduate curriculum development and new professional development programs on demand led plant variety design for plant breeders in Africa.

Objective 3: Policy analysis and advocacy: To provide evidence to support new policy development and investments in plant breeding that will help generate more high performing varieties to meet emerging market demands, with emphasis on Africa.

Research Questions
The project seeks to answer three research Questions:

Research Question 1
What are best practices in demand-led breeding and how can these be implemented successfully in breeding programs for target crops in selected countries of Africa?

Research Question 2:
What should be the course content on demand led plant breeding for: (i) post graduate plant breeding education at African universities; and (ii) new professional development programs for plant breeders in Africa?

Research Question 3:
What are the essential policies that underpin demand led breeding programs? What evidence is required when developing business cases to support increased public and private investments in demand-led plant breeding on target crops in selected countries of Africa?

5. METHODOLOGY

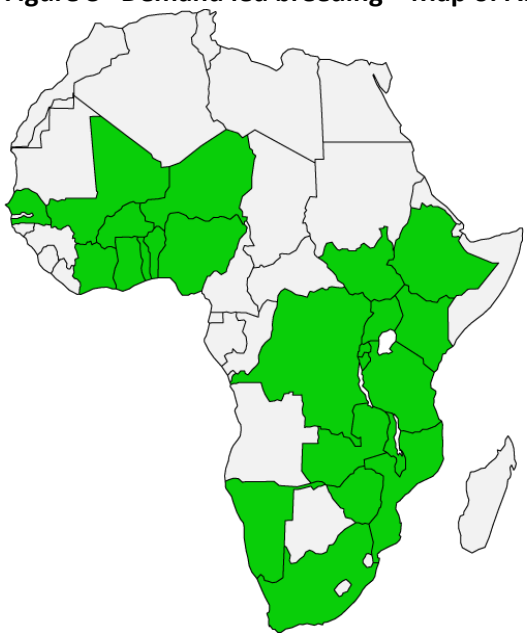
Implementation Partners in Africa

The DLB project is being implemented as a Pan African project, with partners throughout eastern, southern and West Africa. The key partners are a combination of institutional partners and individual participants. The institutional partners are national, regional, and international entities that are active in developing new plant varieties of food crops important for food and nutritional security in the countries of Africa.

Institutional partners: The key project partners in Africa are three regional centres of excellence specialising in R&D for new varietal development, and the post graduate education of plant breeders in Africa, namely: African Centre for Crop Improvement (ACCI) at the University of KwaZulu Natal in southern Africa; West Africa Crop Improvement Centre (WACCI) at the University of Ghana; and the Alliance of Bioversity International and the International Centre for Tropical Agriculture (CIAT) and the Pan African Bean Research Alliance (CIAT/PABRA). In addition to these regional and Pan African entities, other important DLB partners include the Ethiopian Institute of Agricultural Research (EIAR) and Haramaya University, Ethiopia; the Ugandan National Agricultural Research organization (NARO) and Makerere University, Uganda; and the University of Nairobi, Kenya.

Individual participants: The individual participants are primarily plant breeders working within national agricultural research systems (NARS), universities or private sector seed companies in Africa. The individual breeders come together in a DLB Community of Practice, comprised of some of the 400 DLB alumni who participated in the 26 DLB educational workshops conducted under the auspices of the project during 2015-2022. The DLB team, led by a DLB Pan Africa Coordinator located in Nairobi Kenya, is working with the members of the community of practice, through eight crop-orientated working groups, to mainstream demand led breeding approaches within national plant breeding programs for a range of crops and environments in Africa. These working groups are organised around the following crops: Beans; Forages and orphan crops; Horticultural crops and ornamentals; Maize; Millets and wheat; Nuts and peas; Rice; Roots and tubers. Further details are available at: Http://www.demandledbreeding.org

Figure 3 Demand led breeding – Map of Africa showing locations of DLB activities



Methodology for Objective 1

Objective 1 Best practices in plant variety design focuses on the identification and implementation of best practices in demand-led breeding for target crops and selected countries of Africa.

It addresses **Research Question 1:** "*What are best practices in demand-led breeding and how can these be implemented successfully in breeding programs of selected crops in target countries in Africa?"*

The research under this objective tests the hypothesis that it is possible to identify best practices in demand led breeding (DLB) from successful plant breeding programs in the private and public sectors worldwide and apply these new approaches to breeding programs on target crops in selected countries of Africa; and that this will result in the development of new varieties more responsive to market demands, with higher rates of adoption and use, and leading to increased productivity and profitability of crop agriculture for small scale producers.

The intended **research outcome** is that plant breeders in Africa will adopt more demand-led approaches to plant breeding, including in the design of new plant varieties that respond to the preferences of farmers, consumers, and others along the value chain.

Best practices in DLB include the systematic use of product profiles to define the priority traits identified through consultations with farmers, consumers, processors, traders, and others in the value chain for specific crops and countries. The breeding programs can then verify the achievements of the desired product profiles by establishing the technical data by which the performance of new varieties for specific traits can be measured in comparison with the check variety (e.g., a farmer preferred variety). Such technical data also form part of the communications plan to promote a new variety and its desirable attributes with seed producers and traders, farmers, processors, and consumers in the crop's value chain.

Target crops/countries for implementation of best practices within breeding programs

The introduction of best practices in demand led breeding was implemented initially in two crops, as illustrations of new approaches:
(i) **Phaseolus beans**, in conjunction with the PABRA/CIAT regional bean breeding programs in eastern and southern Africa, with emphasis on Uganda and Ethiopia; and
(ii) **Tomatoes** in West Africa, in conjunction with WACCI and the national tomato breeding program in Ghana; and the World Vegetable Centre and its regional tomato breeding program based in Benin.

The aim is to use demand led breeding in these crops to drive the selection of new varieties that are of potential interest to seed companies for multiplication and distribution of high quality seed; and to prioritize future targets for on-going breeding programs.

Emphasis is on:

- Obtaining market research information and preferences from consumers and value chain players in key market segments and translating these into breeding goals and programs.
- Addressing challenges affecting development timelines and varietal release for each of the two target crops in breeding programs in selected countries.
- Creating compelling business cases for investment in the two target crops and engagement by seed organizations and value chain stakeholders.

Promoting best practices in demand led breeding for other priority crops in Africa

Best practices in demand led breeding are also being promoted by partnering with national, regional, and international breeding programs on other crops in Africa including cassava, maize, and sorghum. Initial best practices focus on developing product profiles for new varieties of each crop to establish breeding targets and technical standards to measure and verify the performance of new varieties in relation to key traits (including yield) in comparison with a check variety currently grown by farmers. This performance data is useful in the promotion of new varieties.

The breeding programs with which the project partners worked were identified in consultation with African partners, especially the DLB alumni of breeders of these crops who were introduced to the concepts of demand led breeding through the project's early (Phase 1) education and training programs during 2015-19.

Methodology for Objective 2

Objective 2: Education and training: To build capacity within plant breeding programs on demand led variety design, through strengthening education and training programs for plant breeders, including through post graduate curriculum development with African university faculty; and developing new professional development opportunities on demand led plant variety design for plant breeders in Africa.

This objective addresses **Research Question 2:** *What should be the course content on demand led plant breeding for: (i) post graduate plant breeding education at African universities; and (ii) new professional development programs for plant breeders in Africa?*

The intended **research outcome** is that plant breeders in Africa will adopt more demand-led approaches to plant breeding, including in the design of new plant varieties that respond to the preferences of farmers, consumers, and others along the value chain.

A comprehensive education and training program has been developed by the DLB team since 2015 to build capacity within plant breeding programs in Africa on demand led variety design. This objective is being met by: (i) producing and disseminating new education and training materials related to the implementation of demand-led breeding programs; and (ii) providing new professional development opportunities for plant breeders in Africa.

This objective targets education and training activities and outputs in two main areas:
(1) **Development of education and training materials on demand led breeding** for inclusion in the curricula of post graduate plant breeding programs at African universities; and for use in professional development activities with plant breeders working in national, regional, and international crop improvement programs in Africa.

(2) **Advanced educational modules** on additional aspects of demand led breeding, including gender, diversity, and inclusivity in plant breeding, for use in post graduate university programs and/or new professional development opportunities to support practicing plant breeders and related crop improvement professionals, mainly those working within African universities and national plant breeding programs in Africa.

Professional Development Opportunities for Plant Breeders in Africa
The project aims to identify the needs and opportunities for continuing professional development to support plant breeders and associated crop improvement professionals, mainly those working in

national agricultural research systems (NARS) in Africa. Alumni from the DLB project's education and training activities in 2015-22 consists of 400 professionals working on 31 crops in 28 countries of Africa.

The project consulted with the DLB alumni of some 400 scientists as to the areas in which they would welcome continuing professional support and how this support could best be delivered to breeding teams working throughout the various countries of Africa. As a result of these consultations with the DLB alumni and others in the field, the DLB African educators' group identified how best to communicate with and professionally support the "Community of Practice" of demand led breeders in Africa.

Methodology for Objectives 3

Objective 3: Policy analysis and advocacy: To provide evidence to support new policy development and investments in plant breeding that will help generate more high performing varieties to meet emerging market demands, with emphasis on Africa.

Objective 3 addresses Research Question 3:

What are the essential policies to underpin demand led breeding programs? What evidence is required for developing business cases to support increased public and private investments in demand-led plant breeding on target crops in selected countries of Africa?

This objective aims to influence African policy makers, governments, investors, and international development agencies to increase the use of demand-led approaches in plant breeding, with the aim of increasing the availability and adoption of high performing varieties in Africa. The uptake of new varieties in Africa currently lags well behind Asia and Latin America (30% in Africa versus 60 to 80% uptake in Asia and Latin America, respectively).

Objective 3 addresses policy issues that can accelerate or limit the speed of release and adoption of new varieties. Advocacy, policy briefs, promotional materials and communication activities will be targeted at four audiences, each of whom can influence the enabling environment. The target audiences for policy analysis and advocacy are:

(i) Breeders and crop improvement professionals in the public and private sectors
(ii) Institutional R&D leadership and R&D management
(iii) Government officials, particularly policy makers and regulators, including members of variety release panels; and
(iv) Investors in plant breeding in the public and private sectors, nationally and internationally.

The approach to achieving the activities and outputs of this objective focus on:

- **Developing a methodology and evidence base for creating new business cases for increasing public and private investments in demand led breeding:** The activities and outputs cover developing an innovative methodology and evidence base for breeders and R&D professionals to create compelling business cases and proposals for public and private sector investments in plant breeding. The methodology will use quantitative data and other evidence on the range of benefits that result from the development of new crop varieties that respond to market demand, and lead to increases in genetic gains, productivity, and profitability of crops able to contribute towards the transformation of smallholder agriculture in Africa.

  In developing the framework for making the business cases for further investments in demand led plant breeding, expertise was sought from leading organizations in this field from both the private and public sectors, including IFPRI and its IMPACT and other econometric models. The outputs

from this component of Objective 3 will be used in developing a new education module (Module 10) on "*Making the Case for Investing in Demand led Breeding"*.

- **Developing examples of business cases for specific crops and selected countries:** These examples are being developed by partners in Africa, especially for the target crops and countries selected for DLB implementation under Objective 1. Three business cases have been prepared, on beans in Uganda and Ethiopia; and tomatoes in Ghana.

- **National and regional policy and advocacy activities:** The policy and advocacy activities focus on supporting national policy improvements to encompass incorporating demand led approaches to plant breeding in Ethiopia (through the Ethiopian Agricultural Research Institute (EARI) and Ghana (in conjunction with WACCI and the national research agency (CSIR)). Regionally, the African Centre for Crop Improvement (ACCI) at the University of KwaZulu Natal will lead a regional approach to policy and advocacy on demand led breeding in southern Africa.

Master Class for R&D leaders and policy makers: It is proposed that national and regional policy and advocacy activities be linked with developing and conducting a Master Class on "The Business of Plant Breeding", in conjunction with the Crawford Fund. The Master class program will include a substantive component on making the case for future investments in demand led breeding and ways of measuring the likely return on such investments. The DLB project is working with the UQ agribusiness group in developing the content of the Master Class. This group has expertise and developing country experience (including in other ACIAR projects) in introducing systems thinking in identifying benefits and unintended consequences of introducing innovations into agricultural value chains. The group also has expertise in the various methodologies and models for cost/benefit analysis for ex ante and ex post evaluations of the impact of new crop varieties being introduced into agricultural systems.

6. ACHIEVEMENTS

The Achievements of the DLB project during Phase 2 (2019-2023), in relation to activities and outputs/milestones, are summarised in:

Table 6.1 Achievements: Demand led Breeding Phase 2 2019-2023

Table 6.1 ***Achievements: Demand led Breeding Phase 2 2019-2023***

Objective 1: To identify and implement best practices in plant variety design

no.	activity	outputs/ milestones	completion date	Comments
1.1	Develop Product Profiles (PPs) and Technical Data sheets (TDs) for bean breeding program in Ethiopia in consultation with value chain participants and technical experts	**Implementing best practices for bean breeding in Ethiopia** Develop at least 2 new PPs and 2 accompanying TDs for new bean varieties in target markets	December 2020	**Completed by CIAT/PABRA**: Dr J C Rubyogo 2 PP and TDs for two new bean varieties in Ethiopia completed, available at: https://www.demandledbreeding.org/_files/ugd/aff4c0_481d35ab5359474eb3a71652d31583e1.pdf https://www.demandledbreeding.org/_files/ugd/aff4c0_690f8d4a42f747ae8a17506c153299c5.pdf
1.2	Conduct market research with consumers in Uganda on bean cooking time Final report on consumer preferences in bean cooking time	**Implementing best practices for bean breeding in Uganda** Market research study conducted on reducing bean cooking time, to determine targets (specifications) for breeding new bean varieties	December 2021	**Completed by CIAT/PABRA**: Dr Enid Katungi and Dr Clare Mukankusi Fieldwork for market survey on bean cooking time in Uganda completed in 2021. Market research report prepared, peer reviewed and revised. **Final market survey report** completed, April 2022. **Slide set** prepared as educational resource and posted on project web site https://www.demandledbreeding.org/slide-presentations https://www.demandledbreeding.org/_files/ugd/aff4c0_274084f239dc4399ad9502c1ff9d6d34.pdf

1.3	Develop PPs and TDs for bean breeding programs in Uganda in consultation with value chain participants and technical specialists	**Implementing best practices for bean breeding in Uganda** Develop at least 2 new PPs and 2 accompanying TDs for new bean varieties in target markets	December 2021	**Completed by CIAT/PABRA and NARO Uganda**: Dr Clare Mukankusi (CIAT) and Dr Stanley Tamusange Nkalubo (National Agricultural Research Organization (NARO) PPs of two bean varieties suitable for Uganda completed and included as examples in DLB publications on *Product Profiles: A Practitioners Guide, and* available at https://www.demandledbreeding.org/_files/ugd/9abdc5_e5996dcf55794df889bbd6c88e0a6e22.pdf Demand led breeding approaches now incorporated as standard operating practice within national bean breeding program in Uganda; and within CIAT/PABRA regional bean breeding network in eastern Africa. In Uganda, there is a growing demand for nutritious fresh green bean pods, especially in urban markets. The new bean varieties have been designed to meet this demand and farmers and marketers are growing the new bean varieties that respond to this new market opportunity.
1.4	Develop PPs and TDs for the tomato breeding program in Ghana and other tomato breeding programs in Africa in consultation with value chain participants and technical experts	**Implementing best practices in tomato breeding in Africa** Develop at least 2 new PPs and 2 accompanying TDs for new tomato varieties in target markets	June 2021	**Completed by WACCI,** University of Ghana: Prof P Tongoona Two new PPs for tomato varieties in West Africa developed and included as examples in the DLB publication on *Product Profiles: A Practitioners Guide (2020)* and available at https://www.demandledbreeding.org/_files/ugd/9abdc5_68c0b146e2ea46ea92b7de1f406c34ce.pdf https://www.demandledbreeding.org/_files/ugd/9abdc5_0372fec9846047d1973d7dc8268d2b71.pdf

1.5	Develop PPs and TDs in conjunction with breeding programs, value chain participants and technical experts for at least 3 additional priority crops in Africa (e.g., cassava, sorghum and one other crop)	**Promoting best practices in DLB for other priority crops in Africa** Develop PPs and TDs for 3 additional priority crops in target markets (at least 2 new PPs and 2 accompanying TDs per crop)	December 2023	**Completed, and expanded,** led by Pan African Project Coordinator Dr Nasser Yao **Expanded,** with additional work in progress with breeders to develop additional PPs for a wider range of crops, to promote new varieties with farmer, consumer and/or market preferred traits**.** New PPs are being developed by breeders working on a range of crops in Africa, to introduce demand led breeding approaches to the DLB Community of Practice, through 8 CoP working groups. Some 20 new PPs for varieties of 11 crops have been completed and published on the DLB web site in 2022, and a further 10 PPs are in preparation during 2023. https://www.demandledbreeding.org These new **PPs** include: ***New bean varieties with more rapid cooking time:*** A new (regional) PP has been developed by CIAT/PABRA for breeding new bean varieties with the novel trait of more rapid cooking time, as a guide for further refinement into country-specific PPs for six countries in eastern Africa. These PPs are being developed in conjunction with a related ACIAR project led by CIAT/PABRA and UWA on rapid bean breeding (BRIO breeding) for faster cooking time beans for 6 countries in eastern and central Africa (***Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda***.). A new product profile for a bean variety suitable for ***Zimbabwe*** was also developed, with high iron and zinc content and disease resistance (https://www.demandledbreeding.org/_files/ugd/aff4c0_e3d44252d6604177b788cdbdad497d81.pdf) ***Kersting groundnut:*** Product profile prepared for a new variety targeting short cooking time for urban markets in ***Benin*** and other countries in West Africa (https://www.demandledbreeding.org/_files/ugd/aff4c0_5eba6c39819b488597805afb3edfc7f2.pdf) **Other Crops: Product profiles for cassava, coffee, maize, pigeon pea, sorghum completed** by breeders participating in the DLB Community of practice. All are posted on the DLB project website: https://www.demandledbreeding.org Other product profiles are under development for: **Legumes**: chickpea, lentil**; Vegetables:** kale**,** okra**; Oil crops:** cotton**,** oil palm, soybean; **Roots, tubers, banana:** sweet potato, yam, and plantain.

Objective 2: To build capacity within plant breeding programs on demand led variety design through education and training.

no.	activity	outputs/ milestones	completion date	Comments
2.1	Develop content of an additional unit on *Gender, Diversity and Inclusivity in Demand led Plant Breeding*	Introductory course on DLB – Gender related issues DLB Introductory Course *Unit Module 8: Gender, Diversity and Inclusivity in Plant Breeding*	December 2021	**Completed by CIAT/PABRA**: Drs Eileen Nchanji, Clare Mukankusi and Enid Katungi); and Prof. Paul Kimani (Uni. Nairobi); and Dr Nasser Yao (DLB) Gender, diversity and inclusivity module completed. ***DLB Module 8 Slide set*** as educational resource at: https://www.demandledbreeding.org/_files/ugd/aff4c0_12754ca358304c96a06627a1272f74c2.pdf
2.2	Develop content of the new advanced module on "Creating PPs and TDs," in conjunction with Objective 1, including examples from implementing DLB in a range of crop breeding programs in Africa	DLB Advanced Module 1 (Module 9) - *"Creating Product Profiles and Technical Data Sheets"*	December 2021	**Completed by Pan African Coordinator** – Dr Nasser Yao *Product Profiles Practitioners' Guide,* templates and examples developed and launched via international webinar in August 2020. **DLB Module 9** *Creating Product Profiles and Technical Data Sheets* *https://www.demandledbreeding.org/_files/ugd/aff4c0_835ee5aa7de448d0b1843ceb76d7e24c.pdf*
2.3	Develop content of new advanced module on investing in demand led breeding, in conjunction with Objective 3.	"DLB Advanced Module 2 *"Making the case for investing in demand led breeding"*	December 2023	**In progress, led by ACCI:** Prof Shimelis Hussein ACCI led work in southern Africa, by hosting 2 webinars during 21/22, in conjunction with the DLB educators' group, to provide professional support to plant breeders and R&D leaders in making the case for increasing investments in plant breeding by African governments, private sector & funding agencies. A workshop on innovative investment strategies is being planned for October 31 2023 in Nairobi with DLB project participants and other partners, including AATF, based in Kenya and WAVE, based in Cote D'Ivoire, both potential new partners of the DLB program.
2.4	Consult with DLB alumni on their future professional development needs	Professional development opportunities for plant breeders in Africa Analysis of DLB alumni views on their future professional development needs	December 2023	**In progress, led by Pan African Coordinator** Dr Nasser Yao DLB alumni and members of the DLB Community of Practice has identified two priority areas, where they would value DLB support and educational resources: (1) Developing ***business cases*** to justify future investments in plant breeding; and (2) ***Agri-entrepreneurship***, including identifying ***innovative financing*** mechanisms for breeding, promotion of new varieties and seed systems.

2.5	Develop a strategy and operational plan to communicate with and support the evolving "Community of Practice" on DLB in Africa	A "Community of Practice" on DLB in Africa Strategy and operational plan for communications with a "Community of Practice" on DLB in Africa	December 2021	**Completed and in operation by Pan African Coordinator** – Dr Nasser Yao Communication strategy completed and is being implemented by the DLB team, though various communications channels. CoP: Whatsapp group and social media platform created to expand discussion amongst COP members, through 8 crop specific working groups (https://www.demandledbreeding.org/thematicgroups) DLB team in Africa, led by Pan African Coordinator, developed a refreshed web site in 2021/22 and has responsibility for management of the new DLB website www.demandledbreeding.org
2.6	Consult with DLB alumni breeders to identify promising new varieties from their breeding programs that meet market demands	Promotion of promising new varieties developed by DLB alumni breeders "Africa Seeds" catalogue to be developed and published, including product profiles and supporting technical data, to promote promising new varieties of at least 5 crops	December 2023	**In progress, led Pan African Coordinator** Dr Nasser Yao The promotional modalities for new varieties were modified during 2021 on advice of the DLB team in Africa to focus on producing a Compendium of preferred varieties of key crops across several counties in Africa as being more attractive than a seed catalogue. The first edition of the Compendium will be based on compiling the initial suite of completed DLB PPs of preferred varieties, as identified by COP members, and for which further promotion and seed scaling would be beneficial to increase their availability and wider adoption by farmers. The intended publication date is December 2023.

Objective 3: To provide evidence to support new policy development and investments in plant breeding through policy analysis and advocacy.

no.	activity	outputs/ milestones	completion date	Comments
3.1	Develop new methodology and evidence base for creating business cases, in support of increasing public and private investments in DLB, when applied to individual crops and countries	Evidence-based methodology for creating business cases for increasing public and private investments in DLB.	December 2023	**In progress, led by UQ** Prof Gabrielle Persley and UQ agribusiness team, **ACCI** and **CIAT/PABRA** (linked to Objective 2.3) Framework for "*Making the Case for Investing in Demand led plant breeding"* presented at Australian Plant Breeders Conference, May 2022; Methodology document being finalised with UQ agribusiness group, ACCI (Prof Shimelis Hussien) and CIAT/PABRA (Drs Enid Katungi and J C Rubyogo)
3.2	Apply the new methodology and evidence base from Objective 3.1 to develop a business case for investing in beans in Ethiopia	Business case for investing in bean breeding in Ethiopia	December 2023	**In progress, led by CIAT/PABRA**: Dr J C Rubyogo Bean Business case workshop held with Ethiopian Institute of Agricultural Research (EARI); Business case for Investing in Beans in Ethiopia drafted and undergoing peer review before finalisation. Business Case will be presented at DLB Innovative Investment workshop in Nairobi on October 31 2023
3.3	Apply the new methodology and evidence base from Objective 3.1 to develop a business case for investing in beans in east Africa (e.g. Burundi, Tanzania, Uganda)	Business case for investing in bean breeding in Uganda	December 2023	**In progress, led by CIAT/PABRA**: Dr J C Rubyogo and Dr Clare Mukankusi Bean business cases being prepared with CIAT /PABRA network member countries in eastern Africa. Business case for Investing in Beans in Uganda drafted and undergoing peer review before finalisation. Business Case will be presented at DLB Innovative Investment workshop in Nairobi on Oct 31 2023
3.4	Apply the new methodology and evidence base from Objective 3.1 to develop a business case for investing in tomato in Ghana	Business case for investing in tomato breeding in Ghana	March 2023	**Completed by WACCI**, University of Ghana: Dr Agyemang Danquah WAACI consulted with value chain participants in developing a business case for tomato breeding in Ghana; Business case on Investing in Tomato completed. https://www.demandledbreeding.org/_files/ugd/aff4c0_92a389e6796e4e4aacdf052b9fb67716.pdf
3.5	Identify policy issues affecting the development and adoption of new high performing plant varieties in Ethiopia	Policy brief on DLB-related policy issues identified by a policy round table in Ethiopia	December 2023	**In progress, led by CIAT/PABRA and University of Haramaya, Ethopia**: Dr J C Rubyogo and Prof Firew Mekbib, Department of Crop Science Policy dialogue initiated with EIAR during 2022 bean business case workshop in Ethiopia; EIAR plans to adopt DLB approaches for breeding of all crops. The policy dialogue in Ethiopia has been initiated by Prof Firew Mekbib, who is also Chair of the National Variety Release Committee, Ethiopia

3.6	Identify policy issues affecting the development and adoption of new high performing plant varieties in Ghana	Policy brief on DLB-related policy issues identified by a policy round table in Ghana	December 2023	**In progress, led by WACCI at the University of Ghana:** Prof Eric Danquah and Dr Walter Alhasan Policy dialogue initiated by WACCI, including conduct of a policy roundtable in Ghana in December 2021. The Government of Ghana has committed approx. USD 1m from a World Bank loan to support WACCI in breeding of key crops.
3.7	Identify policy issues affecting the development and adoption of new high performing plant varieties in Southern Africa	Policy brief on DLB-related policy issues identified by a policy round table in Southern Africa	December 2023	***In progress, led by ACCI****: Prof Shimelis Hussain* First ACCI/DLB hosted policy webinar to identify key issues held on 29 June 2021**.** 2nd ACCI/DLB webinar held on Oct 10th 2021. Speakers Webinar presentations available on ACCI and DLB websites. A summary of the key elements of these dialogues is being used to develop a policy brief.
3.8	Develop content, identify participants, and conduct a Master Class on DLB in Africa Master Class course content published	Master Class on: "The Business of Plant Breeding in Africa"	December 2023	**In progress, led by UQ**: Professor Gabrielle Persley and UQ agribusiness team (Drs Risti Permani, Ammar Abdul Aziz, & Adam Kamarek) are developing content for a Master Class on investing in demand led breeding and encouraging agri-entrepreneurship. The course will employ a systems approach to analyse demand-led breeding dynamics within each value chain element, to discern the interconnectedness and reciprocal influences amongst the various components. Various IFPRI and other models will be utilised to illustrate ways to assess both the economic and non-economic benefits of various technology interventions, such as introducing new plant varieties (or livestock breeds) with diverse options available for cost/benefit analysis. The goal is to obtain insights into the practical and theoretical aspects of demand-led breeding and agri-entrepreneurship, by encouraging innovative thinking in these domains.
3.9	Promotion of DLB approaches in various national and international fora	Communications and advocacy	December 2023	**On going promotion of DLB approaches in African and international events,** led by Pan African Coordinator Dr Nasser Yao, and other DLB project partners in Africa, as well as project leaders in Australia (ACIAR, Crawford Fund, UQ) and Switzerland (SFSA). For example, recent promotions of DLB approaches were presented at various national, regional, and international fora, by several DLB partners in Africa and Australia. These opportunities included DLB-led sessions of the African Plant Breeders Association (APBA), Rwanda Oct 2021; presentations by DLB representatives at meetings in West Africa, including in Cote d'Ivoire and Nigeria; and a joint symposium sponsored by UQ at the Australian Plant Breeders Conference, May 2022; DLB events were also conducted in Rwanda in 2022 in conjunction with AGRF22 and PABRA@25, Rwanda, September 2022. A DLB invited symposium and a project workshop were held at TropAg22, Australia, November 2022; Early career breeder training course in DLB was conducted by Dr Nasser Yao, Tanzania, May 2023; A 2023 DLB webinars series has been initiated by Dr Yao, with on line events held in July, August, September 2023, with presentations on various aspects of DLB to an African and international audience.

Table 6.1 Acronyms and abbreviations

PPs = Product Profiles
TDs = Technical Data Sheets
Partners
AATF – African Agricultural Technology Foundation
ACIAR = Australian Centre for International Agricultural Research
ACCI = African Centre for Crop Improvement, University of KwaZulu Natal, South Africa
BecA-ILRI Hub = Biosciences eastern and central Africa (BecA)- International Livestock Research Institute (ILRI)
CF = The Crawford Fund
CIAT/PABRA = Pan African Bean Research and Development Alliance (PABRA) at the International Centre for Tropical Agriculture (CIAT)
DLB = demand-led breeding
EIAR = Ethiopian Institute of Agricultural Research
GREAT = Gender Related Plant Breeding Program
SFSA = Syngenta Foundation for Sustainable Agriculture
UQ = The University of Queensland School of Agriculture and Food Sciences, St Lucia, Brisbane, Australia
UWA = The University of Western Australia
WACCI = The West African Centre for Crop Improvement, University of Ghana, Accra Ghana
WAVE = West Africa Virus Epidemiology Centre, Cote d'Ivoire

7. KEY RESULTS AND DISCUSSION

This section provides an overview of the key results of the Demand led Breeding project, based on the achievements, outputs and milestones delivered, as detailed in **Section 6, Table 6.1**. The significance of the results are discussed in Section 7.2 under each of the project Objectives:

- ✓ Objective 1 Best Practices in Plant Variety Design
- ✓ Objective 2 Education and Professional Development of Plant Breeders in Africa
- ✓ Objective 3 Policy, Advocacy and Communications

7.1 Overview

The key results of the project over the period 2015-2023 are summarised below:

1. Product Profiles – A Practitioners' Guide: Developing product profiles to develop and promote new varieties that respond to market demand.

An important early step in demand led breeding is developing product profiles that identify the priority traits required by various actors along the value chain. During 2020-21, DLB convened a working group of African and international plant breeders, who worked virtually during the Covid pandemic, to develop new guidelines for preparing and communicating product profiles.

These guidelines are applicable for a wide range of crops, environments, and markets. The DLB publication on ***Product Profiles: A Practitioners Guide,*** including guidelines and templates for creating new product profiles was launched at an international Webinar in August 2020. The suite of tools for preparing Product Profiles is available at:
https://www.demandledbreeding.org/_files/ugd/9abdc5_efc58213447c4d55a3cca49fdc0950dc.pdf

2. **Development and applications of new product profiles by plant breeders in Africa:** During 2021-23, the DLB product profile guidelines and templates have been used by African plant breeders participating in the DLB community of practice to develop some 20 new product profiles for 12 different crops (beans, cassava, coffee, cowpea, green gram, groundnut, Kersting groundnut, maize, pigeon pea, rice, sorghum, and tomato).

These product profiles serve to characterise promising and potential new crop varieties with traits of value to farmers, traders, consumers and seed producers to meet household needs and/or market demands; and to identify traits important for climate resilience. The suite of product profiles describes varieties suitable for a range of crops, countries, and environments. The product profiles will be used both to promote the benefits and value of breeding new crop varieties and to promote the scaling up of currently available, highly promising varieties. This will be achieved though creating demand for high quality seed, to enable their wider distribution and use in target markets and environments. The suite of illustrative product profiles is available on the project web site: https://www.demandledbreeding.org/product-profiles

The keys traits identified in the product Profiles that make new varieties of greater interest to farmers, traders, consumers and seed producers are summarised in **Table 7.1**: These are:

- *Farmer preferred traits* include early maturity, disease resistance, high yielding, drought tolerance and ease of plot management during cropping
- *Traders* are more interested in the harvest product transformation quality (milling quality, post-harvest storage quality, short cooking time)
- *Consumers* are only interested in taste, nutrition and health values of the product developed using these varieties
- *Seed Producers* are interested in generating high quality seed.

Each product profile developed under the auspices of the DLB project address all or partially each of the farmer, consumer, processor and seed producers preferred traits.

Table 7.1 *Product Profiles of various crops illustrating key traits of interest to different value chain actors*

Crop / Target country or region	**Product profile – Variety characteristics Target country**	**Farmer preferred traits or agronomic traits**	**Trader-preferred traits**	**Consumer preferred and/or nutrition and health benefit traits**	**Seed producers preferred traits**
Bean (Fresh beans) **Uganda**	High yielding, attractive bean pod with a longer shelf-life for the emerging fresh pod bean market	Yield, disease resistance, drought tolerant, early maturity, erect bush	long shelf life	Palatability, high Fe and Zn, low gas production, good seed and pod appearance, long shelf life, short cooking time	
Bean (Yellow dry beans) **Tanzania & eastern Africa**	Early maturing, attractive dry yellow beans for growing markets in Tanzania and elsewhere in eastern Africa	Yield, disease resistance, drought tolerance, early maturing	High dry grain weight	High Fe and Zn, low flatulence, short cooking time, palatability	High seed viability and uniformity
Bean (red mottled beans) **Zimbabwe**	High yielding, high Fe and Zn and disease tolerant red mottled bean variety	Yield, disease resistance, drought tolerance, early maturing	High dry grain weight, high seed density, long storage life, ease of threshing	Palatability, fast cooking time, glossy and large red mottled, high Fe and Zn content	
Cassava **Nigeria**	High root yielding cassava varieties with high dry matter and carotene content	High yield, disease resistance, low hydro cyanide content	Conical-cylindrical root shape, very mealy, high storability	Sweet to sour taste, high pro vitamin A content, high carotenoid content, low fibre content	High numbers of sprouted cuttings per plot, distinctiveness, high number of cuttings per plant
Coffee **Ethiopia**	Coffee wilt disease (CWD) resistant coffee varieties with high yielding and very good cup quality	High yield, disease resistance, drought tolerance, acid resistance	High bean weight, short harvest duration, grinding ability, cup quality	Low caffeine content, longer volatileness after roasting & grinding, medium bean size	high viability and seed germination
Cowpea **Nigeria**	Higher concentration of micronutrients (iron, zinc, copper, manganese and boron. High yielding, drought resistance, big grains	High yield, disease resistance, drought, biomass, flooding	dry grain weight, early maturing	Sweet honey taste, long shelf life, high grain micronutrient content (Fe, Zn, Cu, Mn and B), short cooking time, not gaseous	Kidney-shaped seed, soft testa, big sized grains
Green Gram **Ethiopia (for export markets)**	Bold, larger, attractive green seed with higher yield for export markets in India, Pakistan and China.	Yield, drought, disease resistance, early maturing	long shelf life	Colour and flavour, fast cooking, uniform colour and size, high sprouting ability	

Crop	Product profile – key characteristics Target country	Farmer preferred traits or agronomic traits	Trader-preferred traits	Consumer preferred and/or nutrition and health benefit traits	Seed producers preferred traits
Groundnut **Ghana**	Drought tolerant groundnut variety with high economic yield	Yield, drought, Disease resistance	High oil content, high butter and paste content	High number of seeds per plant	
Kersting's groundnut **Benin and West Africa**	Fast cooking, High-yielding, cream-seeded Kersting's groundnut	Yield, disease resistance, early maturity		Low flatulence, seed coat and hilum colour, short cooking time	High seed viability and uniformity
Maize **Ghana**	Development and dissemination of Pro-vitamin A orange maize varieties	High yield, disease resistance, drought, nitrogen tolerant, early maturity	Flint to semi flint, high storage days, high brewing quality	Palatable and aromatic, high pro vitamin A content, high fibre content, orange colour	High germination rate, distinctiveness
Pigeon pea **Kenya and eastern Africa**	High yielding, drought tolerant and short duration dry grain pigeon pea for eastern Africa	High yield, disease resistance, drought tolerance, short height	large seed, early maturing, short cooking time	Palatability, low gas production, short cooking time	high viability and uniformity
Rice **Nigeria**	Early maturing, lowland, long slender grain rice	High yielding, disease and pest tolerance; ion, salinity and drought tolerance,	High grain storage time, high milling recovery	Aromatic, medium amylose content, soft	High viability, less bulky
Sorghum **Tanzania**	High yielding, Striga resistant and *Fusarium oxysporum* f.sp. *Strigae* (FOS) compatible and low tannin sorghum for	High yield, disease resistance, bird resistance, drought tolerance, high carbohydrate, low fibre content	Tolerance to breaking, low fodder digestibility, low amounts of ash, protein, fat, total dietary fibre, total phenolic and higher starch content, less starch,	Digestible (low tannin, fibre, protein and high carbohydrate), short cooking time, white colour, Medium duration from harvesting to processing	High number of seed per panicle, large grain size,
Tomato **Benin**	High-yielding hot-set Tomato hybrid	High yield, disease resistance, heat tolerance, pest tolerance	high firmness, high shelf life	less acid, red pericarp, oval, oblong, square round	

The details of these illustrative product profiles developed by plant breeders in Africa are available on the project web site: https://www.demandledbreeding.org/product-profiles

3. Educational and professional development resources developed with plant breeders in Africa

The DLB project develops and makes available educational resources and other professional development materials for use by plant breeders in Africa. These resources are available at:
https://www.demandledbreeding.org/education-modules
https://www.demandledbreeding.org/product-profiles

The resources include a textbook, on "*The Business of Plant Breeding – Market led approaches to plant variety design in Africa*", published by CABI Publishing UK in November 2017. The book's chapters cover DLB Modules 1-7 as educational and teaching resources at a post graduate level on topics ranging from identifying priority traits that respond to farmer needs and/or market demand, through to varietal development processes, high quality seed production and varietal registration and dissemination of newly released varieties. The textbook and its associated research and educational resources, including slide sets suitable for teaching purposes, are available as open access publications via the CABI website at: https://www.cabi.org/products-and-services/about-cabi-books/open-resources/the-business-of-plant-breeding/ and at: https://www.demandledbreeding.org/publications

The textbook has been widely disseminated amongst at least 500 members of the African plant breeding community, and to libraries at African national research institutes and universities in Africa.

Two additional DLB teaching modules were completed during Phase 2 (2021-22). ***DLB Module 8*** covers '*Gender, diversity and inclusivity in plant variety design* '. It describes the principles and practices for taking account of gender and diversity when determining the traits important to different groups of farmers and/or consumers, and how to accommodate their preferences in designing new plant varieties. Module 8 is available at:
https://www.demandledbreeding.org/_files/ugd/aff4c0_12754ca358304c96a06627a1272f74c2.pdf

Another new technical module, ***DLB Module 9*** provides guidelines and examples in preparing new product profiles, based on the DLB publications and toolbox on Product Profiles: A Practitioners Guide. It is available at:
https://www.demandledbreeding.org/_files/ugd/aff4c0_835ee5aa7de448d0b1843ceb76d7e24c.pdf

4. Demand led Breeding - "Community of practice" of plant breeders in Africa
The DLB team supports an expanding DLB Community of Practice amongst some of the DLB alumni of 400 plant breeders working in national agricultural research systems (NARS) and universities across some 30 countries in Africa. The members of the DLB community of practice are primarily DLB alumni who participated in the 26 DLB-sponsored education and training workshops held in eastern, southern and West Africa between 2015-2022. These DLB workshops introduced to the African plant breeding community the principles of demand led plant breeding and its applications to crops important for food and nutritional security, climate resilience and for increasing incomes in farming communities.

The DLB team is working with the scientists within the community of practice, through eight crop-orientated working groups, to mainstream demand led breeding approaches within national plant breeding programs for a range of crops and environments in Africa. These working groups are organised around the following crops: beans; forages and orphan crops; horticultural crops and ornamentals; maize; millets and wheat; nuts and peas; rice; roots and tubers https://www.demandledbreeding.org/thematicgroups

5. Promoting new partnerships to advance the business of plant breeding in Africa: The DLB project's key research and educational partners in Africa are: the African Centre for Crop Improvement (ACCI) at the University of KwaZulu Natal South Africa; the Alliance of Bioversity International and the International Centre for Tropical Agriculture (CIAT) and the Pan African Bean Research Alliance (PABRA); the West Africa Centre for Crop Improvement (WACCI) at the University of Ghana; the Ethiopian Institute of Agricultural Research (EIAR), and Haramaya University, Ethiopia; the Ugandan National Research Organization (NARO) and Makerere University, Uganda; and the University of Nairobi, Kenya.

The DLB team is also expanding its partnerships in West and Central Africa (e.g., in Cote d'Ivoire, Democratic Republic of the Congo (DRC) and Nigeria), and with the West Africa regional agricultural research for development organization, (CORAF/WECARD) in Senegal, in response to requests from these organizations for sharing demand led breeding approaches with plant breeders especially in francophone Africa.

7.2 Discussion of Results

7.2.1 Objective 1 Best Practices in Plant Variety Design

Objective 1: Best practices in plant variety design: To enable plant breeders to develop new high performing varieties that meet customer requirements and market demand by having increased access and capability to implement start-of-the art knowledge, methodologies, and best practices from the public and private sectors on demand led plant variety design.

Research Question 1
What are best practices in demand-led breeding and how can these be implemented successfully in breeding programs for target crops in selected countries of Africa?

Objective 1 and its associated research question 1 are being addressed by implementing a series of activities with partner organisations in Africa to introduce demand led approaches into plant breeding programs for target crops in selected countries. The aim is to demonstrate through a series of practical examples that the use of more demand led approaches in the design of new varieties will lead to improved varieties that take account of farmer needs, consumer preferences and market demands, and this approach will lead to the increased adoption and use of the new varieties.

Best practices in demand led breeding include the systematic use of ***product profiles*** to define the priority traits, as identified through consultations with farmers, consumers, processors, traders, and others in the value chain for specific crops and countries. The activities therefore included working with plant breeders and others in the value chain in developing several product profiles to guide the breeding of new varieties suitable for the target crops in the priority countries and environments (Table 7.1).

The ***initial priority crops*** to demonstrate the value of demand led breeding are ***beans*** and ***tomato***.

The ***priority countries*** to demonstrate the use of DLB in ***bean breeding*** are ***Ethiopia*** and ***Uganda***, (in conjunction with the CIAT regional bean breeding program for eastern Africa and the Pan Africa Bean Research Alliance's (PABRA) East and Central Africa Research Network). *(Table 6.1 Outputs 1.1, 1.2 and 1.3)*

The ***priority countries*** to demonstrate the use of DLB in ***tomato breeding*** were ***Ghana and Benin*** (in conjunction with the West Africa Centre for Crop Improvement (WACCI) and the World Vegetable Centre tomato breeding program in West Africa, based in Benin). *(Table 6.1 Output 1.4)*

DLB approaches were also introduced for varietal development in several ***other crops and countries,*** via members of the DLB Community of Practice introducing the principles and practices of demand led breeding on the crops for which they are responsible within their national breeding programs. (*Table 6.1 Output 1.5)*

Summary of outputs and activities completed for Objective 1 (details given in Table 6.1)

Output 1.1 Implementing best practices for bean breeding in Ethiopia. Several Product Profiles (PPs) developed in consultation with farmers, traders, consumers, seed producers and other value chain participants, to guide new variety development by the national bean-breeding program for beans in Ethiopia.

Output 1.2 Implementing best practices for bean breeding in Uganda. A market research study was conducted in Uganda on consumer preferences in beans, to determine targets (specifications) for breeding new bean varieties with more rapid cooking time to respond to consumer preferences for beans as a more convenient food to cook.

Output 1.3 Implementing best practices for bean breeding in Uganda. Product profiles (PPs) developed in consultation with farmers, traders, consumers and other value chain participants, to guide new variety development for beans in Uganda by NARO's national bean-breeding program, and by the CIAT regional bean-breeding program.

Output 1.4 Implementing best practices in tomato breeding in Africa. Product profiles (PPs) developed in consultation with farmers, traders, consumers and other value chain participants, to guide new variety development for tomato in West Africa by breeding programs led by the West African Centre for Crop Improvement (WACCI) at the University of Ghana, and the regional tomato-breeding program led by the World Vegetable Centre in Benin.

Output 1.5 Promoting best practices in DLB for other priority crops in various countries of Africa. New Product Profiles (PPs) developed to guide new variety development for several other crops in Africa (apart from beans and tomato) via breeders who are members of the DLB Community of Practice and working on a range of crops in several countries of Africa. Other crops for which product profiles have been developed include cassava, coffee, cowpea, green gram, groundnut, Kersting groundnut, maize, pigeon pea, rice, and sorghum.

7.2.2 Objective 2 Education and professional development of plant breeders in Africa

Objective 2: Education and training: To build capacity within plant breeding programs on demand led variety design through strengthening education and training programs for plant breeders, including through post graduate curriculum development and new professional development opportunities on demand led plant variety design for plant breeders in Africa.

Research Question 2:
What should be the course content on demand led plant breeding for: (i) post graduate plant breeding education at African universities; and (ii) new professional development opportunities for plant breeders in Africa?

This objective is being addressed by the DLB team in developing an education and training program that focuses on: (i) Creating and disseminating new education and training materials related to the implementation of demand-led breeding programs in Africa; and (ii) providing new professional development opportunities for plant breeders in Africa.

DLB Education and Training Modules

During the first phase of the project (2015-2018) a DLB educators' group was formed to focus on Objective 2. The group consisted of senior plant breeders and/or seed sector specialists working within national, regional, or international research institutions or universities in Africa. The group also had

access to private seed company expertise and best practice, especially through Syngenta Seeds and its internal Academy for professional development of Syngenta Seeds own plant breeders.

The DLB educators group focussed on developing an initial set of educational materials by identifying and documenting the principles and best practices for implementing demand led breeding on crops important in food and agriculture in Africa. This led to the development of seven teaching modules, with a text and a set of slides prepared for each module, covering the following topics:

1 *Principles of Demand-led Plant Variety Design*
2 *Visioning and Foresight for Setting Breeding Goals*
3 *Understanding Clients' Needs*
4 *New Variety Design and Product Profiling*
5 *Variety Development Strategy and Stage Plans*
6 *Monitoring, Evaluation and Learning*
7 *Making the Case: Investment Decision Making in Plant Breeding*

This suite of modules constituted the curriculum for a series of workshops to introduce the principles of demand led breeding to plant breeders across a range of countries in Africa. The initial DLB workshops were conducted in 2015-16 with the PABRA network of bean breeders in eastern Africa, who gave useful feedback on the beta version of the modules, which were then revised for subsequent workshops.

The 7 modules also formed the basis of developing Chapters in a textbook on "*The Business of Plant Breeding – Market-led approaches to new variety design in Africa"* which was published by CABI UK and launched at a DLB symposium held at TropAg in Brisbane in November 2017. It is available as open source publication at either: https://www.cabi.org/products-and-services/about-cabi-books/open-resources/the-business-of-plant-breeding/
https://www.demandledbreeding.org/_files/ugd/aff4c0_7b6ec82b7eae48b79f91b4b0d8341b83.pdf

The textbook has been widely disseminated to (more than 500) plant breeders throughout Africa, including to participants at the DLB sponsored education and training workshops and to plant breeders studying for MSc or PhDs at African universities, through the regional post graduate programs led by ACCI in southern Africa and WACCI in West Africa. The DLB principles have also been formally incorporated into the postgraduate curricula of African universities (e.g. University of Nairobi; University of KwaZulu Natal, South Africa; and University of Ghana).

Additional DLB education modules completed in 2021-22
Module 8: Gender, diversity, and inclusivity in plant breeding
The aim of this module is to ensure that gender related preferences and consequences are considered when setting breeding goals, by applying a gender lens in the design, development and delivery of new plant varieties. The module includes examples of crops and situations where gender related issues have consequences in the design of new plant varieties. These examples are helpful in the conduct of education and training courses for postgraduate education and workshops on demand led breeding conducted at universities and research institutes in Africa. For example, cooking time and taste (palatability) in beans have emerged as critical traits to consider when developing PPs and setting breeding objectives for beans. Module 8 is available at:
https://www.demandledbreeding.org/_files/ugd/aff4c0_12754ca358304c96a06627a1272f74c2.pdf

Module 9: Creating product profiles and technical data sheets for illustrative crops
This module describes the process of preparing PPs and the technical data sheets that communicate the value of the new varieties. The module includes examples of preparing product profiles in 5 crops (e.g. beans, tomato, cassava, maize and sorghum). It is based on a suite of DLB publications and tools to assist breeders in the preparation of PPs.

An important component of best practices in DLB is the systematic use of these PPs as a tool to enable breeders to consult with various actors in the value chain as to their preferred traits for inclusion in breeding programs for new varieties. This then enables breeders to determine priorities amongst the numerous traits desired by various actors within the value chain. Ultimately, these priority traits are translated into breeding targets.

A "*product profile*" is a means to describe the priority traits that would be contained in a new variety that responds to these market demands. In a demand led breeding program, "*technical data sheets*" also need to be created for specific crops that identify the full value of the characteristics delivered in the new variety. These demonstrate the performance of new varieties, relative to existing varieties being used by farmers, and address the full and varied uses of crops for food, feed, energy, medicinal uses and other purposes. These technical data (sheets) form an essential part of the communications plan to position and promote a new variety and its desirable attributes with seed distribution companies, traders, farmers, consumers, and processors.

The content of this new Module draws on the outputs of Objective 1 where best practices are introduced into breeding programs on specific crops in selected countries of Africa. Examples are given for: (i) new product profiles and (ii) technical data sheets, to characterise new varieties of individual crops (e.g. beans, tomato, cassava, maize and sorghum). The achievement of the desired product profiles will be verified by breeding programs in establishing the technical data by which the performance of new varieties for specific traits can be measured in comparison with the check variety (i.e. a farmer preferred variety that is currently grown). Module 9 is It is available at:
https://www.demandledbreeding.org/_files/ugd/aff4c0_835ee5aa7de448d0b1843ceb76d7e24c.pdf

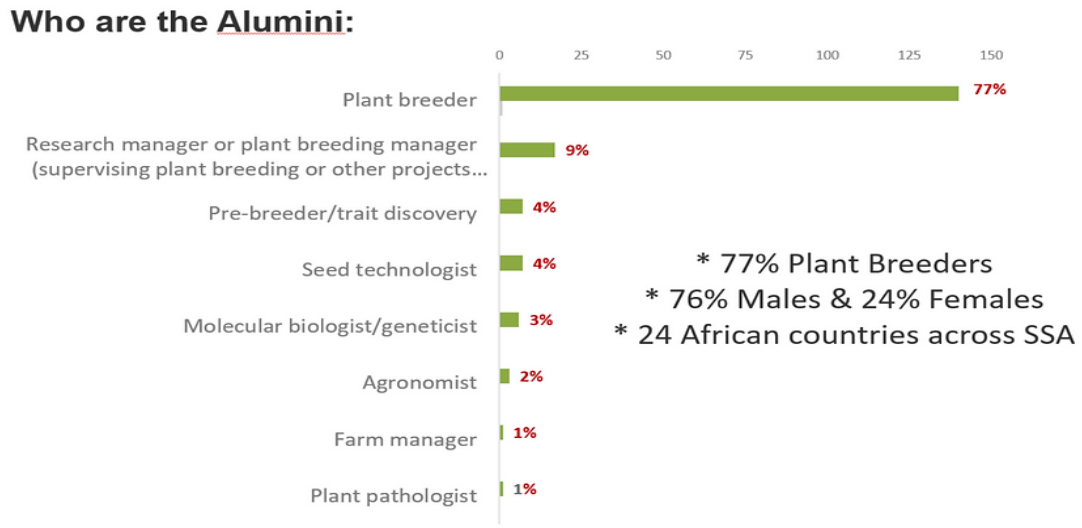
The DLB publications and guidelines on ***"Product Profiles – A Practitioners Guide"*** *is available at:*
https://www.demandledbreeding.org/_files/ugd/9abdc5_806c5850744d4e219479b0f714f218da.pdf

Demand led breeding workshops with plant breeders in Africa

The aim of the DLB education workshops was to introduce to the African plant breeding community the principles of demand led plant breeding and its applications to crops important for food security and increasing incomes in farming communities throughout Africa. Over the course of the project (2015-2023) 26 DLB workshops were held to introduce demand led breeding to plant breeders in eastern, southern and West Africa. The DLB workshops were organised and led by teaching and research faculty from the regional plant breeding programs at ACCI, in southern Africa; the BecA-ILRI Hub, CIAT/PABRA and the University of Nairobi for eastern and central Africa; and WACCI in West Africa.

More than 400 plant breeders and other professionals attended these DLB workshops during 2015 – 2022. These participants constitute a DLB alumni of some 400 crop improvement professionals working on 31 crops in 28 countries of Africa. Approximately 300 DLB alumni are practicing plant breeders in Africa, while another 100 alumni are professionals also engaged in crop improvement, either in related sciences (plant pathology, entomology) in seed systems, or as regulators and/or policy makers. Approximately 100 alumni are African woman scientists (25% of the total alumni). See Figure 7.1 below for a breakdown on the alumni disciplines.

Figure 7.1 DLB Alumni 2015-2023 – Range of expertise



Source: N Yao www.demandledbreeding.org (Presentations)

DLB Community of Practice

Demand led breeding community of practice developed with plant breeders in Africa:
The breeders attending the DLB workshops formed the basis for establishing a DLB Community of Practice (CoP) for further engagement on the implementation of demand led breeding, during the second phase of the project (2019-23).

The DLB team is working with the members of the CoP to mainstream demand led breeding approaches within national plant breeding programs for a range of crops in the countries of Africa. The DLB team supports the CoP through 8 crop-oriented working groups, and by developing educational resources, including two new technical modules, which are publicly available to download via the DLB website at: https://www.demandledbreeding.org/education-modules

The DLB CoP is organised around eight thematic groups based on a crop or groups of related crops, including: Beans, Forage and orphan crops, Horticultural and ornamental crops, Maize, Millets and wheat, Nuts and peas, Root and tuber crops and Rice.

The DLB Pan African Coordinator, Dr Nasser Yao, is primarily responsible for developing and supporting the DLB community of practice of plant breeders by developing and making new education resources widely available, and by establishing a variety of communication channels including a current series of DLB Webinars during 2023. The DLB team also use various communications and social media channels, such as:

- Twitter (https://twitter.com/DLB_Program)
- YouTube (https://www.youtube.com/@demand-ledbreeding5657/featured)
- Facebook (https://www.facebook.com/DLBProgram)
- Flickr (https://www.flickr.com/photos/demand-ledbreeding)

These virtual educational and professional development activities were initiated in 2019 and became increasingly important during the Covid pandemic 2020-22, when there were limited opportunities for in person meetings, and national, regional and international travel was restricted.

Feedback from CoP members regarding communication within and across thematic groups through WhatsApp indicated that this means of communication was not convenient for larger working groups. This feedback is informing the development of a new database using Samawati software licenced to the DLB project by AATF to facilitate knowledge sharing amongst the CoP working groups and individual CoP members.

Promoting promising new varieties developed by DLB alumni breeders

Breeders working on a range of crops and in various countries have identified their advanced lines with potential to become promising new varieties that have market potential due to their desirable traits responding to market demands, farmer, and consumer preferences. These promising new varieties require additional communications and promotion of the variety's attributes and technical specifications with farmers, seed companies and others along the value chain. This information on promising new varieties will be collated into an "Africa Seeds" compendium (handbook) and other promotional materials to disseminate information on promising new varieties for each crop, with the accompanying product profile and technical data to verify the attributes of the promising new variety and how/where to access seed of the new variety in each country.

The project partners work closely with the related SFSA project on 'Seeds2B' and with the growing number of small and medium enterprises (SMEs) emerging in the seed sector in Africa. These connections enable, for example, the possibility of trialing breeders' newly released varieties or late stage selections in other African countries to broaden the variety's adoption in other markets beyond its home country.

7.2.3 Objective 3 Policy, Advocacy and Communications

Objective 3: Policy analysis and advocacy: To provide evidence to support new policy development and investments in plant breeding that will help generate more high performing varieties to meet emerging market demands, with emphasis on Africa.

Research Question 3:
What are the essential policies that underpin demand led breeding programs? What evidence is required when developing business cases to support increased public and private investments in demand-led plant breeding on target crops in selected countries of Africa?

The aim is to demonstrate that the use of more demand led approaches in the design of new varieties will lead to improved varieties that take account of farmer needs, consumer preferences and market demands, and this approach will lead to their increased adoption and use.

This objective is being addressed by implementing a series of activities with partner organisations in Africa to identify the ***policy issues*** that may affect the successful implementation of demand led breeding approaches within plant breeding programs for target crops in selected countries in Africa.

The ***initial priority crops*** to demonstrate the value of demand led breeding are ***beans*** and ***tomato***.
The ***priority countries*** to demonstrate the use of DLB in ***bean breeding*** are ***Ethiopia*** and ***Uganda.***

The ***priority country*** to demonstrate the use of DLB in ***tomato breeding*** is ***Ghana.***

Policy and advocacy
The DLB community of practice members identified two priority areas where they would value the DLB team's professional support and new resource materials on:

(1) Making the *business cases* for sustainable investments in demand led breeding for targeted crops and countries; and
(2) Identifying *innovative financing mechanisms* and *encouraging agri-entrepreneurship* amongst the breeding and seed system communities for the development, promotion and scaling up of new plant varieties in Africa.

Policy and advocacy consultations initiated by the DLB team in these priority areas include:
(i) Two webinars organised by ACCI in South Africa on "*Making the case for demand led breeding in southern Africa*; *(Table 6.1 Output 3.7)*

(ii) a workshop in Ethiopia to prepare the business case for strengthening investments in breeding beans (and other crops) in Ethiopia, sponsored by the Ethiopian Institute of Agricultural Research (EIAR) CIAT/PABRA and the DLB program; *(Table 6.1 Output 3.2)*

(iii) Presentations by DLB team members on a framework for preparing business cases for innovative investments in demand led plant breeding and encouraging agri-entrepreneurship in Africa, at a DLB-led international session during the Australasian Plant Breeding Congress in May 2022. *(Table 6.1 Output 3.1)*

The activities completed under Objective 3 include developing three ***business cases*** to illustrate the rationale for investing in new varietal development for beans in Ethiopia and Uganda, and for tomato in Ghana. These business cases also serve as examples of the type of rationale and evidence base required to advocate for the use of demand led breeding in a wider range of countries, and other crops beyond beans and tomato, which serve as examples in these cases (*Table 6.1 Outputs 3.2, 3.3, 3.4*)

The activities also include consulting with a range of stakeholders, including through the DLB Community of Practice of plant breeders, as to the ***policy issues*** that they consider important in advocating the greater use of demand led breeding approaches.

Making the case for investing in demand led plant breeding
An important policy issue is the need for ***more sustainable financial support***, including ***innovative financing mechanisms***, for plant breeding programs in Africa, to complement more short term, external project driven support. The project driven approach tends to lead to a start-stop approach in many breeding programs, a lack of continuity in staff and operations, and the lack of a career path for plant breeders in many national (and international) plant breeding programs on crops important for food, feed and agriculture. In the light of the policy and advocacy activities being conducted under Objective 3, a new Education module is being prepared on this topic. A workshop to review the content of the module with DLB partners is planned for October 31, 2023.

The experiences of ACCI in southern Africa, the Pan Africa Bean Research Alliance (PABRA), and WACCI in Ghana in mobilising resources for long term support of plant breeding through post graduate education and in new varietal development by their graduate alumni, will be discussed at the workshop to inform the content of the module and future advocacy.

These organizations, who have been founding and leading partners with the DLB program since the beginning (2014-2023) have been recognised recently for their outstanding contributions to post graduate education of plant breeders in Africa and to new variety development. For example, Professor Eric Danquah WACCI Director at the University of Ghana was awarded the Africa Food Prize 2022. The Pan Africa Bean Research Program (PABRA) led by Dr J C Rubyogo was awarded the Africa Food Prize in 2023.

Module 10: Making the case for investing in demand led plant breeding *(in preparation)*
An important aspect of building support for plant breeding in Africa is creating business cases for increasing public and private sector investments in plant breeding programs, and in identifying innovative and sustainable funding mechanisms. This module draws on the results of Objective 3 that is developing the methodology and evidence base for developing business cases to support investments to support new variety development for specific crops in particular African countries and environments; and developing new varieties of crops with characteristics that meet farmer needs; consumer preferences and market demand.

Communications and Advocacy

Objective 3 also includes developing and implementing a ***communications strategy***, to ensure that the results of the activities and outputs in addressing its three project Objectives are widely disseminated both to project participants, and more broadly to the African plant breeding community.

This strategy included establishing a project web site as a resource to share project publications and other educational and training resources, as well as information on project activities. The web site was initially established and supported by the Syngenta Foundation for Sustainable Agriculture (SFSA) in Switzerland as part of its scientific and technical contribution to the project. In 2021, the responsibility for the future content, design and management of the web site was transferred to the project team in Africa, under the leadership of the DLB Pan Africa Coordinator, as part of transitioning to African leadership of the DLB program. The DLB website is a key site to enable plant breeders in Africa ready access to new publications, research and teaching resources, and identifying other professional development opportunities for plant breeders in Africa and internationally. The web site address is: https://www.demandledbreeding.org

Members of the DLB team also made many presentations at various national, regional and international symposia, conducted on line during 2020-22 (due to pandemic restrictions on travel) and more frequently at in person meetings, since mid 2022. *(Output 3.9).*

8 IMPACT

8.0 Overview

Demand led Breeding – Examples of success in new variety development in Africa

A series of Success Stories, illustrating the successful applications of demand led breeding principles in new variety development by early to mid-career plant breeders in Africa is given in **Tables 8.1 and 8.2** on the following pages. These new generation breeders, who have developed near to market new varieties of a range of crops, based on applying DLB principles and practices in their breeding program, are DLB alumni who are closely connected with DLB partners in Africa. Many are PhD or MSc graduates from the regional post graduate programs for plant breeders, led by: ACCI at the University of KwaZulu Natal, South Africa, WACCI at the University of Ghana, and the University of Nairobi, Kenya. The DLB alumni may also be members of the PABRA bean networks in eastern, southern or West Africa; and/or also associated with Biosciences eastern and central Africa (BecA) Hub at the International Livestock Research Institute (ILRI) Nairobi, Kenya.

DLB Education and professional development tools produced by the DLB team 2015-2023

Several DLB Education and professional development tools have been produced by the DLB project team over the period 2014-2022 and are now in widespread use by institutional partners in Africa, and by individual plant breeders in Africa who are members of the DLB Community of practice. These tools include:

1. A Textbook on ***The Business of Plant Breeding – Market-led Approaches to Plant Variety Design in Africa*** **(2017)** was prepared by the DLB education working group during 2015-17 as an introductory course in Demand led breeding. It contains 8 Chapters covering all aspects of implementing a market led approach to new plant variety development within breeding programs in Africa. The textbook was published by CABI UK. The Book was launched at TropAg in Brisbane in November 2017. It is available to download freely from the CABI or DLB web sites at:
https://www.cabidigitallibrary.org/doi/epdf/10.1079/9781786393814.0000
https://www.demandledbreeding.org/_files/ugd/aff4c0_7b6ec82b7eae48b79f91b4b0d8341b83.pdf

2. **"*Product Profiles: A Practitioners Guide*" (2020)** is a suite of guidelines and templates prepared by the DLB education group, to facilitate the preparation of product profiles that reflect the priority traits in new varieties that reflect farmer needs, market demands and environmental imperatives for crop production in various environments. The DLB Product Profiles suite of publications are available on the project web site at: https://www.demandledbreeding.org/_files/ugd/9abdc5_efc58213447c4d55a3cca49fdc0950dc.pdf

3. **Product profiles of a range of crops**. There are more than 20 examples of product profiles that have been developed by plant breeders in Africa to guide new variety development and set breeding objectives in a wide range of crops. These product profiles are available on the DLB web site at www.demandledbreeding.org https://www.demandledbreeding.org/product-profiles

4. **DLB Education modules** Nine DLB teaching modules covering various aspects of demand led breeding have been developed by the DLB team to date as slide sets suitable for post graduate teaching purposes in African universities, and for use in professional development courses within African national agricultural research systems. https://www.demandledbreeding.org/education-modules

5. **French translations of key DLB publications** The DLB Pan African Coordinator has initiated the translation of the key DLB documents into French, so that these can be made available to Francophone plant breeders, especially those working in West and Central Africa. The regional entities of West Africa Virus Epidemiology (WAVE) Centre at the University of Abidjan in Cote d'Ivoire and CORAF/WECCARD in Senegal have expressed strong interest in distributing these materials to their partners in member countries.

Table 8.1 Impact: DLB Success Stories - Examples of successful applications of Demand led breeding principles in new variety development by early /mid-career plant breeders in Africa

No	Country/ region	Crop	Lead Investigator/Institution and Engagement with DLB project and DLB team in Africa	Innovation developed with DLB principles	Comments/Sources of verification
1	**Benin West Africa**	**Tomato**	**Dr Mathieu Ayenan,** Leader, Tomato breeding program, World Vegetable Centre, Benin. mathieuayenan@gmail.com **WACCI** alumni, PhD graduate who participated in early DLB courses, while doing PhD at WACCI in 2017-18 **Dr Ayenan** is now applying DLB approaches in leading World Veg centre's regional tomato breeding program in Benin to develop new tomato varieties, suitable for various markets and changing climatic conditions in West Africa **WACCI PhD Supervisor and DLB team member**: Dr Agyemang Danquah, WACCI, Univ Ghana	New tomato varieties suitable for fresh consumption and/or processing in Ghana and elsewhere in W Afr. Tomato Product profiles developed to set breeding objectives. Targets are tomato hybrids with high yield, disease and pest resistance, heat tolerance, high firmness and long shelf life. Aim is to increase local tomato production to replace imports of processed tomato products from China and Europe (e.g imported tomato paste for fast food outlets)	www.demandledbreeding.org Tomato product profiles on DLB website Two new PPs for tomato varieties in West Africa developed and included as examples in the DLB publication on *Product Profiles: A Practitioners Guide (2020)* and available at https://www.demandledbreeding.org/_files/ugd/9abdc5_68c0b146e2ea46ea92b7de1f406c34ce.pdf https://www.demandledbreeding.org/_files/ugd/9abdc5_0372fec9846047d1973d7dc8268d2b71.pdf Breeder's testimonial (Slide Presentations | Demand-Led Breeding (demandledbreeding.org)
2	**Benin, West Africa**	**Kersting's ground-nut**	**Dr Eric Agoyi,** Legume breeder, University Abomey-Calavi Benin ericagoyi@gmail.com **PABRA West Africa** network member in West Africa who participated in early DLB courses in Phase 1 (2016-18), including for beta testing of DLB modules 1-7. He now	New variety, **LEA-Doyiwe 1,** submitted for registration and release in Benin. New variety is high yielding, cream seeded Kersting's groundnut, with medium cooking time and palatability suitable for	**DLB Product Profile** – High-yielding, cream-seeded Kersting's groundnut, Benin Product profile on DLB project web site at: aff4c0_009e44f64ee541c4a626f9b7a27d4b95.pdf (demandledbreeding.org)

			teaches DLB in many PABRA workshops and at Univ of Abomey Calavi, Benin. **Dr Agoyi** developed product profiles, to set a breeding objective to develop a variety of Kersting's groundnut, a locally important but under researched crop in West Africa. **DLB mentor**: Dr Nasser Yao, DLB Pan Africa Coordinator	urban markets in Benin and nearly countries in West Africa Dr Agoyi's future objectives are to develop other new varieties of Kersting's groundnut with tolerance to pest and diseases (*Pythium* resistance)	
3	**Kenya** **Eastern Africa**	**Tomato**	**Dr Francis Katimba** Tomato breeder, Continental Seeds, Kenya francisgath@gmail.com **University of Nairobi (UoN) graduate alumni** who was introduced to DLB in 2017 during his PhD course at UoN, and attended DLB courses at BecA in Nairobi Now a tomato breeder with Continental Seeds, Kenya, Dr Katimba is leading a new tomato breeding program, for hybrid tomato lines suitable for growing conditions and markets in eastern Africa **UoN PhD Supervisor and DLB team member (educators' group)**: Prof Paul Kimani, University of Nairobi	**10 hybrid tomato candidate lines** developed with the following traits: Resistance to bacterial wilt, high fruit yield, and market demanded traits, (such as oval, square or oblong shapes, firm fruit, high brix, long shelf life). Dr Katima's future plans are to expand breeding of hybrid tomato lines with resistance to bacterial wilt, high fruits yield and market demanded traits	Slide Presentations | Demand-Led Breeding (demandledbreeding.org)
4	**Kenya** **Eastern Africa**	**Bean (Snap and runner beans)**	**Ms Serah Njau**, University of Embu, Kenya njauserah23@gmail.com **University of Nairobi graduate alumni**: Ms Njau was introduced to DLB concepts at an early DLB workshop hosted by BecA in Nairobi in November 2017, when she was a MSc student at the UoN. Her first application of DLB principles was in development of new snap and runner	**New Bean Varieties KSB-13-01 and KSB13-05 released in Kenya:** These varieties are for snap and short-day runner beans, which exceed the industry standards, and are suitable for use in Kenya and elsewhere in sub Saharan Africa. Key traits are: high pod quality, resistance to rust,	**Demand-Led Breeding for snap bean improvement in sub-Saharan Africa** Slide Presentations | Demand-Led Breeding (demandledbreeding.org)

			beans for the canning industry in Kenya, which has led to the release of two new bean varieties. **UoN MSc Supervisor and DLB team member (educators' group)**: Professor Paul Kimani, University of Nairobi **BecA/DLB mentor**: Dr Nasser Yao, DLB Pan Africa Coordinator	anthracnose, Angular Leaf Spot (ALS), plus good taste, aroma and long shelf life. Future plans include developing value added snap bean products for export markets from Kenya to new markets in the Middle East and in other countries of Africa	
5	**Malawi** **Southern Africa**	**Pigeon pea**	**Dr Esnart Yohane** Departments of Agricultural Services, Malawi nyirendaesnart55@gmail.com **Dr Yohane** is an ACCI graduate alumni who was introduced to the DLB concepts in 2018 at a DLB course hosted by BecA in Nairobi, for ACCI alumni breeders working in eastern and southern Africa. **ACCI PhD Supervisor and DLB team leader for southern Africa**: ACCI Director Professor Shimelis Hussein **BecA/DLB mentor:** Dr Nasser Yao DLB Pan African Coordinator	**Three new pigeonpea varieties (Mthawajuni Wofiira, Mthawajuni Wamawanga, and Mthawajuni Woyera)** released in Malawi in 2021 with grain yields of 2-2.5 t/ha, brown/cream/speckled seed colour, highly resistant to insect pests and good flavour and shorter cooking time. Dr Yohane started developing new pigeon pea varieties suitable for Malawi, following DLB principles, as part of her PhD thesis at ACCI. She is now continuing this work as national legume breeder in Malawi.	DOI:10.1080/15427528.2021.2022059 *Journal article* Esnart Nyirenda **Yohane**, Hussein Shimelis, Mark Laing, Isack Mathew and Admire Shayanowako 2022 *Combining ability and gene action for agronomic traits and Fusarium wilt resistance in pigeon pea* Journal of Crop Improvement 36, Issue 6, pp 842-865 Link DOI:10.1080/15427528.2021.2022059
6	**Namibia** **Southern Africa**	**Sorghum**	**Dr Wanga Arton** Crop Research and Production Directorate of Agricultural Research and Development Ministry of Agriculture, Water and Land Reform, Namibia maawanga@gmail.com	**Sorghum Varieties NAMSO-01 (L7P7-3) and NAMSO-02 (L7P9-4) are early maturing (100-130 days).**	*Publications:* GXE interaction of newly developed sorghum lines in Namibia. https://doi.org/10.1007/S10681-022-03099-5/FIGURES/2

			Dr Arton is an ACCI graduate alumni, who was introduced to DLB concepts in 2018 through the ACCI/DLB partnership. He immediately conducted a participatory rural appraisal in six sorghum-growing regions in Namibia to establish the state of sorghum production in northern Namibia. This information led him to develop several product profiles for rainy season sorghum, off-season sorghum for food, feed and industrials uses, and sorghum for forage use. He also used gamma irradiation to fasten the breeding process **ACCI PhD Supervisor and DLB team leader for southern Africa**: ACCI Director Professor Shimelis Hussein	**Sorghum Varieties NAMSO-03 (L7P9-13) and NAMSO-04 (L3P15-16) are higher yielding (2-3 t/ha),** Four new sorghum varieties were released in Namibia in 2022. All are drought tolerant, and suitable for porridge and/or brewing use. White and red seed colour. Seed production and scaling out for dissemination underway, to expand sorghum production in Namibia.	Sorghum Production in Northern Namibia: Farmers' Perceived Constraints and Trait Preferences. https://doi.org/10.3390/SU141610266 Responses of Elite Sorghum (Sorghum Bicolor [L.] Moench) Lines Developed Via Gamma-Radiation for Grain Yield and Component Traits and Drought Tolerance. Available at SSRN: https://ssrn.com/abstract=4503741 or http://dx.doi.org/10.2139/ssrn.4503741
7	**Nigeria** **West Africa**	**Sorghum**	**Dr Muhammad Yahaya** Institute of Agricultural Research, Ahmad Belo University Samaru Nigeria risland6@gmail.com **Dr Yahaya** is an ACCI graduate alumni, who participated in early DLB courses, while doing his PhD at ACCI; he then applied DLB approaches in Nigeria to develop sorghum hybrids suitable for ariid conditions, in collaboration with local and international partners (ICRISAT). The hybrids were the results of a participatory rural appraisal conducted in northern Nigeria to understand the needs and preferences of farmers.	**Two new sorghum hybrids developed (HT1 and HT2)** with the following traits: High yielding, good grain quality, drought tolerant, early maturing, medium plant stature, ideally suited for the semi-arid regions of northern Nigeria and elsewhere in West and Central Africa	Two sorghum hybrids submitted for registration in Nigeria

			ACCI PhD Supervisor and DLB team leader for southern Africa: ACCI Director Professor Shimelis Hussein **DLB mentor**: Dr Nasser Yao, DLB Pan Africa Coordinator		
8	**Tanzania** **Eastern Africa**	**Sorghum**	**Dr Emmanuel Mrema** Plant Breeder, Tanzania Agricultural Research Institute (TARI), Tumbi Centre, Tanzania Mremaemmanuel1977@gmail.com ACCI graduate alumni who participated in early DLB courses at BecA in Nairobi, and then introduced DLB approaches into his sorghum breeding program in western Tanzania. **ACCI PhD Supervisor and DLB team leader for southern Africa**: ACCI Director Professor Shimelis Hussein **DLB mentor**: Dr Nasser Yao, DLB Pan Africa Coordinator	**Varieties TARISOR1 and TARISOR2** released in Tanzania in 2018 with the following characteristics: high-yielding (3-4 t/ha), *Striga*-resistant, and *Fusarium oxysporum f.sp. strigae* (FOS) compatible, low tannin. Seed scaling up for wider dissemination of these two new low tannin sorghum varieties is underway in western Tanzania. For example, 5t of seed of the 2 new varieties was produced in 2023, and distributed to sorghum farmers in Tanzania, and there is demand by farmers for more seed of these preferred varieties in the next growing season.	Low tannin sorghum (Tanzania) product profile aff4c0_c6397114ad434fa187aba35a9fc174f5.pdf (demandledbreeding.org)
9	**Tanzania Eastern Africa**	**Bean (Yellow bean)**	**Dr Teshale Mamo** CIAT Bean Breeder and PABRA Coordinator for Eastern and Central Africa Bean Research Network (ECABRN) Alliance Bioversity-CIAT, Arusha, Tanzania Teshale.Mamo@cgiar.org **Dr Mamo** is a CIAT plant breeder and the PABRA regional coordinator for eastern and central Africa. From 2020, Dr Mamo participated in the early development of the DLB guidelines for designing product	3 candidate lines at F5-6 generation developed with the following traits: early maturing, short cooking time, resistance to Anthracnose Leaf Spot Future plans are to advance these lines to generation F7-8, to start their registration and release process as new varieties.	Yellow dry bean (Tanzania) product profile 9abdc5_4427caccbb9246409a3b4f19118e6a1d.pdf (demandledbreeding.org) Video link to "*The Golden bean of Tanzania*" (PABRA video link) https://www.youtube.com/watch?v=ZXyYEBl_jVc

			profiles. He then used these guidelines to develop a product profile (PP) for a yellow bean variety suitable for northern Tanzania; and then translating the PP into breeding objectives and activities for his CIAT bean breeding program based at Arusha, Tanzania. Dr Mamo is a key member of the DLB team in eastern Africa, working closely with the DLB Pan Africa Coordinator Dr Yao. **CIAT /PABRA Supervisor**: Dr J C Rubyogo, Head of CIAT Bean program and PABRA Director.		
10	**Uganda** **Eastern Africa**	**Bean** **(Fresh bean pods)**	**Dr Stanley Nkabulo** Legume Breeder, National Crops Resources Research Centre (NaCRRI), Uganda tamusange@yahoo.com **Dr Nkabulo** is the leader of the Ugandan national legume breeding program and a member of PABRA's network in eastern Africa. He is one of the original members of the DLB team, who since 2015 participated in early DLB courses, and beta testing of DLB Educational modules 1-7 with PABRA bean breeders; and in developing DLB guidelines for preparing product profiles (2020). He has used these guidelines to prepare PP for new bean varieties to respond to rising demand for fresh bean pods in urban markets in Uganda.	New varieties (NABE 15, NABE 20 and NABE 23), with high yield, attractive bean pod and long shelf-life, released in Uganda. Future plans are to put in place a well-organized seed system; and facilitate the development and distribution of value-added product from fresh bean pods, especially in urban markets, where there is increasing demand for fresh, nutritious vegetables.	Fresh bean pod (Uganda) product profile 9abdc5_e5996dcf55794df889bbd6c88e0a6e22.pdf (demandledbreeding.org)

11	**Uganda** **Eastern African**	Sormaize Sorghum and maize hybrid	**Dr Alexander Bombom** Principal research scientist-Forage breeder National Livestock Resources Research Institute (NaLIRRI) xander.bombom@gmail.com Dr Alexander Bombom is a co-founder of Bomvitae Agro Industries Limited (BAIL) a spinoff of the novel intergeneric sorghum x maize wide cross agricultural invention. Dr. Bombom has been affiliated with the Biosciences eastern and central Africa (BecA)-International Livestock Research Institute (ILRI) Hub, Nairobi, where he was introduced to DLB principles since 2015 **DLB/BecA mentor**: Dr Nasser Yao, DLB Pan-African Coordinator	New varieties (SMH1. SMH2 and SMH3) with high grain yield, high biomass, high sugar content and nutrient dense for the brewing, feed, fodder and pharmaceutical industries Future plans are to complete the release process for additional DUS tests given the nature of the innovation and to produce seed for farmers and stakeholders, to develop and scale up added-value products for the Ugandan and neighbouring countries markets	Patent for the Sormaize innovation https://patents.google.com/patent/WO2015042621A3/en
12	**Zambia** **Southern Africa**	**Maize**	**Dr Chapwa Kasoma** CABI Biosciences, Zambia chapwak@gmail.com Dr Chapwa is a BecA/DLB and ACCI Alumni who was introduced to the DLB concepts during her PhD at ACCI in 2017 and applied the principles to her maize breeding program in Zambia. **ACCI PhD Supervisor and DLB team leader for southern Africa**: ACCI Director Professor Shimelis Hussein **BecA/DLB mentor:** Dr Nasser Yao DLB Pan African Coordinator	2 Fall Army worm (FAW) resistant experimental maize hybrids (CML334/EBL173782 and CML545-B/EBL169550) with high resistance to FAW Experimental hybrids to undergo trials for validation and DUS trials before release	**Journal article** *Combining ability of maize genotypes for fall armyworm (Spodoptera frugiperda J.E. Smith) resistance, yield and yield-related traits* https://www.sciencedirect.com/science/article/pii/S0261219421002325

Table 8.2 Regional Bean Breeding Initiative *– Rapid bean breeding for quick cooking beans – Collaboration between CIAT/PABRA, University of Western Australia (UWA) and Demand led Breeding (DLB)*

	Region	**Crop**	**Lead Investigator/Institution and** **Engagement with DLB project and DLB team in Africa**	**Innovation developed with DLB principles**	**Comments/Sources of verification**
1	Eastern and Central Africa - 6 countries in eastern and central Africa	Beans - Quick cooking beans	**Dr Clare Mukankusi,** CIAT Bean Breeder Alliance Bioversity-CIAT – PABRA Uganda c.mukankusi@cgiar.org **Professor Wallace Cowling** University of Western Australia (UWA) wallace.cowling@uwa.edu.au Reduced cooking time was identified as a key trait during DLB/PABRA joint meetings in 2016/17 (by JCR and VMA), as this is a constraint limiting increasing bean consumption, especially in urban areas. DLB team in Australia (at UWA and UQ) made representations to ACIAR in 2017 (including convening a meeting with ACIAR at TropAg 2017 to support development of a new project led by UWA and CIAT/PABRA to introduce rapid breeding methods (BRIO) to bean, targeted at identifying genetic basis to select for reduced cooking time in beans. The ACIAR 5 year BRIO project commenced in 2019.	New bean breeding materials with reduced cooking time developed by African breeders working in 6 countries: Uganda (CIAT regional breeding program (Clare Mukankusi); and Ethiopia (Kidane T), Kenya (Ruben O.), Burundi (Astere B), Rwanda (Anuarite U)and Tanzania (Julius M), using new accelerated breeding methods developed by Prof Cowling at UWA in related ACIAR project on accelerated (BRIO) bean breeding for reduced cooking time. These materials are now being used in 6 countries in eastern and central Africa for developing locally adapted bean varieties with reduced cooking time suitable. DLB is facilitating the development of PPs tailored to the needs of each participating country. Potential USD value of reduced cooking time as a novel trait is estimated as USD 1.4 billion in a study by CIAT economists.	Presentations on rapid bean breeding https://www.demandledbreeding.org/slide-presentations **Final market survey report Uganda** April 2022. DLB commissioned a market research study by CIAT in Uganda on reducing bean cooking time, to determine targets and specifications for breeding new bean varieties (Table 6.1 Output 1.2) DLB-CIAT-PABRA Bean market report Uganda https://www.demandledbreeding.org/_files/ugd/aff4c0_274084f239dc4399ad9502c1ff9d6d34.pdf **Slide set** prepared as DLB educational resource and posted on DLB project web site https://www.demandledbreeding.org/slide-presentations https://www.demandledbreeding.org/_files/ugd/aff4c0_274084f239dc4399ad9502c1ff9d6d34.pdf

8.1 Scientific Impacts – Now and in 5 years

The intended scientific impact is to ensure greater availability of new, high performing crop varieties that respond to customer needs, market demand, and climate challenges, leading to increased adoption of new high performing varieties by farmers in Africa, thus contributing to food and nutritional security and income generation.

Success in demand-led plant breeding will depend on the development, dissemination, and communication of new decision support tools to the plant breeding community. This will enable R&D programs in Africa to obtain and evaluate information about market demands and use this information to set targets and product specifications within plant breeding programs.

The scientific impacts of this project will be to better integrate all aspects of market demand into the design of new plant varieties. This involves the systematic use of product profiles to define the priority traits identified through consultation with the value chain participants for each crop and country. This approach also includes incorporating demand from farmers (primarily addressing biological constraints) as well as demands from consumers (such as taste, colour, quality) and demand from suppliers and traders (e.g. storage quality). Developing new varieties that are resilient to climate change, including more frequent extreme weather events, is also increasingly important.

Demand-led approaches to plant breeding are being introduced progressively into regional and national plant breeding programs in Africa by plant breeders who have participated in the DLB project since 2015. For example, demand led approaches to plant variety design are being successfully implemented by project partners for the following crops: *Beans* in eastern and southern Africa, through the PABRA/CIAT regional bean breeding networks and national bean breeding programs in Ethiopia and Uganda; tomato in West Africa, through WACCI at the University of Ghana and the Ghanaian national tomato breeding program, and the World Vegetable Centre regional tomato breeding program in Benin; rice in Nigeria through the University of Port Harcourt; and Kersting's groundnut in Benin through the University of Aborney Calavi, Benin.

In the case of the three PABRA bean breeding networks across Africa, four years after the first exposure of PABRA bean breeders to DLB principles during phase 1 of the DLB project, many of these bean breeders have made advances on implementing DLB practices into their breeding programs. This includes, for example, by understanding market segmentation and its roles in defining the breeding objectives, and engagement of the value chain actors in various stages of germplasm evaluation. Product profile concepts are being mainstreamed by PABRA members at national institutes in their home countries, and by CIAT's international bean breeding program.

In addition, the results from the *market research study on rapid bean cooking time,* commissioned by the DLB project team in Uganda are being shared with bean breeders through the PABRA regional networks in eastern, southern and West Africa to support their utilisation in developing product profiles tailored to their various environments and markets. This data is being used also to develop an investment case for breeding for rapid bean cooking time and other priority traits for farmers and consumers in Uganda.

The importance of the demand led approaches that have been adopted for bean breeding in Africa was widely recognized during the 2021 African Plant Breeding Association meeting in Rwanda in 2021, with the results of DLB applications in their breeding programs presented by several members of the DLB community of practice. These examples are available at https://www.demandledbreeding.org (African breeders testimonials 2021)

New scientific partnerships to increase adoption of demand led breeding principles and practice in national and international breeding programs

The DLB educational resources and toolbox have been shared with a range of national, regional, and international plant breeding programs in Africa. This is exemplified by the CIAT/PABRA Global Breeding lead for Common beans (Dr Clare Mukankusi who was one of the founding members of the DLB team in Africa in 2015) who shared the DLB website and tools during the PABRA regional steering committee meetings for ECABREN, SABRN and WECABREN, in eastern, southern and West Africa, respectively, and with the Kirkhouse Trust's African Bean Consortium (ABC) in 2020-21. This close collaboration between DLB and the bean breeding teams in eastern, southern and West Africa continues during 2021-23.

Africa - Australia research collaboration on rapid bean cooking time: The DLB team is working closely with the University of Western Australia and its ACIAR funded project on rapid bean cooking time, led by Professor Wallace Cowling at the University of Western Australia. The DLB team's role is to support this related ACIAR project by facilitating the development of product profiles to target breeding new bean varieties for rapid cooking times in the six project partner countries, and to provide training in DLB approaches to scientists in these countries. Six new product profiles for bean varieties with rapid cooking time, suitable for each of the participating countries, are being developed in 2023. The DLB Pan African Coordinator is facilitating the development of these Product Profiles with the bean breeder in each participating country.

International collaborations: The DLB Pan African coordinator (Dr Nasser Yao) participated in several international meetings during 2021-23 on behalf of the DLB team, and shared the *DLB Product Profiles* suite of publications, including guidelines and a toolkit for preparing product profiles, and examples for use by breeders in preparing product profiles of their target crops, markets and environments.

These international collaborations also included sharing the DLB product profiles tool kit and examples with the SFSA Seeds2B team, for their use in related international programs that SFSA is supporting, particularly *The Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA).*

Other international programs with which the DLB team has shared its educational resources and expertise include the CGIAR initiatives on *Excellence in Breeding (EiB)* and *Crops to End Hunger (CtEH)* and the 1CGIAR accelerated crop breeding initiatives within the CGIAR Centres. These international crop breeding programs are all giving increasing emphasis to using product profiles as a means to set targets and determine priorities within the crop breeding programs they lead.

The DLB approach is to enable crop improvement teams in Africa, including plant breeders and their social science colleagues, to work with all actors across the value chain for specific crops to better understand farmer needs and market opportunities. This knowledge can then be organized into "product profiles", which set targets for plant breeding programs to develop new varieties that have a high chance of adoption by farmers.

The new varieties are designed to reflect farmers' needs, by meeting the biological imperatives of the environments where the crops are to be grown, as well as responding to new market opportunities, especially for consumer preferred traits.

8.2 Capacity Impacts – Now and in 5 Years

A comprehensive education and training program has been developed to build capacity within plant breeding programs in Africa on demand led variety design. This objective is being met by: (i) Providing new professional development opportunities for plant breeders in Africa; and (ii) Producing and disseminating new education and training materials related to the implementation of demand-led breeding programs.

Capacity impacts are coming from the project partners working with the teaching and research faculty in African universities and with research scientists and private sector expertise to develop and disseminate new educational materials for introducing new demand led approaches to plant breeding.

In addition, there has been a new and innovative educational nexus established between Africa and Australia on training the next generation of plant breeders in Africa on demand-led plant breeding approaches, including new linkages with the UQ Agribusiness group.

DLB educational materials incorporated into African university curricula
Several African universities have now incorporated the demand led breeding approaches developed through the DLB project into their formal postgraduate teaching programs on plant breeding, including the University of Ghana, the University of KwaZulu Natal, South Africa, and the University of Nairobi, Kenya.

Demand led breeding community of practice developed with plant breeders in Africa The DLB project has developed a demand-led breeding "community of practice", who come from the DLB alumni of some 300 plant breeders (120 of whom are women), who work largely within African national agricultural research systems (NARS) and universities in eastern, southern and West Africa. A further 100 alumni are professionals also engaged in crop improvement, either in related sciences (plant pathology, entomology) in seed systems, or as regulators and/or policy makers. These 400 professionals are working on 31 crops within 28 countries of Africa. (**Figure 7.1**-*Who are the alumni?)*

The members of the DLB community of practice are primarily African plant breeders who first participated in the DLB sponsored education and training workshops, some 26 of which have been held between 2015-2022. These DLB workshops introduced to the African plant breeding community the principles of demand led plant breeding and its applications to crops important for food security and increasing incomes in farming communities throughout Africa. These African plant breeders now constitute a "community of practice" with whom the DLB project is working to mainstream demand led breeding approaches within national plant breeding programs for a range of crops in the countries of Africa.

The DLB Pan African Coordinator, Dr Nasser Yao, who is based in Nairobi Kenya, is primarily responsible for developing and supporting the DLB community of practice of plant breeders, including making available new educational resource materials and establishing regular communication channels and new distance learning opportunities. These virtual educational and professional development activities were initiated at the start of Phase 2 in 2019. They became increasingly important due to the Covid pandemic-induced restrictions throughout 2020 to 2022.

Most countries in Africa, as elsewhere, have restrictions on movement within and between countries, as part of the COVID-19 control measures. These restrictions gradually eased enabling more face to face learning at universities and increasing opportunities for safe travel between countries in Africa, for example to attend scientific meetings. The African Plant Breeders Association (APBA) met in Rwanda in October 2021 and DLB hosted a side event during this annual meeting.

8.3 Community Impacts – Now and in 5 Years

8.3.1 Economic Impacts

Economic impacts are not yet evident, but it is anticipated that the project will deliver economic impacts in the future as a result of the adoption of new crop varieties that better meet market demand. Some examples of near to market new crop varieties are given in Table 8.1

The DLB Success Stories summarised in Table 8.1 show a range of new varieties developed with DLB principles that are recently released or are close to release in 2023. The DLB team, in conjunction with the UQ agribusiness team, are developing a new educational module and planning a Master Class to demonstrate ways to assess the economic and non-economic benefits of new plant varieties. This includes information on what data needs to be collected as a base line, what needs to be tracked over time, and what are the options for using the various models developed by IFPRI and others to estimate costs and benefits of new varieties after their release. (Table 6.1 – Output 3.8)

8.3.2 Social impacts

The development of a new DLB educational Module on *Gender, Diversity and Inclusivity in Plant Breeding* illustrates the importance of identifying and including traits of special importance to women in new variety design. For example, reduced cooking time and taste were identified in Uganda as key traits for developing new bean varieties for which consumers would be prepared to pay a price premium. (Output 1.2 Market research study in Uganda).

An ex ante assessment conducted by CIAT economists in Uganda shows the value of adding the rapid cooking time trait to new varieties, will reduce cooking time for beans by 30% from 120 minutes to 84 minutes. This is a time saver for women cooking beans as a nutritious food for their families. It is also an energy saver, by reducing the fuel needed to cook the food. The availability of “quick beans” has the potential to save up to USD 400.6 million per year for the consumers in Uganda if the average cooking time of beans is reduced from 120 min to 75min—and if quick beans are preferentially used and is likely to increase overall bean consumption. Increased consumption of beans also improves nutrition, especially for women and children as beans are a high protein legume, more affordable than animal protein, and more able to be grown in arid and semiarid environment

8.3.3 Environmental impacts

The DLB Success Stories summarised in Table 8.1 highlight the need to take account of environmental trends, including the need for resilience to climate change in developing new varieties (e.g. new sorghum varieties suitable for arid and semi arid conditions in Namibia and Western Tanzania are being well received by farmers and by markets, and seed production of the new varieties is increasing in both countries.

8.4 Communications and Dissemination Activities

The DLB project team and partners in Africa have developed and implemented a communications and advocacy program. This includes refreshing the DLB web site, as well as using a wider range of communication channels. Expanding these new communications channels was particularly important when most countries in Africa, as elsewhere, continued to experience restrictions on movement within and between countries, as part of their COVID-19 control measures during 2021-22.

The DLB web site has educational and training materials available as open sourced materials at www.demandledbreeding.org. The DLB website was initially designed and managed by the Syngenta Foundation for Sustainable Agriculture (SFSA), as part of SFSA's contributions towards program management. This was very helpful and much appreciated by the DLB team during the first phase of the DLB program. During 2021-22, the refresh of the DLB website was completed, and the management of the site transferred from SFSA to the DLB team in Africa, led by the Pan African Coordinator, based in Nairobi. This transfer of communications responsibility to African based partners strengthens the capability of African partners to update the website on a regular basis with news and add new educational materials as they are finalized, and to host the eight community of practice working groups on specific crops and breeding topics.

The communications channels include new social media channels, as well as ensuring that the DLB website is a key site to enable plant breeders in Africa ready access to new publications, research and teaching resources, and identifying other professional development opportunities for plant breeders in Africa and internationally.

9. CONCLUSIONS AND FUTURE OPPORTUNITIES

The DLB partners in Africa have identified several new opportunities for promoting and applying the principles and practices of demand led breeding across a wider range of crops, feeds, and livestock in Africa, and across a broader range of countries and regions within Africa. These opportunities will involve continuing and potential new partners, who are willing to explore new partnerships for 2024 and beyond. These new opportunities are summarised below.

Pan African Opportunities with current and potential new partners

Pan-African Bean Research Alliance (PABRA) is a bean business and research program, hosted by CIAT, and one of the founding partners of DLB. PABRA and DLB have been engaged end to end in promoting the DLB approach through the various PABRA bean corridors across the whole bean value chain. PABRA will be implementing a new 6-year project entitled Bean for Women empowerment with a strong focus on gender, inclusivity, and equity. Inclusion of a gender lens into varietal development has been one of the key focuses in implementing DLB and has led to the development of a gender module (Module 8) and a gender-based product profile on beans in identifying traits of special interest to women, such as reduced cooking time. The new opportunity is to expand demand led breeding approaches with PABRA under the "Bean for women empowerment project" which will expand the gender knowledge base regarding developing new bean varieties with improved nutrition, better seed systems and social inclusion in DRC.

African Agricultural Technology Foundation (AATF)
AATF believes that use of appropriate technology can improve agricultural productivity in Africa. AATF has identified with DLB possible areas of collaboration to include 1) Access to the AATF database for foresight and market survey/intelligence, 2) Identification, generation and scaling up of suitable technologies to farmers and value chain actors and 3) Joint-Experts contribution to webinars, policy dialogues to invest in DLB and professional development for breeders in Africa.

Regional Universities Forum for Capacity Building in Agriculture (Ruforum)
Ruforum is an association of African agricultural universities for capacity building that spans 163 universities in 40 countries across sub Saharan Africa. DLB aims to introduce demand led breeding approaches into the curriculum of as many of these universities as possible in partnership with Ruforum. The new opportunity is to expand the use of the DLB educational tools and teaching modules through the Ruforum network of universities, is to reach a new generation of future plant breeders in Africa, from bachelor level onward to PhD level.

New opportunities and future partnerships for DLB in Eastern Africa:

The **Nelson Mandela African Institution of Science and Technology (NM-AIST**) is a leading Pan-African Institution of Science and Technology based in Arusha, Tanzania. Its mission is to train and develop the next generation of African scientists and engineers to stimulate and catalyze their innovation and entrepreneurship qualities. The DLB CoP members also identified entrepreneurship as one the key priorities axes for professional development. The opportunity identified by NM-AIST and DLB is to add a dimension of agri -entrepreneurship and the "business of plant breeding" into NM- AIST's technical training to post graduate students in plant breeding.

The **International Livestock Research Institute** with its headquarters in Nairobi Kenya and Addis Ababa Ethiopia is the international livestock research institute operating of the CGIAR. ILRI has long standing genetic improvement programs in chicken, dairy cattle, pigs, and small ruminants, as well as plant

breeding for improved feeds and forages. There is an opportunity for a more demand led approach to genetic improvement within livestock value chains for several species, such as chicken and pork, where there is rising demand for these commodities in both rural and urban areas, as well as on neglected livestock species such as cavies in West and Central Africa . ILRI also hosts Biosciences eastern and central Africa (BecA) as a shared research platform with laboratory and greenhouse facilities suitable for modern plant breeding, and which has previously hosted the DLB project, and mentored many early and mid career plant breeders who came to use the facilities of the BecA platform. The opportunity is to expand demand led breeding approaches to livestock value chains, and for BecA/ILRI to host and mentor a new generation of early to mid career plant and animal breeders.

Bomvitae Agro Industries Limited (BAIL) is a start-up company registered in Uganda to promote the dissemination and scale-up of value-added products from Sormaize technology. Sormaize is a set of proven innovations derived from a wide cross between sorghum and maize, which was initiated while the Principal Investigator was undertaking research using the BecA/ILRI Hub facilities. These new products from the wide cross can be used in the baking, pharmaceutical, brewing and feed & forage industries. Evidence of its adoption by farmers and key some actors of the value chain has been mapped out, and there are opportunities to scale out wider use of the value added products. DLB and BAIL are working together to develop a new proposal to fill this gap.

New Opportunities in Southern Africa

African Centre for Crop Improvement (ACCI) is an education institution based at the University of Kwazulu Natal, Pietermaritzburg in South Africa, and one of the founding partners of the DLB program. ACCI is one the pioneers in designing and implementing DLB approach to PhD level. ACCI alumni are prominent among the breeders in eastern and southern Africa who have successfully implemented DLB approaches to develop and release new varieties of sorghum and other crops (Table 8.1). The opportunity is to continue to mentor ACCI alumni in the implementation of DLB approaches within their breeding programs, and to expand the ACCI curriculum to introduce DLB within their MSc program.

New Opportunities in West and Central Africa

West African Centre for Crop Improvement (WACCI) University of Ghana
WACCI is one of the founding partners of DLB, and the WACCI director and faculty have supervised many of the new generation of plant breeders in West Africa, who are developing new varieties based on DLB principles (e.g. in tomato breeding -Table 8.1). WACCI is expanding its curriculum to include entrepreneurship, which has also been identified by DLB, along with professional and business development, as drivers of success and impact for the DLB alumni as they implement their breeding programs to develop new varieties that respond to farmer needs and market demands.

West African Virus Epidemiology (WAVE), University of Abidjan Cote D'ivoire
WAVE has recently been established by the Economic Community of West African States (ECOWAS) as a Regional Centre of Excellence for transboundary plant pathogens on May 27, 2021. WAVE has also established a strong partnership with 14 countries in west and central Africa with a high level of institutional and political connection with CORAF as a partner in West Africa. The opportunity is for DLB and WAVE to collaborate in introducing demand led breeding approaches to plant breeders in West and Central Africa, especially in francophone countries. This will require translation of the DLB education modules into French, and this work has commenced in order to widen the reach of DLB into more countries of Africa.

West and Central African Council for Agricultural Research and Development (CORAF/WECARD)
CORAF is the technical arm of ECOWAS and ECCAS for agricultural research and development. ECOWAS and ECCAS are regional political organisations in West and Central Africa dealing with economic issues. Early engagement with CORAF has identified possible areas of collaboration with the DLB program which include aid in engaging with heads of Missions, academic, public and private sector representatives to support policy agendas across west and central Africa, to link with the proposed new scientific and technical partnership between DLB and WAVE.

These new opportunities and potential new partnerships will be elaborated through further discussion amongst the African partners, including at a forthcoming DLB workshop, to be held in Nairobi on November 1- 3 2023.

Conclusion

These future opportunities with partners throughout Africa, and other emerging initiatives on promoting innovative financing mechanisms for sustainable support for demand led plant breeding in Africa and encouraging entrepreneurship amongst plant breeders in Africa are being further developed by the DLB team and its partners in Africa and internationally during 2023, as part of advocating the *business of plant breeding in Africa.* This is not as a cost to the public purse for governments, nor as a philanthropic grant, but as an investment in the future of African agriculture, and the farmers, traders, processors and consumers who drive this dynamic and critically important sector.

REFERENCES

List of Publications produced by the project

DLB Publications:
DLB publications are available on the project web site www.demandledbreeding.org
These include the following:

1.1 **Recent DLB Annual Reports:**
2021-22 Demand led Breeding Annual Report
https://www.demandledbreeding.org/_files/ugd/aff4c0_b0af639032d946e186c3542887377ec5.pdf
2020-21 Demand led Breeding Annual Report
https://www.demandledbreeding.org/_files/ugd/aff4c0_dcf817f35ee24070bcc1b6f99dd86396.pdf

1.2 **DLB Product Profiles Toolbox (2020)**:
https://www.demandledbreeding.org/product-profiles, including the following guides:
Product Profiles - A Practioners Guide: Overview (2020)
https://www.demandledbreeding.org/_files/ugd/9abdc5_806c5850744d4e219479b0f714f218da.pdf
Product Profiles: A Practioners guide: Creating Product Profile Summaries (2020)
https://www.demandledbreeding.org/_files/ugd/9abdc5_efc58213447c4d55a3cca49fdc0950dc.pdf
Product Profiles – 20 product profiles published on 12 different crops, including:
Beans, Nuts and Peas, Horticultural and Ornamental Crops, Rice, Maize, Roots and Tubers, Millets and Wheat.

1.3 DLB Education Modules 2017-2022: https://www.demandledbreeding.org/education-modules
Executive Summary:
https://www.demandledbreeding.org/_files/ugd/aff4c0_c56222aa64984841a7a8ee5b3bef329d.pdf
Chapter 1: Principles of DLB Variety Design:
https://www.demandledbreeding.org/_files/ugd/aff4c0_050cc177785d43cca754470e18b20d21.pdf
Chapter 2: Visioning and Foresight:
https://www.demandledbreeding.org/_files/ugd/aff4c0_b3d7ecc398fc498aadcc0437c87a7268.pdf
Chapter 3: Understanding Clients' Needs:
https://www.demandledbreeding.org/_files/ugd/aff4c0_52fca93503f547d5983ce35474ceb7c9.pdf
Chapter 4: New Variety Design and Product Profiling:
https://www.demandledbreeding.org/_files/ugd/aff4c0_f1b52197b81c447ea4522b21329217d3.pdf
Chapter 5: Variety Development Strategy and Stage Plan:
https://www.demandledbreeding.org/_files/ugd/aff4c0_1bd4a64f298041249c9a9c76d2469cd1.pdf
Chapter 6: Monitoring and Evaluation and Learning:
https://www.demandledbreeding.org/_files/ugd/aff4c0_496e7863bfef4cc2bf5f6800bbf634fa.pdf
Chapter 7: The Business Case for Investment in New Variety Development:
https://www.demandledbreeding.org/_files/ugd/aff4c0_924627793a8546659ac6cd09ec1745f8.pdf
Chapter 8: Gender, Diversity and inclusivity:
https://www.demandledbreeding.org/_files/ugd/aff4c0_12754ca358304c96a06627a1272f74c2.pdf
Chapter 9: Product profiling tools and Product concept:
https://www.demandledbreeding.org/_files/ugd/aff4c0_835ee5aa7de448d0b1843ceb76d7e24c.pdf

2. DLB External publications:
2.1 CABI Textbook (2017): *The Business of Plant Breeding -Market Led Approaches to plant variety design in Africa* edited by Gabrielle Persley and Vivienne M. Anthony
https://www.cabi.org/products-and-services/about-cabi-books/open-resources/the-business-of-plant-breeding/

https://www.demandledbreeding.org/_files/ugd/aff4c0_7b6ec82b7eae48b79f91b4b0d8341b83.pdf

2.2 Earthscan Food and Agriculture (2020): Chapter 11 *Crop Improvement for agricultural transformation in Southern Africa*, Hussein Shimelis, ET Gwata and Mark D Laing.
https://www.demandledbreeding.org/_files/ugd/aff4c0_f647d1114771493e9e5acee003135b05.pdf

2.3 African Journal of Rural Development Vol 4 Issue 3 (2019): *Advances in market-oriented approaches for legume breeding in eastern Africa*, page 305, PM Kimani and VM Anthony.
https://www.demandledbreeding.org/_files/ugd/aff4c0_286789472983447b973dad85ff159ef8.pdf

2.4 *Counting on Beans* (2020) Building bean business investment and strengthening PABRA breeding approach, R Kessy (ABC Tanzania) E Omondi (ABC Kenya) P Onyango (ABC Kenya) JC Rubyogo (ABC Kenya) G Persley (Doyle Foundation) N Yao (ILRI Kenya)
https://www.demandledbreeding.org/_files/ugd/aff4c0_f0233fa0d3fc4e6491c6d61b89ded8d9.pdf
(ABC: Alliance for Bioversity International and the International Centre for Tropical Agriculture)

2.5 Journal article
Esnart Nyirenda **Yohane**, Hussein Shimelis, Mark Laing, Isack Mathew and Admire Shayanowako 2022 *Combining ability and gene action for agronomic traits and Fusarium wilt resistance in pigeon pea* Journal of Crop Improvement 36, Issue 6, pp 842-865 Link DOI:10.1080/15427528.2021.2022059

DLB Report Authors

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