NextGen Cassava Breeding Project

Report for Year 5 Review and Planning Workshop

IITA Ibadan, Nigeria, 14th -16th March 2017

Disclaimer

This report documents the year five review and planning workshop for NextGen Cassava Breeding Project that was held on 14th to 16th March 2017 at IITA in Ibadan, Nigeria. The report is not a synthesis, but a documentation of the proceedings and outcomes of the workshop without interpretation. It serves as a reference document for NextGen and workshop participants by providing details of what transpired. The results of the working groups and plenary discussions are reported as they were presented. The opinions expressed in this report are those of the workshop participants and do not reflect the position of PICOTEAM - they are a compilation of participants' contributions.

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Photos in the report provided by Samantha Hautea (Cornell University) and Anita Msabeni (PICOTEAM)

Table of contents

Acronyms and Abbreviations

BMGF	Bill and Melinda Gates Foundation
CBSD	Cassava Brown Streak Disease
DFID	UK Department for International Development
DUS	Distance Uniformity and Stability Analysis
GBE	Genotype by Environment
GS	Genomic Selection
IITA	International Institute of Tropical Agriculture
NaCRRI	National Crops Resources Research Institute (Uganda)
NRCRI	National Root Crops Research Institute (Nigeria)
UBIC	Uganda Bioscience Information Center

Acknowledgments

The three day Annual General Meeting for the NextGen Cassava Breeding Project that brought together a wide range of participants representing different project partners to take stock of progress of phase I and develop key thrusts for phase II was an interesting experience for PICOTEAM to facilitate.

We are optimistic that we managed to support the NextGen Cassava team identify and prioritize action areas to be pursued in phase II of the project as well as potential partners to work together to achieve the work including developing and leveraging capacity and learning among the actors and beyond the project.

We sincerely thank all the participants for their active and enthusiastic participation throughout the workshop in addition to sharing their practical know-how, insights and technical knowledge. This enabled to articulate future plans of the project, expected products, new partnerships and roles of each partner. PICOTEAM also extends its appreciation to all individuals that provided logistical support that led to the success of the workshop.

Special thanks to the process steering group, which spent time in reflecting with us the daily proceedings and then jointly planning for the next day's process. Through their steering we were able to navigate through the process and put together the finer details of the workshop procedure.

We surely enjoyed working with all of you and wish you the best as you transit to the 2nd phase of implementing the accelerated breeding and developing end-user preferred varieties.

Best Wishes,
Edward Chuma and Anita Msabeni

PICOTEAM
Institute for People, Innovation and Change in Organisations
Facilitation - Coaching - Research for Change

Foreword by workshop organizers

This document has been condensed and edited by Canaan Boyer.

Please click on embedded links to find PDFs of the meeting presentations and posters.

Executive Summary

The Next Generation Cassava Breeding Project (NextGen Cassava), started in 2012, has been implementing and empirically testing a new breeding method known as ***genomic selection***; it has also been identifying possibilities to improving flowering in cassava, understanding roles different gender groups in the development of new varieties, and created a premier open-data breeding database (Cassavabase), among many other activities. The project is now in a transition stage bridging the phase of development and testing of these novel technologies and that of implementing them in accelerated breeding and development of end-user preferred varieties.

The NextGen Cassava breeding project is funded by the Bill and Melinda Gates Foundation and the UK Department for International Development. Project partners include: College of Agriculture and Life Sciences, Cornell University, USA; National Crops Resources Research Institute (NaCRRI), Uganda; National Root Crops Research Institute (NRCRI), Nigeria; International Institute of Tropical Agriculture (IITA), Nigeria; Boyce Thompson Institute (BTI) for Plant Research, USA; US Department of Energy (DOE) Joint Genome Institute (JGI), USA; Makerere University, Uganda; and West African Centre for Crop Improvement (WACCI), Ghana. NextGen Cassava has expanded to include Tanzania, partnering with the Lake Zone Agricultural Research and Development Institute (LZARDI).

In order to move seamlessly to the 2nd phase, a three-day meeting was hosted to review progress made from inception of the project to-date and enable the team identify future plans for the project comprising expected products, new partnerships and resultant roles of each partner.

The workshop commenced with taking stock of progress made where various presentations were made highlighting lessons, gaps, challenges and possible solutions for the NextGen Cassava Breeding Project. Major successes identified include: germplasm exchange; NextGen variety release; development of genomic resources; trainings; genomic selection working; Cassavabase; genetic architecture; gender responsive initiatives; better understanding of farmers' and processors' preferences. Main challenges encountered: phenotyping; effective advocacy; trait management; genetic load; genotyping quality control; complexity of germplasm exchange system; limited use of Cassavabase - ensuring usage of existing features as well as new features and publication of an African cassava reference genome. The implications for the next phase of these challenges are the need for increased capacity development; making Cassavabase a one stop shop; breeding for target traits; genetic load during cyclic improvement through GS and enhanced communication and advocacy.

Some of the emerging technologies and trends essential to successful cassava breeding that were discussed include: Optimum Haploid Value selection technology; phenotyping through image analysis; NIRS phenotyping and calibration; field phenotyping; and artificial intelligence

(AI) for phenotyping. Participants then identified phenotyping, variety release and dissemination, SAH, genomic selection models, and flowering induction as technologies with the highest potential for success and which need to be developed further in Phase II. Intermediate products proposed include: protocol and technology and training packages, while varieties and trained personnel were proposed as final products.

The 9 fundamental steps of the variety release process in Nigeria were elaborated to the NextGen team to guide them as they work on registration and release of new cassava varieties that will be produced under the NextGen pipeline. This would enable the NextGen project to evaluate its trials and register their varieties harmoniously with the variety release committee.

To manage the transition from Phase I to Phase II, interconnectivity of the three divisions of Phase II (research, breeding and communication) were examined and potential areas of expertise and pathways of activities proposed.

Finally, on the basis of trends and future demands in view to Phase II, participants developed work plans of what needs to be focused on in the remaining time of Phase I.

1. Setting the Scene

This session was intended to create a relaxed environment during the three days of the workshop, an environment that fosters open interactions among the participants to enable them bring out key issues to be addressed for successful transition to Phase II. It involved agreeing on the ground rules, introductions of participants and clarifying their expectations, understanding of objectives and looking over the general programme of the workshop.

1.1. Welcome Remarks

The meeting started with welcome remarks from Chiedozie Ngozi Egesi - Project Manager for NextGen Cassava; who thanked everybody and welcomed them to the 5th AGM of NextGen Cassava which is also the biggest in terms of age, number of participants and diversity. Over the past four years NextGen Cassava has expanded and there are now more partners onboard. Chiedozie appreciated all the partners for working together in making the modest steps of growth enabling the project deliver in its efforts along the cassava breeding cycle.

Picture 1 - welcome remarks from Chiedozie Egesi

He urged participants to feel free, relax and use the meeting as an opportunity to share experiences as everyone would get an opportunity to illustrate the progress they have made and discuss intensively the future trends. He prompted the participants to identify their "moon shots" as members of the cassava team. *"Moon Shot - what would be my best strategy to deliver the best products/cassava varieties to cassava end users and farmers"*.

Chiedozie then introduced the facilitation team who would help the participants look at what has happened, how to transition to the next phase, and future trends. Edward Chuma, a professional facilitator from the Institute for People, Innovation and Change in Organizations (PICOTEAM) explained that PICOTEAM specializes on facilitation and coaching, change management and organizational development – with a predominant focus on innovation processes in agriculture. PICOTEAM supports organizations to perform better. Edward introduced Anita Msabeni, who was in the meeting for documentation of the proceedings.

1.2. Co-management of the Workshop

The facilitator was assisted by a nine-member Workshop Process Steering Group (WPSG). The WPSG consisting of a cross-section of the participants and project partners, who represent the whole group well, was responsible for co-management of the workshop. They first met on the day preceding the workshop and at the end of each workshop day to review the

progress towards achieving the outputs of the workshop in addition to addressing concerns arising on the workshop procedure. This process-oriented procedure allows participants to take an active role in co-creation of the process, responsibility for the success of the workshop and ownership of the outcomes.

Workshop Process Steering Group

A mechanism for co-management of the meeting by participants and organizers

Tasks:

- To get feedback from participants on the workshop process and contents
- To plan with the facilitator and adjust the programme accordingly

Members:

Hale, Jean-Luc, Peter, Robert, Chiedozie, Canaan, Ismail, Seun, Anita, Edward

Box 1: Workshop process steering group task

1.3. Facilitation principles

To manage dialogue during the three days of the workshop, the facilitator introduced participants to key facilitation principles and rules as practiced by PICOTEAM. The meeting agreed to adapt these core values to help create an atmosphere of effective interaction and constructive sharing of ideas.

1.4. Getting to know one another

To help participants familiarize with each other and create an atmosphere for free interaction, the facilitator requested them to sit at tables with people they knew least.

Who is here?

An exercise aimed at exploring who is represented in the workshop and the implications this may have on the discussions was performed as shown here below:

Category	No	Remarks
Gender	Men = **Majority** Women = **15** Age under 30 = **6 pax** Age 30-50 = **40 pax** Age 50-65 = **12 pax** Over 65 years = **1 person**	• Ratio of women to men is 1:8, it is important to increase female participation at all levels of the project • Note: gender is not about women, but more of social differentiation and social groups (men, women, youth and their different roles) • The age distribution is wholesome and reflects a wise group. • For Africa, when discussing agriculture the youth is a key social group which should be widely integrated into agriculture
Technical area of training	Breeders - conventional = **18 pax** Agronomists = **2 pax** Social Scientists = **4 pax** Extension and communication = **1 pax**	• The group is rich with a good number of people with the required expertise and experience. • Conventional breeders are the majority and this being a breeding project the need to focus is critical • Non-conventional breeding includes molecular and transgenic breeding • The other disciplines add the required technical areas to ensure multi-disciplinarity of the project
Institutional representation	IITA = majority ; CIAT = 2 pax ; UBIC = 1 pax; EMRAPA = ; NRCRI = 10 pax; BMGF = 1 pax; Cornell = 23 pax; NaCRRI = 1 pax; BTI = 5 pax; Other = 13 pax	• The Institutional composition is diverse • However the ultimate clients, the consumers, farmer and processors are not represented
Country of origin	**Africa = majority** (Nigeria = 27, Uganda = 4, Kenya = 2, Tanzania = 4) **Europe, Asia and America =** (USA = 6, Brazil = 1, France = 1, Netherlands = 1, Columbia = 2, India = 3, Switzerland = 1)	• We are very diverse • We communicate differently and push differently with some being confident in articulating themselves while others are timid in expressing themselves

Conclusion

Throughout our discussions, we should take into consideration our different backgrounds – THIS SHOULD BE A POINT OF STRENGTH RATHER THAN A PROBLEM.

1.5. Workshop agenda and process

The facilitator formally presented the workshop objectives of meeting. The overall objective of the workshop was to take stock of progress of the NextGen project and develop the key thrusts for the phase II. The anticipated specific outputs of the workshop were:

a. To update on NextGen's work and review progress with lessons, gaps, challenges and exchange ideas and possible solutions to gaps and challenges.
b. To identify emerging technologies/processes and trends integral to a successful cassava breeding, including breeding pipelines and products.
c. To understand the future demand for products and results of the project and possible partners and pathways for success / impact.
d. To identify and prioritize action areas to be pursued in phase II of the project and potential partners to achieve.
e. To develop further the collaborative network of actors as a means for developing and leveraging capacity and learning among across actors.
f. To clarify the way forward and come up with a revised workplan for year 5.
g. Getting to know and appreciate each other more and having fun!

A detailed overview of the workshop programme is summarized in Appendix one.

2. Official workshop opening session

This session sought to show the high level goals behind the meeting so that participants can relate to the same during the discussions. This was achieved through key note addresses presented by representatives of the various partner institutions.

The master of ceremony, Godwin Atser of IITA, again formally welcomed all participants to IITA Ibadan campus to the 5th NextGen AGM aimed at looking at the past, what has been done and what needs to be done going forward. Godwin recognized the presence of everyone from different countries and institutions. He also noted the presence of the deputy director general of IITA who was representing the director general; the principle investigator for NextGen cassava project; Bill & Melinda Gates foundation representative; executive director for NRCRI; representatives from the ministry of agriculture whose presence showed the government of

Nigeria's commitment to development of agriculture; west Africa director for IITA and all colleagues from the various institutions.

For the opening and welcoming remarks he called the following to give their remarks:

2.1. Welcome message by IITA

Dr. Kenton Dashiell the Deputy Director General for Partnerships for Delivery of IITA welcomed all to the meeting and specifically to IITA headquarters and campus. He enquired

of the participants how many had used any of the extensive research and recreational facilities in the campus including the swimming pool, tennis court, golf course, squash courts and the nature reserve area. Having seen the energy in the group, he encouraged them to spare time after the workshop and use the facilities.

To illustrate the importance of cassava in Africa and to Nigeria, Dr. Dashiell narrated a story - he was in a meeting to discuss how to stop hunger in Nigeria by 2025 whose chair was General Olusegun Obasanjo the former Nigerian President. IITA asked the former president what would happen to Nigeria if there was no cassava. The former president acknowledged it is not possible to have a Nigeria without cassava as it is a major food in different forms such as garri, abar, fufu and abacha eaten as a meal throughout the day.

Bearing all this in mind, Dr. Dashiell reminded the participants they are the world's top cassava experts and should endeavor to develop new varieties of cassava with higher yield and nutritional content. Dr. Dashiell reminded that about 25 years ago, cassava was almost wiped out by a disease, but concerted efforts by scientists came up with a solution that combated the disease. He concluded by reminding the participants the work they do on a daily basis is critical for survival of many in Africa.

2.2. NextGen Cassava project in brief

Professor Ronnie Coffman began by joining other distinguished visitors in congratulating IITA on its 50th anniversary. Cornell University and the other partners involved in NextGen Cassava are proud to be among the many global partners working with IITA to generate the agricultural innovations needed to meet Africa's pressing challenges. Ronnie also appreciated the diversity in age groups and experience represented in the meeting and informed that he loved working with young people as they bring new ideas.

NextGen Cassava project, which is now in its 5th year, is a remarkable example of successful partnerships in agricultural development. NextGen works with 10 institutional partners across

six countries on three continents. Ronnie commended Chiedozie Egesi, for his leadership as well as the many scientists in the US and in Africa who are working on this project.

Ronnie exemplified NextGen as a remarkable model for collaborative, open-source, shared-data networks that are needed to improve agricultural crops globally in the 21st century.

Ronnie publicly recognized the scientists from the various institutions praising their ability to successfully collaborate across scientific precepts, across cultures, and across oceans. In Africa, we have IITA (our hosts here in Nigeria), the National Root Crops Research Institute in Nigeria, the National Crops Resources Research Institute in Uganda, and, most recently, the Lake Zone Agricultural Research and Development Institute in Tanzania. In South America, NextGen partners with Embrapa in Brazil, and the International Center for Tropical Agriculture in Colombia. In the US, partners include Cornell University (the lead institution), the University of Hawaii, the Boyce Thompson Institute, the U.S. Department of Agriculture-Agricultural Research Service, and the U.S. Department of Energy Joint Genome Institute.

Ronnie reported that since 2012, partners on NextGen Cassava have been using a state-of-the-art plant breeding approach known as genomic selection to improve cassava productivity. Genomic selection shortens breeding cycles, provides more accurate evaluation at the seedling stage, and gives plant breeders the ability to evaluate a much larger number of clones without the need to plant them in the target environment. Ronnie recognized Jean-Luc Jannink, from the USDA-ARS for his leadership of this objective.

Using the kind of statistical predictive analyses offered through genomic selection, new releases of cassava, which used to take a decade or more to develop, are ready in as little as six years. Ronnie happily reported that after 5 years, some of the best clones from this upstream work are in Uniform Yield Trials this year due to be released to farmers in the next two years. In addition to using genomic selection, scientists are also working to identify possibilities to improving flowering in cassava, and understand the roles of different gender groups in the development of new varieties. Project leaders have created a premier open-data breeding database, called Cassavabase.

As a long-time plant breeder, Ronnie reiterated how important it is to train the next generation of plant breeders. Without that important pipeline, long-term sustainable improvements in crop production will wither in the face of future challenges. As such Ronnie was very proud that NextGen has been working to not only improve the next generation of cassava, but, very importantly, is educating the next generation of cassava breeders.

NextGen is providing education and training for nine Ph.D. students (6 of whom are at Cornell and 3 of whom are at WACCI), who are well on their way to obtaining advanced degrees, in research ranging from farmer root quality preferences, to spectrometric analyses of roots, to genotype by environment interaction, to genomic prediction and association studies, to bioinformatics. An additional nine Masters students were trained at Makerere University in Kampala. This training pipeline will increase the efficiency of breeding staple crops for African smallholder farmers.

Ronnie explained the NextGen project is now in a transition stage, bridging Phase I of development and testing of these novel technologies and that of Phase II in implementing the products of accelerated breeding and development of end-user preferred varieties. The meeting aimed to review the progress made from inception of the project to date and flesh out future plans for Phase II, including expected products, new partnerships and roles for each partner.

We are hoping that we have a renewal of the NextGen grant for another five years. Another five years will allow NextGen plant breeders and objective leaders to make more progress in delivering improved cassava varieties to smallholder farmers through sub-Saharan Africa. Another five years will help strengthen the long-term sustainability of cassava improvement.

In closing, Ronnie recognized Bill & Melinda Gates Foundation and the Department for International Development of the United Kingdom (DFID) under its UK Aid program who are the main donors. These two organizations have tremendous foresight and vision when it comes to the importance of agricultural development and the need to improve the world's staple crops to meet the biotic and abiotic stresses of the 21st century. They are making the critical investment necessary to fund the objectives of the project to improve the production and nutritional value of cassava and build human and technical capacity for plant breeding in sub-Saharan Africa.

2.3. Goodwill from Bill & Melinda Gates Foundation

Jim Lorenzen the Senior Programme Officer, BMGF expressed great pleasure and honour to be among the largest cassava meeting. He appreciated the workshop organizers for the great logistics in bringing together people from all over the world to the biggest land of cassava – Nigeria.

Jim informed participants that the NextGen cassava project is very important to BMGF where cassava is at the top with maize as robust crops to feed Africa. Cassava and maize are key food security crops.

A key core value that drives BMGF work is that everyone deserves the right to live a good life. For Africa, the ability to intensify food production is very critical and the NextGen cassava project is key in helping agriculture achieve its objective. NextGen cassava project is one of the largest investments for BMGF. BMGF will use the NextGen cassava project model to uplift other crops using its approaches such as data sharing, clones, trials, breeding cycles.

Jim notified the participants that NextGen cassava project has gained the attention and recognition of Bill and Melinda as a leading research programme with great potential for improving food security in Africa. Jim applauded the progress made especially in understanding the tools for developing the cassava crop and noted these tools will be used to improve other tubers.

He concluded by appreciated the hard work done and looked forward to a successful Phase II that would validate the genomics work and assured of BMGF support to Phase II.

2.4. Goodwill from National Root Crops Research Institute

Dr. Joseph of NRCRI on behalf of Julius Okonkwo declared the NextGen Cassava project as the best thing to have happened to NRCRI. It has enable NRCRI to make progress in breeding and built capacity of staff over the last four year.

Joseph reaffirmed NRCRI's full support to the NextGen Cassava project and is ready to give out its best staff to bring about the required change as well as any other capacity that will be required.

2.5. Goodwill from ACAI Project

On behalf of Abdulai Jalloh Dr. Christine Kreye of IITA explained that the African Cassava Agronomy Initiative project works at last scale supporting farmers and extension workers on fertilizer recommendations and best planting practices.

ACAI and other partners look forward to working with the NextGen Cassava project as cassava is a very important crop. Partners await the NextGen cassava products to be used in the next level. She urged the NextGen team to build sustainable systems for development and up scaling at the farmer level

such as cassava seed systems. It is anticipated that NextGen Cassava project will reduce the wait period for new varieties.

Christine also hailed the wide involvement of students as it is important to train and improve the capacity of next generation of breeders. She also cautioned against focusing on increasing productivity without addressing the marketing and processing features. She gave an example of a 25% higher yielding chickpea which was released to farmers who produced it in huge quantities but 5 years later abandoned it because millers had difficulties processing it and so paid low prices for it.

She concluded by advocating the benefits of working with all partners to ensure the right product is released. Work with the "end" in mind.

2.6. BASICS Project

Hemant Nitturkar, the project coordinator of roots, tubers and bananas, explained that the BASICS project aims to take more varieties to farmers and consumers (to the table).

He envisaged seeing more varieties with farmer preferred traits released to farmers by the NextGen cassava project.

Hemant informed that ECOWAS block had developed a document to enable varieties released in a country to be released across the region. NextGen has already entered into an agreement with the board, and equally the national variety release committee in Nigeria is comfortable with NextGen procedures and is ready to work together in release of upcoming varieties. NextGen should clearly understand and adhere to the procedures for bringing varieties to the committee.

2.7. Semi-Autotrophic Hydroponics Technology

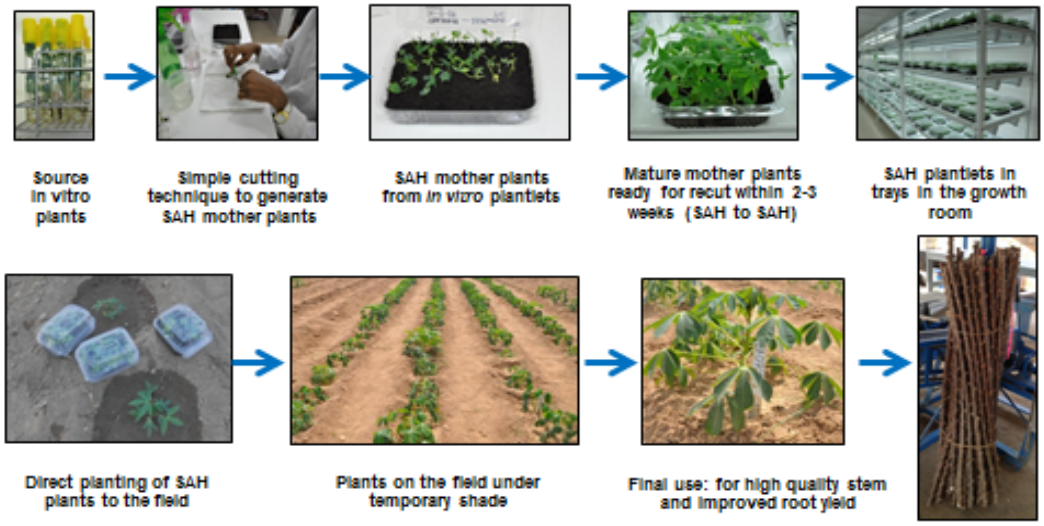
Lava Kumar of IITA explained that Semi-Autotrophic Hydroponics (SAH) is a technology for cassava propagation systems. SAH is a new, rapid multiplication technology of virus-free cassava planting material.

Clean seed systems are important to control virus diseases particularly cassava mosaic and cassava brown streak diseases which are spread through vegetative propagation. Virus-free plants are produced using in

vitro meristem cultures. In vitro propagation is a rate limiting step compared to tissue culture which require sophisticated facilities and skilled personnel; has relatively slow bulking rate and requires hardening of plants before using in the fields. There is also high rate of tissue culture plant loss during transportation and distribution.

SAH enables rapid propagation of tissue culture (in vitro) plantlets under semi-hydroponic and semi-controlled environmental conditions; offers high quality 'rooted plants' transferable to screen house or field and genetic purity and plant health comparable to in vitro plants.

Process: In vitro → SAH Lab → Field



Potential production rate

tissue culture to tissue culture cycle	SAH to SAH cycle
• In one year 15,625 plantlets • 1:5 every 2 months • Additional hardening stage prior to use of plants, effectively reduces to 3,000 to 7,000 SAH equivalent plants per year	• In one year 200,000 -250,000 plants • 1:2 every 3 to 4 weeks • Moving 5,000 plants to the field per week; 10 - 15 ha stem production fields per year • No hardening stage

The SAH facility in IITA – Ibadan was initiated in July 2016. The SAH room (20 sq. m) holds up to 25,000 to 30,000 plantlets and can produce virus-free cassava planting material for up to 10 ha per annum.

SAH technology is cheaper and efficient alternative to in vitro propagation of virus-free, true-to-type planting material.

2.8. Unleashing the Power of Cassava: Breeding and Varieties of Change

Alfred Dixon, the director of partnerships, IITA, was pleased to see the team of young cassava breeders fully engaged and moving into modern science for improvement of cassava and general agricultural development.

He voiced the need for transformation of African agriculture and noted this requires "business unusual" approaches. Africa is confronted with a rapidly growing population and rising urbanization; parallel increase in demand for food, feed for livestock, and raw materials for industries as well as huge food import bill: $35b in 2016, $110b in 2025. Climate change has dramatic effects on agricultural production in Africa. Simple steps for transformation of African agriculture include shift to agriculture as business and not a way of life; Integrated approach to developing Agricultural Value Chains and catalyzing financing of the agriculture sector.

Dixon went on to explain the importance of cassava: it is the second most important food crop in Africa (Africa is the global leader in cassava production); it is an appropriate commodity to feature in Africa's economic development (NEPAD, CAADP, IFAD, GCDS) and recent projections forecast even higher dependence for food security and poverty alleviation; famine reserve crop (food insurance) and rural food staple; cash crop for urban consumption; source of industrial raw material and a foreign exchange earner. All parts of the cassava are useful – foliage as a tropical spinach and alfalfa; stem as planting material and roots for unique starch properties and yellow roots for carotenes. More focus should be put on cassava transformation to end products such as fresh roots cooked, boiled, baked or fried at the household level to highly processed starch as a food additive. This can be achieved through efficiency, modernization and competitiveness of cassava value chain.

There are two pathways - surplus cassava products find no market (this is a disincentive to farmers) or markets available for surplus cassava products (source of income for farmers and therefore an incentive).

Genetic improvement of cassava is important to contribute to reliable supply and demand (increasing production, productivity, marketing opportunities, and profitability); source of improved cassava varieties responsive to changing demands and markets by driving down costs of production, harvesting, processing and marketing to make cassava products competitive with other raw materials as well as improve the quantity and quality of cassava products for diversified uses.

Limitations/constraints in cassava production:

- ❑ Bulkiness – this has implications for handling, transport, storage, crop hygiene.
- ❑ Perishability- this has implications for marketing, utilisation, crop management.
- ❑ Low multiplication ratio of plant propagules - this has implications for area planted per unit time.
- ❑ Lengthy growing season - long breeding cycle and its genetics is largely unknown.
- ❑ Plant pests and diseases.
- ❑ Shortening fallow periods and declining soil fertility.
- ❑ Difficulties in transferring useful genes (high genetic load and poor flowering ability).
- ❑ Insufficient and poor quality planting material of more adapted germplasm on farmers' field.
- ❑ Untapped market opportunities.
- ❑ Cyanide scare.

Addressing the Limitations/constraints

- ❑ Production Orientation - entry point for research agenda is prioritization of production constraints
- ❑ Market Orientation - entry point for research agenda is the identification of market opportunities

This requires knowledge of producers to consumers' continuum; along with application of modern science and technology as well as conventional breeding and increased partnerships.

Breeding research needs for varieties of change for Africa in the new millennium

- ❑ Multiple sources of resistant genes (pyramiding multiple genes) for emerging pest threats for durable resistance.
- ❑ High storage root starch quantity per unit area and time, and quality, for food, feed, and agro-industrial uses.
- ❑ Enhanced nutritional content of storage roots (high protein and micronutrient contents).
- ❑ Delayed onset or deactivation of physiological postharvest deterioration (PPD) of storage roots.
- ❑ Drought resistance as cassava expands to non-traditional areas and in the light of global climate change.
- ❑ Nutrient use efficient varieties (Nutrient responsiveness).

- Herbicide resistance for durable weed control.
- Good plant architecture for ease of mechanized operations and ease of processing.
- High root and foliage yield (dual purpose cassava) for food and feed.
- Acyanogenesis to reduce costs of processing, enhance nutrient bioavailability and prevent setback in cassava global market.

Breeding efficiency and effectiveness can be tackled through: shortened breeding cycle; robust seed production methods (e.g. double haploids for rapid production of homozygous lines, pure hybrid seed production, apomixes and seed systems); profuse flowering "at will" to access a greater diversity of parental materials; development of effective molecular markers and database to optimize the use of genetic resources and marker-aided introgression/selection; and rapid, cheap molecular diagnostic tools for important diseases surveillance and to ensure the safe movement of germplasm.

A CGIAR-commissioned study to assess impact of IITA germplasm improvement reveals that:

- Between 1965 and 1998, 200 cassava cultivars were released by NARS
- IITA materials represented 80% of the germplasm incorporated in new varieties for the 1990s and resulted in yield advantage of about 49%
- Represents an increment to annual production that provides food security to a further 14 million people
- 1381 cassava scientists (38% of senior, and 49% of intermediate level researchers) trained in SSA

In conclusion Dixon pointed out unfinished tasks - arrest of the limitations, modernizing cassava production, enhancing productivity, adaptability, value addition, and adoptability. This requires forcing a "breakthrough" in cassava improvement through both conventional and new innovative approaches and tools. He urged the scientists to beware of increasing prominence of Cassava Brown Streak Disease and emerging pest threats such as chlorosis which affects the bottom of leaves; brown streaks on stems; dry necrotic rot – most damaging to roots and bemisia tabaci (whiteflies) as a direct pest.

He also emphasized that without markets, technology will go nowhere and the need for more resources and effective capacity building, networking for sustainability of R&D and effective partnerships with effective coordination.

2.9. Official opening of the workshop

Olusegun Ayeni the deputy minister for agriculture and rural development on behalf of the Hon. Minister Chief Audu Ogbeh was glad to be part of the important NextGen AGM event as well as to be in IITA when the institute celebrates its 50 years of research. He congratulated

IITA for their excellent research not only in cassava but also in other important crops such as maize, soybean, banana/plantain, yam and cowpea.

Ayeni reiterated the importance of cassava – it's a major staple crop and poverty fighter in Nigeria. Traditionally, cassava is processed into gari, fufu and akpu, but recently with increased investments cassava is now processed into flour, ethanol and starch. The entrance of the companies has increased the demand for cassava in Nigeria and this is good news to the farmers.

Ayeni was concerned that although Nigeria is a major producer of cassava the yield per hectare is not impressive. Farmers get between 8-10 tons per hectare; comparing cassava yield in Nigeria with other countries such as Thailand, where yields go above 20 tons per hectare, then Nigerian farmers cannot compete. For these reasons, researchers are important and the first phase of the NextGen Cassava project already produced good results. Science is critical for a transformational change of the cassava sector especially because there more issues to contend with such as low cassava productivity, climate change, pests and diseases among many others. These emerging limitations call for new breeding options that are quick and smart. Ayeni congratulated the NextGen team for the work they are already doing to address the constraints for current as well as future generations.

The Nigerian government has made a commitment to reposition agriculture for economic and inclusive growth and has launched the Agricultural Promotion Policy, 2016 -2019, tagged "the green alternative." The green alternative roadmap recognizes the key role of both smallholder farmers and large scale farmers in maximizing agricultural output, achieving increased efficiency of agricultural operations by entrusting the private sector with the role of driving growth of the agriculture sector. The private sector is also tasked with the responsibility of creating linkages to help smallholder farmers to take advantage of better organization methods, technological access, financial services and linkages to input supply chains and markets.

Ayeni concluded by acknowledging that NextGen Cassava goals are in alignment with the federal governments agenda by working towards agriculture revitalization through provision of better seeds. He emphasized the critical role of researchers for the success of the green alternative and urged all partners to continue working together to take cassava to the next level and put smiles on the faces of farmers and households.

Ayeni declared the workshop open and wished the participants fruitful deliberations.

3. Taking stock of progress made in phase I

This step of the meeting aimed at looking at the state of the art of the work in the NextGen project. Using presentations, group and plenary discussions participants explored the state of the work done by the different partners so as to understand progress made so far, successes, challenges faced, gaps and implications for the future.

A select number of Input presentations were made detailing the progress done after which participants offered feedback, sought clarifications and identified the successes, challenges and implications for the future.

3.1. National Crops Resources Research Institute (Uganda)

The presentation by Robert Kawuki provided updates on:

Genomic Selection under 2-year cycle (Selection, Crossing, Evaluating): Ranking TP based on GEBVs (2014); Crossing among top clones (2014); Cycle 1 in field (2015-2016); Cycle 2 generation (2016-2017). **Lead Traits** - Cassava Brown Streak Disease, Dry matter content and Harvest Index

GxE studies: 120-150 Clones/site across 32 environments: Environmental components recorded – temperature, rainfall, relative humidity and solar radiation. Candidates for official release - pending registration and yield performance trials.

Genome-wide association studies for CBSD: 714 clones evaluated in 4 locations; 2-3 seasons; genotyping done at Cornell~41,530 SNPs shared the highly significant SNPs for foliar on both chromosome 4 (128) and chromosome 11(29); Re-analysing the root necrosis data and thereafter share the information.

Participatory variety selection trials - 9 farmers (3 from each of the target 3 districts involved); Test clones: top 4 of the 5CP varieties; Target datasets - qualitative social data and quantitative biological data.

M.Sc student in Makerere University under Prof. Paul Gibson and Dr. Richard Edema - 3 have submitted their thesis while 5 are yet to submit.

Take home message

- Gender works
- Good response to selection and other performance selection trials
- Culling for CMD at 6 MAP necessary in selecting candidates for genotyping
- Major achievements – one year cycle and training groups

Data uploads into Cassavabase

Examination of gender disaggregated cassava traits preferences of smallholder farmers in Uganda - information will be used to design appropriate breeding strategies for the preferred traits.

PEARL component - Seedling nursery for improved germplasm from IITA – 35,000 seeds; Phenotyping TP for pro-vitamin A carotenoids; Gender disaggregated study on perceptions on yellow cassava; Crossing block for population improvement – 20 parents; Disease data from TP for pVAC; Enhanced capacity for high throughput phenotyping.

Fascinating challenges and Opportunities:

- Highly resistant clones (potentially progenitors);
- Yield penalty (can increasing ploidy help?)

3.2. National Root Crops Research Institute (Nigeria)

The presentation by Joseph Onyeka provided updates on:

Objective 1: identifying methods to improve flowering and seed set in cassava - Agronomic data was collected on plant height (PH), branching height (BH), level of branching (LB), number of inflorescence/fork (NI), number of male flowers/fork (NMF), number of female flowers/fork (NFF) and number of fruits/fork (NF). Data was analyzed using Analysis of Variance method in GenSTAT edition 3.0 and MS Excel 2007.

The conclusions: BA application on cassava plant showed little or no influence on the flowering induction at the first year of spray; cassava plants carried over the memory of the first year BA application at the second year of establishment (when cloned) and this induced flowering on TME419; the memory of the BA, wears out at the third year of establishment (second cloning).

Objective 2: implementing genomic selection in cassava: C1 prediction and selections of parents: GEBVS were predicted for the C1a individuals from GS and polycross progenies. Fifty progenies with high index values were selected as parents for the next generation. They have been planted out in a crossing block to generate seeds for the next prediction cycle. The 50 progenies were selected using Index weights guided by the price of gari and desired correlation among the selected traits of interest.

Genome-wide association study for CGM: To identify marker-trait associations for cassava green mite resistance and associated traits using genome-wide association studies. 848

diverse NRCRI breeding lines were used in the analyses. Evaluated in 2013/2014, 2014/2015 and 2015/2016 cropping seasons in three different locations: Umudike, Otobi and Kano.

Traits: Cassava Green Mite Severity, Leaf Pubescence, Leaf Retention, Stay Green, Shoot Tip Compactness and Shoot Tip Size.

Conclusion: A well-defined peak on chromosome 8 was observed for CGMS, LP and LR in all the locations. There was no effect of genotype by environment for the traits by comparing the GWAS results across the three years and three locations.

Moving forward

- Officially release NextGen cassava varieties in Nigeria
- Breeding pipelines development for new populations and varieties targeting specific preferred traits.
- Phenotyping reference lab for root quality traits: defining trait profiles, calibration of tools, improved phenotyping using Portable NIRS.
- Preliminary results using our potable NIRS are promising for the quantification of important traits and provides flexibility for field-based sample preparation
- PhD students will resume greater responsibilities in the national cassava breeding programme after their graduation.

3.3. Implementation of Genomic Selection at IITA (2012-2017)

The presentation by Ismail Rabbi provided updates on progress made and future prospects of the cassava Breeding Unit at IITA:

Accomplishments

- Four annual breeding cycles implemented using GS.
- > 8500 clones (C0, C1, C2,C3) genotyped-by-sequencing.
- Thousands of clones from successive GS cycles phenotyped.
- Potential varieties from GS pipeline evaluated:
  - First UYT from Cycle 1
  - Several AYTs from Cycle 2.
- Selection gain trial underway – intend to implement the first NEXTGEN genetic gains trial in 2015-2016 using C0, C1 and C2 clones. Clones from GS C0, C1, and C2 planted in the same replicated trial in 2015-2016 and 2016-2017 seasons at Ibadan and Mokwa.
- Implementation of annual breeding cycle - breeding activities modernized.

- Genetic architecture on important traits understood and trait-linked markers developed. Recorded traits - Pest and disease resistance (MCMDS, MCBBS, MCGM); Agronomic traits (sprout, vigor, Plant type, Flowering); Nutritional content (TCC, b*); Yield and yield components (DM, HI, FYLD, RTWT, RTNO)

Challenges and opportunities

- Phenotyping platform for quality traits
  - Current focus is on observable traits (pest, diseases, yield and yield-components, plant morphology etc.)
  - Limited capacity for quality trait assessment
  - Need dedicated analytical chemistry lab + Personnel?
- Field phenotyping
  - Improve field designs
  - Irrigation facilities
- Genotyping
  - GBS to rAmpSeq: Potential for genotyping more seedlings required upgrading of DNA extraction facilities
  - Need to improve local capacity to prepare rAmpSeq libraries and bioinformatics pipeline.
- Diversify breeding pipeline.

3.4. Cassava Breeding Progress in Tanzania

The presentation by Heneriko Kulembeka provided updates on NextGen activities in Tanzania:

- Visit to Tanzania by NEXTGEN team from Cornell and IITA in April 2016 - discussed and agreed on training populations, activities for LZARDI Ukiriguru and SRI Kibaha
- Signed Sub-Agreement (No. 67724-10707) betweenLZARDI Ukiriguru and Cornell University on implementation of NEXTGEN in Tanzania.
- Establishment of Training population - Clonal Evaluation Trial; Preliminary Yield Trial; Advanced Yield Trial and 5CP GxE trial for ARI-Ukiriguru, ARI-KIbaha and Chambezi site.
- Phenotyping and data collection - number of cuttings planted per plot, sprouting percentage, CMD incidences: 3, 6, 9 MAP, CMD severity: Maximum score: 3, 6,9 MAP, CBSD incidences: 3, 6,9 MAP, CBSD severity-maximum score: 3, 6,9 MAP, Branching height, Plant height in cm, CGM incidences and severity and DMC
- Genotyping - collection and shipment to IITA-Ibadan of Leaf samples for DNA extraction and genotyping

- Training course on data management - 2 staff (1 male, 1 Female) attended training at IITA: experimental design and data analysis, Cassavabase, data capture using tablets and use of electronic field book and tablets: received 6 tablets from Cornell University: 3 for ARI-Ukiriguru and 3 for Kibaha

Successes

- Identified 7 best varieties under 5CP GxE that are good for CBSD, DMC and Yield
- Three candidate genotypes identified for Official Release
- Staff trained

Challenges and gaps

Cassava brown streak disease is still big challenge in Tanzania and the region

- Sources of resistance –not yet enough
- Mechanism of resistance not fully known:
  - Leaf symptoms - root necrosis
  - Leaf symptoms – no root necrosis
  - No leaf symptom – root necrosis
- CBSD Phenotyping methods - mainly visual observations - subjective

Moving forward

- Harvesting of training populations
- Phenotyping of present training populations for second year
- Search for more sources of CBSD resistance
- Genetic crosses and phenotyping for CBSD
- Utilize markers for CBSD resistance (MAS)??
- Participatory varietal selection
- Processes for official release of available candidate varieties (DUS, NPT)
- Seed multiplication of candidate and released

3.5. Cassava Genomics: Genome Assembly v7

Roberto Lozano presented on behalf of Simon Prochnik the following:

- History of improvement - AM560-2 reference versions: total bases - v4* 532 Mb (2012), v5.1† 534 Mb (2014), v6‡ 582 Mb (2016).

- Improving assembly with long reads - 97x depth, 73.3 Gb of sequence (8.1 M reads); Assembly reads (10+ kb) - 63x depth, 48 Gb of sequence (3.3 M reads). Long reads enable a more complete assembly, however long reads are not immune to misassembly

Successes:

- Long reads enabling a longer, more complete assembly.
- Many misassemblies in v6 will be remedied in v7.
- Many gaps in v6 can be filled.

Challenges:

- New misassemblies will occur and must be corrected when identified.
- Repeats continue to fragment long read assembly.

Implications for the future:

- Much manual review is required.
- Must research and develop methods to validate contigs, break misjoins.
- Scaffold over repeats and back-fill resulting gaps, if possible.

3.6. Genetic Load in Cassava and rAmpSeq

Ramu Punna presented the following:

Accomplishments

- **NextGenCassava:**
  - New discovery build was developed in June 2016 with **32000 clones** and **450K SNPs**
  - GBS SNPs were projected to HapMapII sites (28 M variants).
- **Genetic load:**
  - Mutational burden is estimated in all cultivated cassava clones included in HapMapII

    Take home: Genetic load is increasing in cassava, but breeders masking harmful deleterious mutations in heterozygous state to maintain yield.
  - Deleterious mutations affect the fitness traits (yield/clone) in cassava.
  - Machine learning algorithms are being developed to predict the effect of deleterious mutations on yield.
- **rAmpSeq** (formerly repGen): Developed in cassava and is treated as dominant marker system.
  - rAmpSeq is working in cassava.
  - rAmpSeq has similar prediction accuracy as GBS sites.

Challenges	Gaps	Implications for the future
• Maize (lots of repeats) HapMap pipeline did not work for cassava • High edit distance to reference genome due to repeat sequences • Phasing of the parental lines	• Quality of other species' genome prevents regulatory elements from being scored easily • Differentiation between *deleterious* vs *adaptive* variants	• Genetic load is increasing in cassava • Develop new strategies to purge deleterious mutation from the cassava genome • Masking the load is a short-term fix: **'mutational meltdown' is on its horizon**

rAmpSeq (formerly: repGen) in cassava

- 26 primer pairs - primer pair distribution in cassava -reasonably enriched in gene-rich regions
- Evaluated on inbreeding population from IITA (95 samples) = **Cost $3/sample**
- Data generated as dominant marker system = **No SNPs called. Tags (amplicons) used as markers (+/-)**
- rAmpSeq is good for population stratification

Challenges	Gaps	Implications for the future
Less power to map repeat reads to reference	• Training of scientists/students in sequence alignments • Handling big data (programming skills – Java/Python/PERL/R)	• **rAmpSeq works, but it will die soon** • **Why?** Illumina – NovaSeq: cost 3-fold lower • **What is the alternative? WGS**

Conclusions

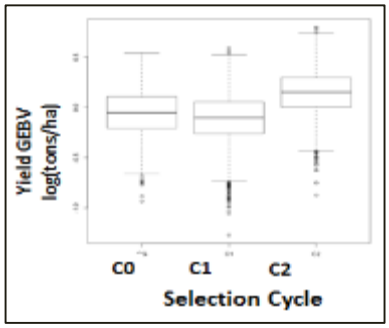
- Genetic load is increasing in cassava
- Breeders are masking load - '*mutational meltdown*' is on the horizon
- Need strategies to purge load
- rAmpSeq is cheap and working well in cassava, but it will die soon - Prediction is similar to GBS, not exploited for trait mapping.

3.7. Genomic Selection in NextGen

Jean-Luc Jannink gave the following highlights:

In theory genomic selection should work. In "theory" there is no difference between theory and practice. In practice, there is. We have to acknowledge the very important role of conventional breeding and phenotyping

- Preliminary evidence of gain (Fresh Root Yield)- Trait is log transformed to satisfy statistical model assumptions. Calculations show ~ 5% gain per selection cycle in these first two cycles. We can't pretend to know whether that will continue (it seems unlikely) but it's a very encouraging result. Contrary to dry matter and CMD resistance, for yield, the very best clones of the C2 are substantially higher yielding than the very best clones of C0 (by 10% !!!)



- Elite cassava masks deleterious alleles - excellent research was done by Ramu Punna and Fei Lu who used population genetic approaches to identify deleterious alleles and whether they were in the homozygous or heterozygous state. Compared to Progenitors (PRO), elite Latin American (LAC) and African cassavas have lower numbers of alleles in HOMOZYGOUS state but greater numbers in HETEROZYGOUS state. To purge these alleles, they need to be exposed in the homozygous state.

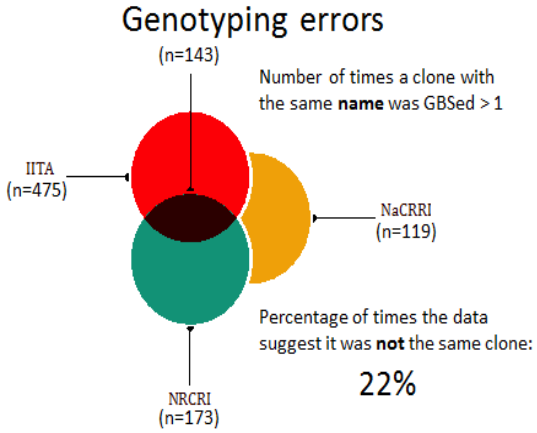
- First year validation trial –same trends as from breeder trials BUT only ~ 2% improvements in yield on the average from C0 to C2.

Take Homes

- Much evidence suggests GS is working: all traits are moving in the right direction; validation and breeder trials are consistent

- The error rate ends my take on a down note BUT: what defines us is the progress we make - continuous improvement is our moonshot (need to work more on quality control)

- Integrating research with practice is an ongoing challenge that is a problem of its own - we apply ourselves to this challenge going into Phase II.



3.8. Cassavabase Update

Lukas Mueller's presentation gave updates on challenges faced, gaps and implications for the future for the ***Cassavabase***:

New features of the *Cassavabase*:

- Trial Design: Support for nurseries + physical design upload and online editing
- Crossing Manager: now supports multicross, polycross and reciprocal cross
- Plant-level phenotyping - each plant on a plot is a separate entity in the database that can be associated with phenotypic scores. Plot-level scores are calculated from plant scores
- Database-direct phenotyping - Use Cassavabase directly in the field; new interfaces emulates field book interface; requires tablet with cellular data, cellular data plan, and cellular signal at field
- Support for barcodes: in field book and database-direct phenotyping; 2-D barcodes; improved barcode printing and soon an interface for portable barcode printers
- Trial Comparison
- solGS tool - added genotype data filters (e.g. MAF, missing data, monomorphic markers); selection gain visualization; expanded job queueing for more time consuming tasks; use list of trials to create training dataset; speed improvements and user interface improvements
- Cassava Expression Atlas

Upcoming Features

- Post-composing of phenotype terms - allow to mix ontologies to create new terms
- Cross Search - Search for crosses using female or male parents
- Accession usage stats page - How often an accession has been used

Planned Features

- Support for more hand-held apps for phenotyping and crossing management (PhenoApps)
- Support for more prediction algorithms (OHV)
- Farmer-based evaluations, questionnaires

Challenges and Gaps	Implications for the Future
Internet stability Data curation - must be on-going, data managers are central Training: Workshops and need to assure that system is used	Cassavabase "Digital Ecosystem" - Cassava Breeding Inc. Users should not have to leave "ecosystem" as this creates problems with data integrity and quality. Support for GOBII Support for BrAPI

Caution:

- Data quality issues

- Data sovereignty issues
- use of good technology and software principles
- The database is currently not available, but plans are underway to create a public version.

3.9. NextGen Cassava Germplasm

Peter Kulakow gave the following highlights:

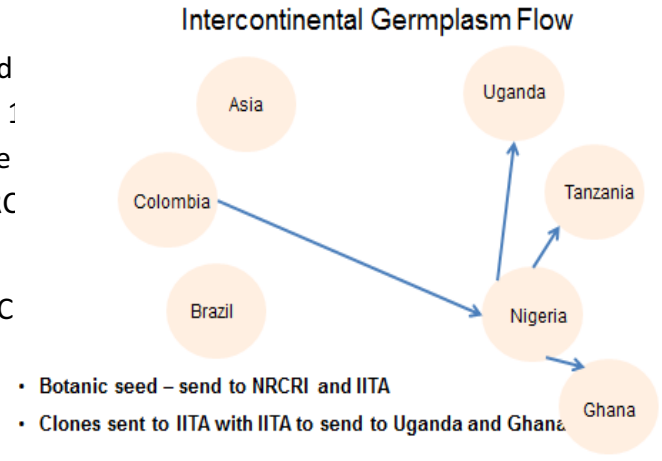
The Germplasm exchange aims to enhance cassava breeding across continents by use of most advanced phytosanitary procedures to ensure safe and effective movement of alleles.

Priority Traits for Intercontinental Germplasm Transfer:

- CBSD resistance sources from Latin America to Africa
- High carotenoids from Latin America to Africa
- CMD resistance to Latin America and Asia
- High starch yield from Latin America and Asia to Africa
- Quality traits: poundability and cooking quality; Starch properties
- Other biotic and abiotic stress resistance: white fly resistance; Cassava bacterial blight resistance
- Mechanization traits: Uniform root shape; Plant type; Herbicide tolerance; Nutrient response
- Heterosis potential for yield

Intercontinental Germplasm transfers achieved

- 24 accessions of 8 *Manihot* species transferred to Uganda through Stephan Winter lab, mediated by Tim Setter's lab
- 103 high carotenoid clones received IITA from CIAT in January 2017 - 1 clones established in tissue culture IITA; Transfer from IITA to NaCRRI, NRC CSIR-CRI in process
- 1500 botanic seed received by NRC from CIAT in 2016
- 75 CIAT clones received by IITA from Stefan Winter lab in February 2017 –



all are established in tissue culture - a similar shipment has been received in March 2017 by NaCRRI; Purpose of the transfer is to CBSD resistance sources

Hawaii Seed Production – Seedling nursery

		No. plants	Seed parents	Total seed	% plants producing seed
IITA	open pollinated	250	156	7198	62.4
CIAT	open pollinated	207	121	4171	58.5
CIAT x IITA	biparental		140	725	
Total		457		12094	

- **Proof of Concept**: High seed production potential from a seedling nursery
- High flowering environment
- Seed can move to Africa, South America and Asia
- Increased technical pollination support during the peak flowering season will result in higher biparental cross seed production
- Crosses need to focus on high priority selected parents

Hawaii Seed Production – 2017 Clonal Evaluation

- 64 clones selected based on seed production, plant type, dry matter content, plant vigor
- 30 CIAT clones, 34 IITA clones
- 5 plants per plot
- Alternating rows of CIAT and IITA clones
- Plans for additional technical support during peak pollination season

The Way Forward – Intercontinental Germplasm Exchange

- Transfer of alleles between continents is critical to the future of cassava production in Africa and Asia
- Critical traits: resistance to CBSD and CMD must be shared to address biotic threats
- Climate change: adaptation to changing environments. These environments have been under selection in Latin American
- Transit centers are challenging to organize - two excellent transit centers have been supported by Nextgen Cassava – Univ. of Hawaii/USDA and Stephan Winter laboratory

Food for thought - Why transfer clones and not seeds? Is it cost effective? What are the merits/demerits of transferring clones?

3.10. Gender Responsive Cassava Breeding

Hale Tufan's presentation highlighted the following:

Gender is not about women – it is the diversity of end users and equitably addressing their needs. Gender Research provides information that will enable development of varieties that meet producer, processor and consumer demands- increased adoption and impact. Thinking like a company in cassava breeding – have to understand demand and consumer profiles (smart economics). Better define traits and relative importance for end users by "ground-truthing" preferred characteristics and refine phenotyping methods for breeding

Summary of progress in gender responsive cassava breeding

- NEXTGEN Phase I focused on understanding- baseline studies in Nigeria and Uganda
- Paper on trait profiles, gender based needs and opportunities in cassava production in Nigeria- submitted to Economic Botany (see partial results below)

Variety (type)	Reasons for preference	
	Men	Women
Molekanga (local)	High yielding, poundable, good for garri, marketable, early maturing (6-9months). Also called poverty removal crop	Poundable, root size, high yielding, weed suppression, low cost of production and early maturing. Also called food security friendly cassava variety
Oko Iyawo (local)	Poundable, mealy, high yielding, early maturing (7-12months) and resistance to pest and diseases	Mealy, short time to cook, good taste and product quality for gari, eba, fufu and lafun
Dangaria (Improved)	Good taste, white color, very tall and multiple stems for planting materials. Good for feeding livestock	High market demand, poundable, good root and product color, weed suppression, tall stems, good product quality for garri, fufu and lafun
Idileruwa (local)	Resistant to pests and diseases, underground storability without rotting, weed suppression, low cost of production	Can survive after pest attack, underground storability without rotting, can stay for 3-4 days after harvesting, good product quality
Nwaocha (local)	Dewaters faster, high dry matter, late maturing, allows for intercropping	Beautiful to behold, good plant architecture, ferments quickly 2-3 days, odourless, good product quality for abacha, lafun and gari
Nwankwo (local)	High yielding, marketable and early maturing	Good product quality, high root number and early maturing

IITA (Improved)	Pest and disease resistance, root size and shape, branches well and smolders weeds, can survive harsh conditions	High yielding, post-harvest storability, high dry matter content makes garri swell.

- CGIAR gender postdoc Bela Teeken joined team, designing next phase of PVS trials
  - ✓ Move from extractive to interactive: Gender responsive PVS
  - ✓ Current varieties and advanced breeding lines evaluated by farmer-processors: agronomic, processing and end-use performance- test pipeline on farm
  - ✓ Uncover new preferences/traits? Relation to social context
  - ✓ Action research- examines process itself: intra- household/intra-village and intra-task group decision making. Power relations and norms revealed by studying PVS process- who decides and why and how- ties to positionality
  - ✓ Test 15 varieties- Mother-baby trials

  Mother: farmer's field that will contain all the 15 varieties plus a locally grown and highly appreciated variety- researcher managed- genetic potential

  Baby: 20 individual field trials with 3 varieties each (Van Etten 2016)
  - ✓ Process study: informal interviews, focus group discussions, income allocation games, life histories, and positionality analysis
- Student update- Key traits identified and phenotyping methods in development

Challenges	Gaps	Implications for the future
• Transcription of what exactly farmers like in a variety is problematic- different aspects are involved and farmers have a tacit feel about what works for them • Farmer preferences are often not determined by single traits only but by a combinations of traits. Trait packages? Prioritization? • Correlating lab based measurements with preferences- weak proxies • What are ”gendered traits”? Binary comparison of men vs women.	• Understanding- quality traits like good for gari are still opaque- need considerable work to unpack these descriptions into “breedable” units • Prioritization- Need to link with economic weights coming out of Ugo’s work. Inform further studies with traits emerging from gender work • Holistic view- only SE and SW Nigeria, and certain districts in Uganda • Linkages- link breeding directly to survey and social research work • Validation- Empirical evidence to back survey information	• Positive re-framing: Focus on tacit knowledge and co-creation • Add 1000minds methodology to toolbox • Refine tools, add varieties and expand geographically to generate user profiles and possible trait packages to match, to inform breeding programs • New lines of enquiry: ”Informal adoption” study- measure diffusion? Comparative study: does participation matter? Deeper study into the quality characteristics- what is good gari? • Formulate breeding strategies in relation to the present and anticipated social dynamics in cassava cultivation and processing

3.11. Uganda Bioscience Information Center

Barbara Mugwanya looked at UBIC as a special initiative under NextGen. UBIC is a biosciences information hub of NARO whose core mandate is Biotechnology and Biosafety education.

UBIC achievements

- Key player in the process of setting up enabling Biotechnology policy environments in Uganda, Tanzania, Rwanda
- Key source for biotech and biosafety education and information – NARO. One-stop center for biotech and biosafety information in Uganda; exhibitions, increased media presence, awareness meetings, seeing-is-believing tours; Integration of modern biosciences in education curriculum
- Trained Biotech spokespersons: scientists and communicators
- Strengthened media dialogue for agricultural research

- Key advisor for agriculture curriculum reforms
- Biosafety compliance and commercialization pathway oversight for Biotech Projects
- Advisor for various regional initiatives: ABNE, OFA
- Strengthened skills for the UBIC Team to support biotech products' research and commercialization - Risk Communication training; training in Grassroots Mobilization; Technology Transfer and IPR management for Biotech; AWARD Leadership training and Biosafety Legislation Implementation
- Drafted a NextGen Publication Policy - to provide the NEXTGEN Cassava project with guidelines to communicate research findings with target audience and provide the groundwork for a standard procedure to enable consistent, fair and repeatable process for project publications. Along with planning policy; research data management policy; authorship policy; manuscript review policy; publication avenues policy and grievance policy

Challenges	Implications for the Future
• Very pro-active and well-funded anti-science advocates • The battle between emotional manipulation vs facts • Increasing negative perception of improved technologies and products • Willingness of scientists to be spokespersons	• Support implementation of enabling biotech policy environments in Uganda and beyond • Up-scale training programs for scientists and communicators • Support commercialization pathways for different biotech products • Increased NextGen communication with IP-CALS Communications Team

UBIC has become the science communication voice for NARO. This model should be replicated in other NARs.

3.12. Embrapa's Supplementary Project for NextGen

Eder J. Oliveira elaborated the Embrapa giving the following highlights:

"Embrapa NextGen" runs from April 2016 to September 2019 to advance ongoing activities of flowering and genome selection in cassava and germplasm exchange to NextGen partners.

1. Genomic selection: two year breeding cycle at Embrapa (1st cycle (2016 - 2017) and 2nd cycle (2018 - 2019))

2. Improving cassava flowering and seed set:

- ✓ Grafts between genotypes with high and low flowering rate - 3 Genotypes; 12 Treatments; Cleft graft; # of successful grafts: ~ 70% (48 – 88%)
- ✓ New grafting method for cassava flowering induction - Multi-grafting on rootstock allows several grafts of the same genotype in a single rootstock plant → facilitating greater transfer of flowering stimulus between contrasting genotypes (high and low flowering rate)

3. Germplasm exchange - Sexual seeds of 11 wild cassava species available for exchange and *M. esculenta* clones with highest GEBV – available on August 2017, after tissue culture introduction

Challenges	Implications for the future
• Severe drought stress in the last years (2011-2016) → low seed set, especially from September to February • Few graduate students (Doctoral) and no Post-doc linked to NextGen Embrapa team	• Low flowering brings difficulties to obtain lots amount of seeds → move to partially half-sib families? • Reinforcing links with Cornell and other institutions mainly for training to develop an standardized pipeline for genomic selection • New breeding approaches and tools to allow rapid phenotyping

Induction of flowering in cassava through grafting

Hernan Ceballos gave an update of CIAT-Cornell University work on flowering in cassava:

- ✓ SM3348-29: Branched and flowered after grafting
- ✓ GM3500-2: Branched but did not flower
- ✓ SM3409-43: Did not branch, nor flowered

All genotypes planted on August 8, 2016

- Percentage of plants with different levels of branching: average of four light intensities vs checks - extended photoperiod induced earlier branching in every genotype; Genotypes that flower by mid-season (GM971-2) or late in the season (CM4919-1) had three levels of branching by 5 MAP

- Fruits developed through five and a half months after planting in four genotypes responsive to extended photoperiod - There was no major difference in the response to the different light intensities; The earlier the extension of photoperiod begins the better; There was a clear impact in enhanced production of fruits in three genotypes

- Number of fruits still in the plant 192 days after planting - In general, the combination of BA+STS provided better results; For the 1st time the “asparagus” cassava flowered and

already had well developed fruits 5 MAP; Notice that there is considerable fruit production (and retention) in the first branching; Clear influence in number of female flowers

- **Consolidated responses**: for grafting, photoperiod, BA, STS, BA+ STS. Combination of genotypes x stimuli is ideal for molecular studies; will combine light AND growth regulators and hope to have a 0.5 ha "red light district" by June 2017

3.13. Flowering - Methods for Cassava Floral Induction and Enhanced Seed Set

Tim Setter gave the following insights on flowering:

The problem: Late flowering delays or prevents crossing and flower numbers are too few.

Overall Goal: to identify methods to induce earlier flowering and stimulate profuse flower numbers and help breeders make more rapid progress by enabling earlier crosses on more flowers, thereby shortening the breeding cycle.

Approaches:

- Graft onto a host plant that is profusely producing flower stimulus - Identification of superior under stock germplasm (Early, profuse flowering genotypes and wild relatives of cassava)
- Environmental responses (Photoperiod X Temperature) - Main target: Flower induction for earlier flowering

  → **Photoperiod treatments:**

    - **Long day-lengths:** Stimulates earlier flowering, does not provide profuse flowering or flower longevity, decreases partitioning to storage roots

  → **Temperature treatments:**

    - **Cool temperature (moderate):** Suppresses vegetative growth, stimulates earlier flowering, does not provide profuse flowering or flower longevity

- Plant hormone and growth regulator applications – Compounds (*Gibberellin – GA; PBZ (anti), Cytokinin – BA, ethylene – STS, AVG (anti), Auxin – NAA, NPA (anti), Salicylic acid, Jasmonic acid, combinations, dosages*)

Successes	Challenges	The way forward
• Long daylength hastens flowering; achievable with dim red light	• STS application methods ✓ phytotoxicity	• Optimize STS+BA application methods and timing • Develop field scale methods to extend daylength

• Optimum temperature for early flowering ≈ 25°C • STS + BA stimulates profuse flowering, and increases percent females	✓ sufficient uptake in field plants	• Workshops and support for adoption of these methods in cassava breeding programs

3.14. Poster session

Additional sharing of progress of work done by the different partners was undertaken through presentation of the following posters which were also analyzed thereafter in round table discussions with the earlier presentations.

Click on a title to access the full poster.

List of posters:

1. The Genetic Basis of Reducing Postharvest Physiological Deterioration in Cassava
2. Progressive Regional Graduate Plant Breeding Training at Makerere University, Uganda
3. Accuracies of Univariate and Multivariate Genomic Prediction Models in African Cassava
4. Evaluation of Spatial Correlation and Genetic Competition to Improve Genomic Prediction in Cassava Field Experiments
5. Genome-Wide Association Studies Accelerates Genomic Selection: Implications for CBSV Resistance in Cassava
6. Introgressed *Manihot glaziovii* Genome Segments Segregate in Cassava Germplasm and Influence Key Traits
7. Social Differences and Genetic Analysis of Preferred Cassava Traits of Smallholder Farmers in Uganda
8. Development of Provitamin A Cassava with Virus Resistance and Farmer-Preferred Qualities in Uganda
9. Plant Growth Regulators' Effect on Flowering in Cassava
10. Flower Initiation Response to Photoperiod and Temperature Environments in Cassava
11. Cassava Germplasm Collections in Tanzania
12. QTL Associated with Field Resistance to CBSD
13. Modification of Flowering in Cassava Using a Transgenic Approach
14. Towards a Gender Responsive Cassava Breeding Program in Nigeria
15. Practicality of Genomic Selection in an African Cassava Breeding Program
16. Genomic Selection to Pre-Breed for Resistance to CBSD in West African Clones
17. Genomic Selection Meets Transcriptomics: Predicting Quantitative Resistance to CBSV
18. Allele Mining and Breeding for Cassava Green Mite Resistance in *Manihot esculenta*
19. Deleterious Mutations are Masked in Cassava Genome
20. Effects of Grafting Time and Methods Used on Scion and Rootstock Compatibility of Cassava
21. NIRS Calibration for DMC and TCC on Whole and Mashed Fresh Cassava Root Samples

4. Synthesis of NextGen project presentations

With refreshed understanding of the progress in NextGen cassava project, the participants were asked to synthesize the successes, challenges and implications for the next phase of NextGen.

4.1. Successes, major challenges and implications for the next phase of NextGen

A small team was formed to cluster the successes, challenges and implications for the next phase of NextGen which are presented under the themes below:

Success

Germplasm exchange

- International exchange of clones to tackle diseases and other challenges
- Hawaii germplasm nursery established – despite cassava being on do not grow list from USDA
- Germplasm transfer platform available
- Establishment of transferring centres e.g. Hawaii for the sharing of genetic material
- Breakthrough in germplasm exchange via Hawaii and Germany
- Proved stability of Hawaii for transfer between continents

NextGen variety release

- Variety release – Tanzania and NRCRI
- Number of prospective new varieties in the pipeline
- Varieties for release in hand
- NextGen varieties will be ready for release in the next three years
- Candidate varieties for release

Genomic resources developed

- More complete and accurate version of cassava genome sequence
- Genomic resources
- Excellent resources developed for community – Genome, Cassavabase, GS performing as expected

- Excellent understanding genomic load in cassava – but how should NextGen respond to this?

Trainings

- Students trained
- Young breeders trained to support breeding efforts
- Capacity building for all involved partner institutions and countries
- PhD students are integrated into programs across all countries and seem to be thriving

Genomic selection working

- Genomic selection works in cassava: gains reported from cyclic improvement
- IITA? C_0, C_1, C_2, C_3
- Genomic selection seems to be working and in good progress (GS by C_2)
- Development and advancement of GC cycles in East and West Africa
- Collaboration is successful for getting fruits
- Transforming from conventional
- Progress in made in applying genetic GS
- Genomic prediction models work

Cassavabase

- New features in database from users feedback
- Cassavabase analysis tool
- Cassavabase flexibility expanded considerably
- Electronic data capture
- Data base developed and accessible
- Data management
- Need for more cross disciplinary work in the next phase as well as intensify gender responsive breeding and training
- Traits are moving in the right direction
- Getting the genomic selection framework and Cassavabase repository going in good time

Communication and publication

- Draft publication policy
- Demystifying concepts with regard to biotechnology
- Efficient communication on GMOs with farmers
- Establishment of UBIC to speak and advocate with a consistent voice
- UBIC has become a good model (for learning)
- Awareness creation through UBIC
- Moving towards end-user preferred varieties through gender involvement

Genetic architecture

- Price reduction on genotyping
- Lots of genotypic data that can be linked to phenotypes
- Greater understanding of genetic architecture
- Enhanced flowering with cooler temperatures and longer day length

Crosscutting

- Gender responsive initiatives
- Better understanding of farmers preference
- Recognized importance of consumer quality traits (softness, Kwin, water holding capacity)
- Enabled seed/cuttings transfer
- Identification of starch trait profiles in north Uganda

Challenges

Phenotyping

- Focus on identifying sources of CBSD resistance
- Phenotyping high thoughtful methods
- Better phenotyping tools for CBSD/CBSD Phenotyping
- How to mitigate spread of CBSD which has negative influence on yield performance
- Standardize data collection and phenotyping trials design
- Capture new sources of variability (CBSD)
- Phenotyping tools for consumer traits (softness)
- Understanding genetic architecture of consumer quality traits and pathways
- New traits – gari quality, cooking quality, nutritional evaluation
- Tacitly evaluating varieties with end users – new varieties appreciated already and new varieties from NextGen and others
- Quality traits definition
- Difficulties in finding proxies for gender traits (i.e. softness)
- Accurate trait characterization
- Lack of phenotyping protocols for good gari
- Connections between genomics and consumers preference
- Intervention of the farmers in the selection process
- Good understanding of farmer preferred traits
- Link genomics with phenotypic data variability
- How to integrate makers into breeding schemes
- How to incorporate consumer preferences into breeding lines
- Better phenotyping method (NIRS) DMC
- Translating preferences into measurable traits
- Transfer of diseases with germplasm internationally

Advocacy

- Emotions vs facts (GMO and Biotechnology communication)
- Antagonism by anti-science groups
- Misconceptions of breeding efforts/products
- Negative perception of biotechnology in Africa
- Communication of science to society (GMO vs marker-aided varieties)

Trait management

- Skill management to transform from conventional to phenotyping to electronic phenotyping
- Protocol optimization
- Adjustment to managing big trials
- Too early for rigorous comparison of 1- + 2-year cycle
- How to measure genetic gains when comparing early cycles ("old" planting material) and late cycles ("young" planting material
- High quality field trails that have low variability, high H^2
- Genotyping skill shortage in Africa – need for capacity building
- Improvement of experimental design to capture better heritability
- Diversify trait breeding
- Adding and identifying cassava traits in relation to end user preferences

Genetic load

- What to do about deleterious alleles
- Purging deleterious alleles prolongs breeding cycle
- Threat from deleterious mutations – need for new methods to purge them out
- Define end users' traits
- How to identify the species diverged at regular interval to characterize the regulatory elements
- How to reduce the genotyping error rate
- How to reduce genetic load
- More discussion of crossing strategy to obtain best recombinants

Genotyping quality control

- Genotyping error – adopt standard operating procedures
- Error rate in genotyping (duplicate clones)
- GBS labeling contamination
- Reduce GBS errors – 22% error rate
- Get consensus on cassava IDs
- Effective quality control

Germplasm exchange

- Complexity of seed exchange with this system
- Moving germplasm from Hawaii or tissue culture from CIAT directly to fields in Africa
- Suitable parents for making crosses to be shared across programs
- Sources of CBSD resistance

Cassavabase

- Should the focus be on making new features or ensuring usage of existing ones
- Is Cassavabase handy to use for cassava breeders within their current daily work
- Use of Cassavabase is limited
- How frequently do country teams share data/information (do countries = silos)
- Maintenance support time for Cassavabase
- Continuous usage of table and Cassavabase site

Reference genome

- Publication of African cassava reference genome
- Get an African cassava genome reference

Implications for the next phase

Capacity development

- Partner independent sustainability
- Strategic development for utilization of developed capacities
- Coordination office in Africa to facilitate germplasm exchange
- Need to have more cross disciplinary work in the next phase
- Intensify gender responsive breeding and training

Cassava base

- Train all NextGen team members to use Cassavabase (especially new features)
- Integrate end user preference studies to inform cassava breeding (including gender)
- Make Cassavabase a one stop shop
- Consider additional training for database managers who are responsible for uploading to Cassavabase
- Analytics is priority
- IITA trials to be all designed with Cassavabase

Breeding for target traits

- Track efficiently starch properties in breeding program
- Drought
- Bio fortification
- Phenotyping for DMC is tricky and highly influenced by arrival of rains
- Understanding the quality of traits
- Expand base of traits being studied (informed by survey work)
- Refine flowering enhancement – light, grafting, PGR, location and timing
- Document rafter cloning PGR seed set treated

Genetic load

- Need to start talking about genome editing
- Take into account genetic load during cyclic improvement through GS
- GS implementation is a journey – manage expectations, incorporate deleterious alleles in GS models
- One year cycle will lead to highly branching types. Induction of flowering highly relevant.
- Crossing strategy is very important. Useful ideas of selecting for dry matter and root yield (120 selections are many plants to recombine).
- Practical implications/usage of transformed Ft
- Find routing ways of enhancing flowering in breeding and GS crossing

Communication and advocacy

- Good scientific communication
- Need for scientists to engage in communication

- Bridge the communication gap between farmers and biotech

4.2. Addressing challenges

Four groups were formed to address the eight main challenges and report back using the guidelines in the Box 5 below. Discussions were held for approximately 1.5 hours.

Group task – Addressing challenges

For each of the challenge(s)/issue(s)

1. What are the underlying issues (why is it an issue?)

2. What are promising strategies or ways to address these issues and challenges? (Take into account good experiences and lessons presented in the workshop).

3. Who are the key players to be responsible for the different aspects of the strategies or ways of addressing the challenges?

Task Box 2: Addressing challenges

Here below the group presentations and plenary discussion

Challenge	Underlying issues	Promising strategies, ways to address issues and challenge	Key players
Phenotyping	•Product quality •Institutional disconnection •Disease – root and leaf •Homogeneity of symptoms for image analysis e.g. CBSD	•NIRS •larger population for training/calculation of multiple farmer preferred traits •Standardize protocols •Optimization of cassava usage by region •Trial management	•Farmers •Personnel
Yield and dry matter	•Precision •Throughput	•NIRS adoption	Breeders
Disease resistance and susceptibility	Precision and throughput of existing tools is deficient	•High throughput tools for traits that we have good understanding •Artificial intelligence to recognize and score disease	•Computer scientists specializing in machine learning/remote sensing

		from images (drones/smartphones)	
Trial management	Non-uniform fields	• experimental design	• Mechanization unit • Field scientists
End-user quality traits	Translating consumer preferences into measurable traits	• Test kitchen • Participatory trials • Relate to measurable trials • NIRS	• Breeders • Social scientists • Food scientists • consumers
Genotyping Quality Control	• Genotypes to phonotypes link has significant errors • Duplication of samples • sample tracking from field to lab and vice-versa • GDF duplication coding (-1) but have to be accorded with comments • IITA strategy – unique barcode for each plate • Clonal mislabeling In the field	• Implement procedures to minimize error • Develop methods to detect problems • Confirm links to genotype when first entered into Cassavabase • Double check by genotyping specific plants used for crosses • ID sources of error - which programs generate errors or ore they uniformly distributed across programs? Develop best practice to minimize errors • Insert “TEST” errors and see what they look like in order to ID real errors • ID every step where there is a possibility of error • implementation of quality control – genotyping in Cassavabase • Cassavabase to be used for tracking samples – users must set up a genotyping trial • Cassavabase to check genotype against parents if available	• BTI, who has identified the problem • Breeders who are doing collections remove errors
Germplasm Exchange	• Resource limitation in Hawaii • Risk of seed born viruses • Using new germplasm	• Clear plan for using new germplasm • Implement a quarantine site for growing seeds upon arrival at research stations	• Research stations

	• Difficult to get permits for field planting • Location outside of US (Vanuatu? –CIRAD program)	• Move germplasm through DSMZ in order to be very careful • Technical capacity for making crosses	
Genetic load	• deleterious alleles – inbreeding depression	• reduce the number of deleterious alleles through introduction of inbreeding step	• breeders
Cassava Base	• Is usage high enough • Duplication between BMS and Cassavabase • Need for more tools for analysis (GWAS, QTL etc.) • Analysis for variance, heritability • Fieldbook not adequate for nursery trails •	• Training out of project breeders • Collaborations with Field Book on app development to avoid duplication • Add useful applications (add new features and ensure usage) • Start trials in Cassavabase (also for genotypes) • Maintenance support	• Cassava Base Team
African Reference Genome	• Is there an African reference Genome	• Yes, TME204 genome will be available soon	•
Communication and advocacy	• antagonism by anti-science groups	• pro-active, relevant information • persuasive communication	• Alliances of all groups involved with science • science communicators • Advocates
Misconceptions	• lack of information (reliable, trusted)	• get more credible sources	• Government agencies • Trusted sources
Integration of communications across project	• Prioritization of communication • Better internal communication	• implement communication strategy	• communication people
Communication infrastructure	• connectivity via internet	• strengthen communications infrastructure	• IT personnel

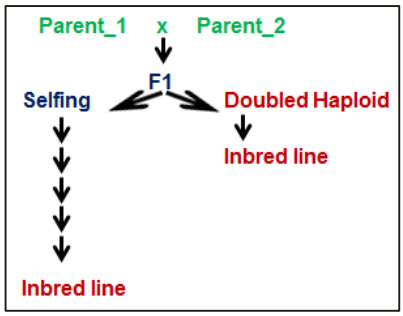
5. Future trends, high potential technologies and products in cassava breeding

Having looked at NextGen's progress, this stage was aimed at identifying emerging technologies/processes and trends integral to successful cassava breeding, including breeding pipelines and products. Input presentations on future trends, high potential/ promising technologies, approaches and products to be focused on in future (including phase II) were made to stimulate participants.

5.1. Optimum Haploid Value selection technology

Ben Hayes explained Optimum Haploid Value (OHV) application as follows:

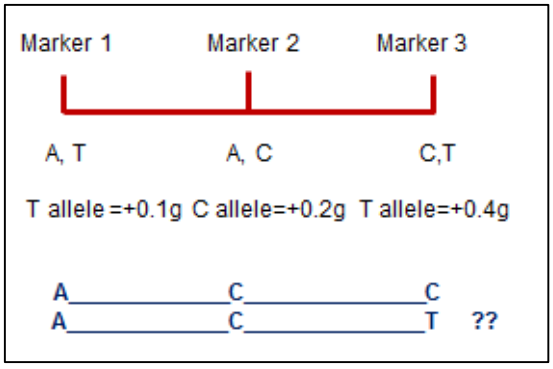
Doubled haploids used in wheat, maize, canola breeding programs - generate inbred lines in one generation vs ~ six



Critical question - Can we take genomic selection to the next level by combining with doubled haploid technology

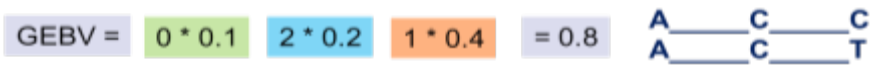
- Develop superior elite cultivars?
- Accelerate rate of genetic gain?

A simple three marker example

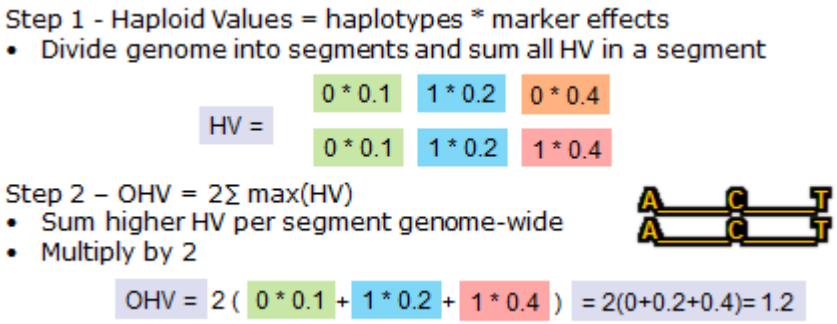


Genomic Selection - GEBV = ∑ genotypes * marker effects

Sum genome-wide



Optimal Haploid Value



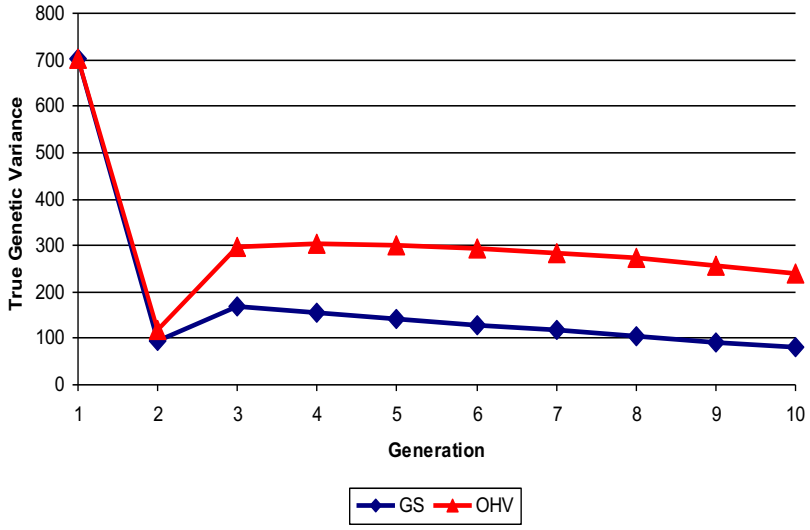
Step 1. If heterozygous parents are used, OHV on F1, if two elite lines are crossed, make OHV on F2, or on parents directly.

Step 2. Haploid values (HV) estimated for each haploid genome segment.

- *In silico*, the optimum haploid value (OHV), the best doubled haploid that could be produced from that line, is predicted.
- Note the line with the highest OHV may not be the plant with the highest average genomic breeding value.

Step 3. Doubled haploids are created from this line until the OHV, or an individual very close to the OHV is created. By genotyping half seeds or very young plants. Doubled haploid closest to OHV of the original plant becomes the new variety.

Does OHV give more gain than genomic selection?



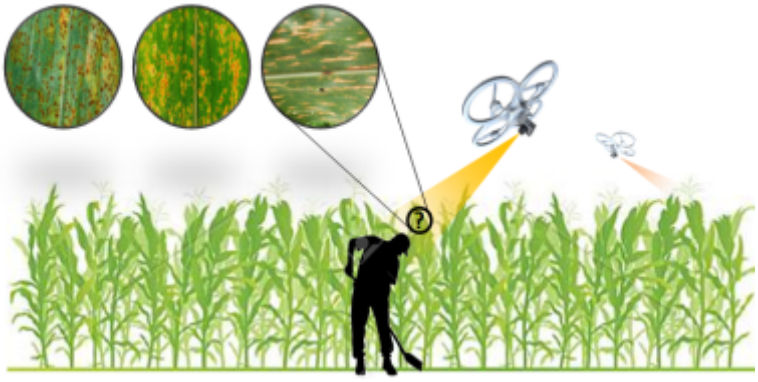
- Test in a simulated breeding program
- Base was real genotypes from Triticeae Coordinated Agricultural Project (TCAP)
  - 1110 Pre-breeding and breeding wheat lines

Take home

- OHV delivers up to 0.5 genetic standard deviations additional genetic progress to Genomic Selection
- Advantage of OHV over Genomic Selection grows as breeding program progresses
- OHV preserves more genetic variation than Genomic Selection → increased long-term genetic gain!
- Works best with large number of recombinants, 100 offspring per line, 100 DH per OHV selected plant

5.2. Improved Phenotyping Through Image Analysis

Mike Gore explained how autonomous robots work side-by-side with humans in the field to greatly enhance disease phenotyping and early disease identification. Such robots perform daily scans and alert human coworkers to unusual or suspected pathologies; they will collect detailed data over time to track disease spread dynamics, consult remote experts in ambiguous cases and guide humans to locations where manual intervention is required.



Convolutional Neural Network (CNN) combined with drones: detect NCLB lesions on maize leaves in the field. CNN are trained to detect NCLB in maize, the CNN coverts pixels into words: extracts multiple layers of non-linear features and then a classifier combines all features to make predictions.

Automated mobile detection of cassava mosaic disease with deep learning algorithms

Ernest Mwebaze Makerere University

Machine vision detection of whiteflies by training a cascading classifier combined with decision trees.

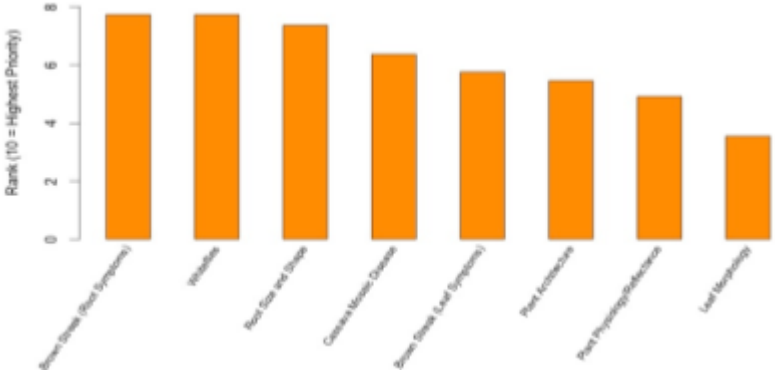
1KK - Seed analysis app. One thousand kernel weight, reference circles for scaling, uses SmartGrain algorithm, Integration with USB scales.

Binary thresholding algorithm extended from ImageJ to Android to count and size (area) cassava roots

Although the autonomous robots can find what the normal eye cannot, it is susceptible to errors.

Depending on the question – you determine the areas e.g. plant basis. You train the AI adequately for each disease (provide enough pictures and sounds).

Average importance ranking for PhenoApp trait development



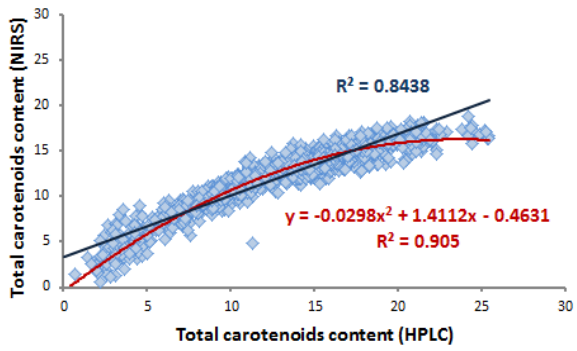
1. Brown streak (root symptoms)
2. White flies
3. Root size and shapes
4. Cassava mosaic disease
5. Brown streak (leaf symptoms)
6. Plant architecture
7. Plant physiology/reflectance
8. Leaf morphology

5.3. NIRS Phenotyping and Calibration

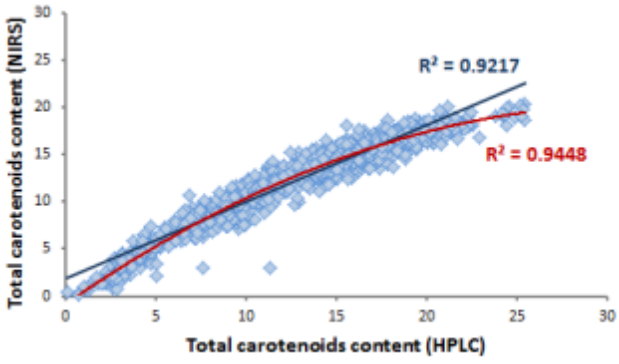
Dominique Dufour explained how high-throughput screening of root quality traits for processing ability and user's preferences works.

NIRS LOCAL Calibration for cassava traits

Scatter plots of TCC HPLC values versus TCC NIRS values of year 2013



Using PLS model



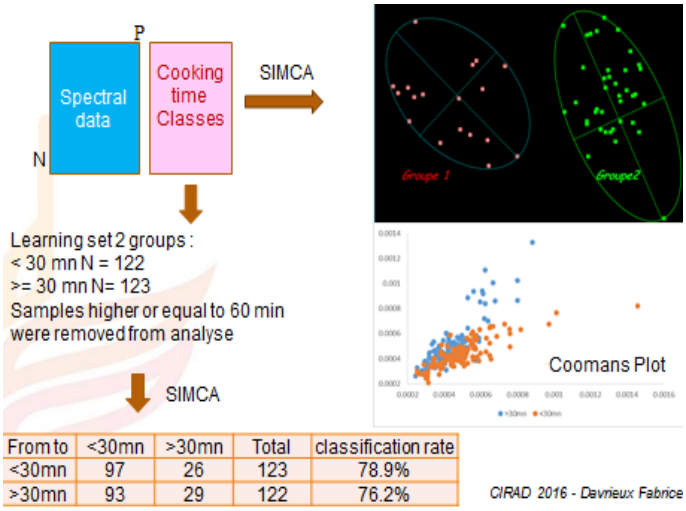
Local regression, based on 2009-2012

Harvest 2016 screening biofortified cassava

Number of clones	Harvested	Daily evaluation
In the field (seedling)	9160	327
Selected for root lab evaluation	1832	65
Second screening in the lab for NIRS evaluation	1065	38
Cooking quality evaluation	515	19
Cyanide and Carotene content (Spectro & HPLC)	134	5

836 Clones were selected for 2017 evaluation (based on NIRS prediction). Traits of the selected clones (836 from 9160):

- Boiled cassava cooking patterns: Cooking time estimation using NIRS - Soft Independent Modelling of Class Analogy (**SIMCA**)
- Cassava mealiness and poundability
- Physiological Postharvest Deterioration (PPD)
- Screening of cassava fermentation ability
- Gari swelling capacity evaluation

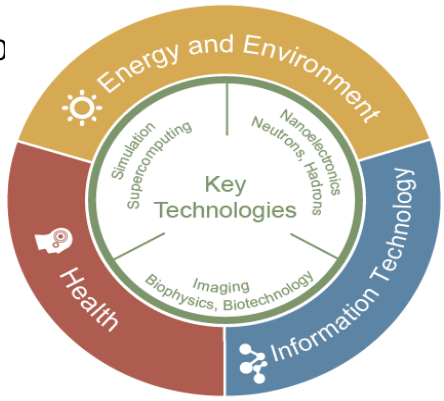


DM variability evaluation trials - 7 clones planted each 15 days in the same plot; DM evaluation on 5 plants each 15 days at exactly 10 months; 3 repetitions by data point.

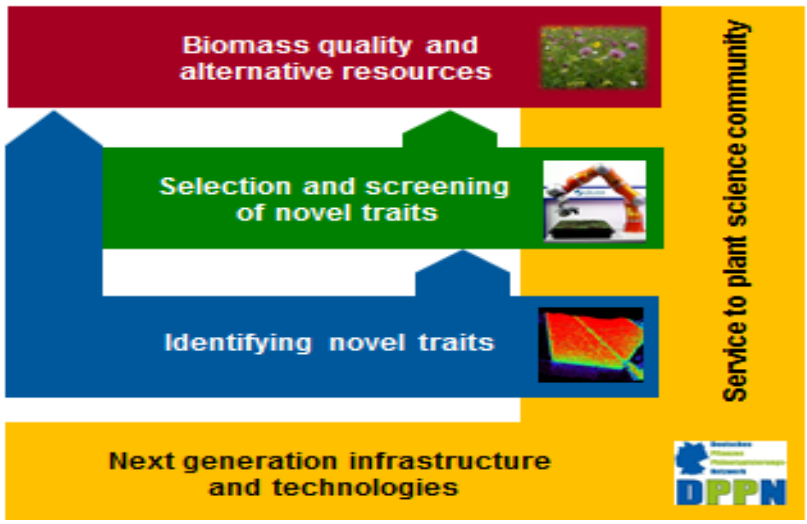
5.4. Field Phenotyping

Onno Muller elaborated on field phenotyping whose aim is to quantify dynamic plant traits in the field across scales.

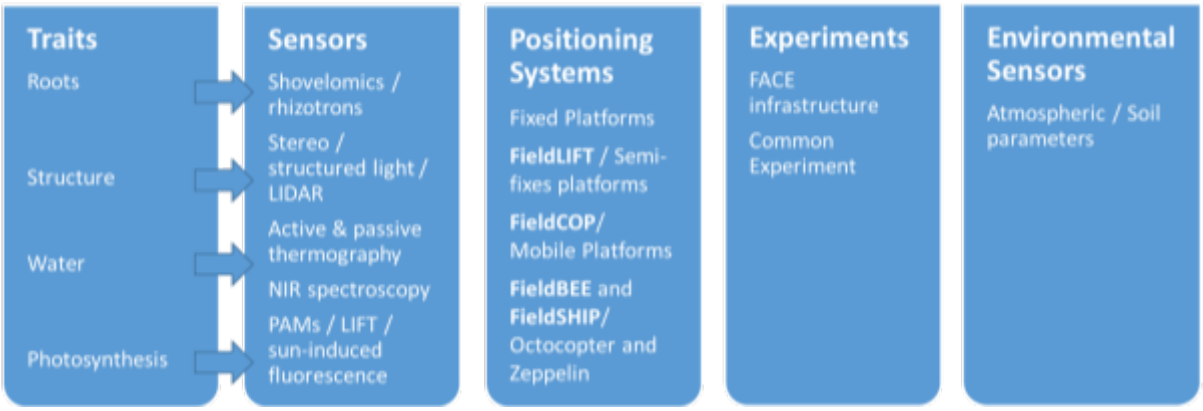
The Jülich research centre in Germany has more than 5,50 employees and 900+ guest scientists from more than 45 countries; budget: 560 M€ and third-party funding: ~ 170 M€. There are three main portfolios as shown in the adjacent diagram.



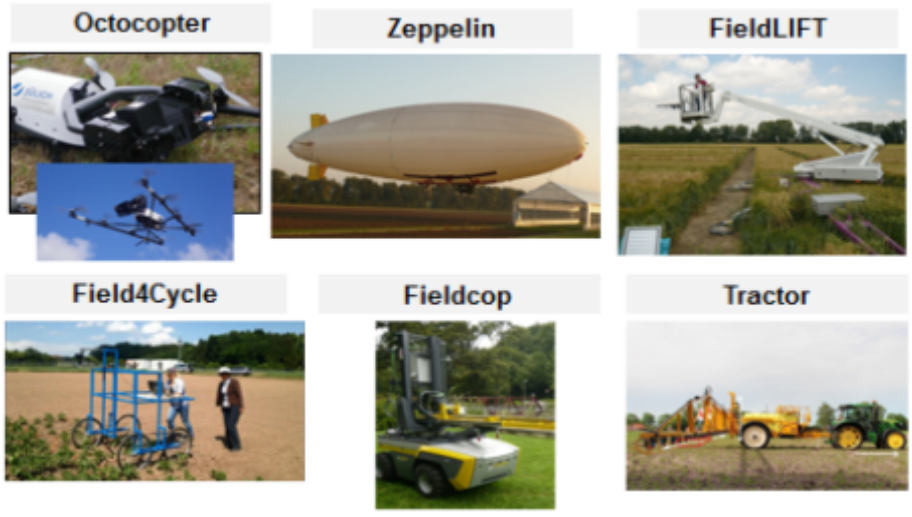
Jülich research centre plant sciences strategy for improved resource use efficiency and optimized biomass (see diagram below)



The 5 pillars of Field Phenotyping: from traits to sensors and experiments



Field positioning systems



Field phenotyping sensors photosynthesis: Fluorescence

Asctec Falcon-8 features:

- 8 rotary wings
- 1,8 kg operational weight
- Autopilot to navigate along waypoints
- Live-video view
- Various sensors: RGB camera Sony Nex5n, VIS/NIR spectrometer, thermalcamera
- Rigid casing
- 9 batteries for almost continuous operation
- Each flight 15 minutes

5.5. More Artificial Intelligence (AI) for Phenotyping

Ernest Mwebaze of AI and Data Science Lab at Makerere University elaborated on the artificial intelligence (AI) technology.

Loosely explained, AI is about getting specific "intelligent" aspects of a human being and putting them into a piece of software, machine, internet, etc. for example in the automation of expert tasks and improved accuracy in measurement. AI/tech-assisted can either be fully automated/assisted – approximately zero human input or semi-automated – human involved to some degree.

AI/tech-assisted Phenotyping facilitates:

- Repeatability in data collection e.g. taking images

- Non-subjectivity / relative uniformity in assessment e.g. automated assessment
- High-throughput

Crowdsourcing surveillance information from farmers

- Farmers given smartphones or those with smartphones recruited
- Farmer takes a several pictures of his garden and his neighbours gardens every week and uploads to online system
- Incentive mechanisms used to encourage farmer to send in information
- Can be a good extension to PVC studies – surveillance of varieties grown, eaten or sold.

Future trends

- Moving towards full AI-integration e.g. drones + geo-spatial analysis, deep learning
- Data science/big data integration e.g. improved/increased measurement of the process (meta-data) and of the phenomena (bio-degradable chips)
- "*-as-a-service" paradigms e.g. phenotyping-as-a-service, breeding-as-a-service, GS-as-a-service, etc.

5.6. Variety release process in Nigeria

Dr. Sunday Aladele - registrar, National Crop Varieties and Livestock Breeds Registration and Release Committee explained the process of registration of varieties for release. A copy of their catalogue can be downloaded from their website: www.nacgrab.gov.ng

The National Crop Varieties and Livestock Breeds Registration and Release Committee was established through Decree No 33 of 1987 (now Act of Parliament 2016 as amended). Functions of the committee include:

- Officially release list of superior crop varieties, livestock breeds and fish strains recommended by the Technical Sub-Committee (TSC),
- Ensure imported crop varieties or livestock breeds into Nigeria meant for commercialization and use pass through the same process as seeds of new crop varieties and livestock breeds developed by breeders in Nigeria,
- Formulate policies on matters concerning the validation, registration, naming and release of new crop varieties and livestock breeds which are either introduced or developed in Nigeria

Activities of this National Committee and Technical-Sub Committees are coordinated by the National Centre for Genetic Resources and Biotechnology (NACGRAB), an agency under the Federal Ministry of Science and Technology.

Membership of national committee	Membership of TSC (crops)
The Director/CEO of NACGRAB also doubles as the Registrar of the Registration and Release Committee • The Chairman • Registrar • TSC Chairmen for Crops, Livestock & Fisheries • River Basin Authority • RTEP • Private Farmer • Seed Association of Nigeria • FDA /ARCN • Observers	• All National Coordinators of different crops • President Genetic Society of Nigeria • Head of GRU, IITA • Private Breeder selected on merit • The Chairman • The Registrar (who must be the Head of NACGRAB) • NASC • Chairman, Committee of Deans of Faculties / Colleges of Agriculture.

Achievements:

Since inauguration in 1989, the National Committee has:

- Registered and released 595 varieties from 38 different crop species (actively and retroactively) as at today (**CASSAVA-46)**
- Launched 166 varieties of 10 Crop species (namely maize, sorghum, rice, pearl millet, cowpea, groundnut, cassava, yam, potato and tomato) into the ECOWAS crop catalogue **(CASSAVA-24**)

Step-by-Step procedure to register new crop varieties

Step 1: Identification of a cultivar or development of a new variety with novel traits better than the existing ones.

Step 2: On-station trial to test for DUS, yield and reactions to insect-pests attacks among other things.

Step 3: Multi-locational trial in relevant agro-ecologies for two years OR growing seasons (minimum of 5-10 testing sites)

Step 4: On-farm trial for a year/season (>20 testing sites).

Note: The on-farm trial can take place simultaneously during the second year multi-locational trial. It must also be monitored by the representatives of the TSC (crops).

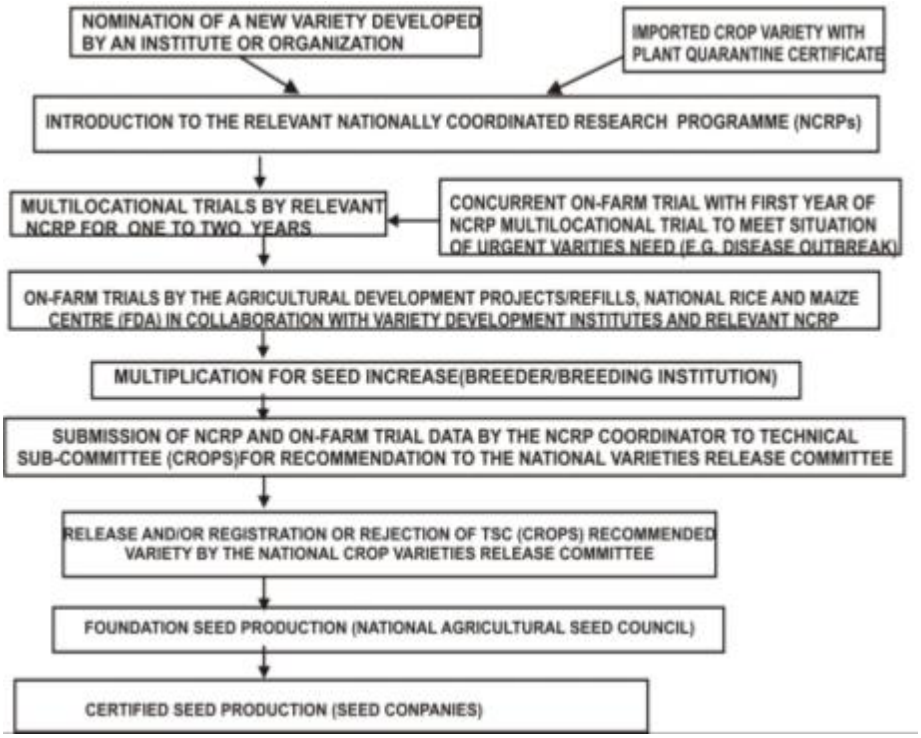
Step 5: Submit your application (including results, required descriptors and relevant pictures) 40 copies to: The Registrar, National Crop Varieties and Livestock Breed Registration and Release Committee

Step 6: Defend the nomination at the TSC (crops) meeting

Step 7: The TSC (crop) reject or recommend the nomination to the National Committee

Step 8: The National Committee approves or rejects the registration and release of the nomination

Step 9: 5kg breeders' seed to be given to NACGRAB while 50kg foundation seed to be given to NASC. Sizeable planting stems for cassava genotypes



Who can register new crop varieties in Nigeria?

The following categories can develop and register new crop varieties:

- National Agricultural Research Institutes (NARIs)
- Universities
- Registered Private Seed Companies
- Non-Governmental Organizations (NGOs)

In case a new variety is developed by other organization apart from the breeding institute, such organization must work harmoniously with the breeding institute to evaluate their trials and register their varieties

Plenary discussions.

- Science (breeding) work is not complete until it gets to the farmer. Success is measured by adaptability of science products.
- Rigid certification process is not meant to discourage breeders, but to ensure quality products are released. The scientists have to convince the committee adequately by elaborating explicitly the new traits, benefits etc.
- Biotechnology policy vs release process – the law captures both and there is an MoU between biosafety and National Crop Varieties and Livestock Breeds Registration and Release Committee.
- AI memory/ability: What are the success rates of AI in multiple disease survey in a plant and in a net plot? – AI works well so long as the problem is described clearly/well and the AI system is trained adequately.
- Integrity and trust issues of data collected by AI – it is possible to get approximately 80% accuracy.
- Incentivizing farmers to use AI – what are the incentives to encourage farmers to use AI? Data airtime; recognition, small micro-funds. However there is still a big problem with the incentive systems.

5.7. Analysis of future trends, high potential technologies and products

The facilitator took participants through the task to analyse potential technologies and products for the future or for Phase II that would address the identified challenges, gaps, demand and trends in the previous sessions. Four groups were formed and discussions held for approximately 1.5 hours following the guidelines in Box 6 below.

Group task – Identification of high potential technologies and products

a) What are **the technologies and products** with the **highest potential for success** so far and which need to be developed further in phase II?

b) What **technologies and products** are in highest demand by different stakeholders and thus have a high potential for successful adoption in the next phase of the project?

c) What are possible pathways of getting the products to the users?

d) What activities could be carried out **in year 5** of phase I to be able to understand more the products and results demanded by different stakeholders?

Box 3: Identification of high potential technologies and products

Group presentations of technologies and products that can be developed further in phase II.

Technologies		
Phenotyping	• Cassavabase • PhenoApp • Fieldbook – social data using field book • NIRS (root and product quality) • E-tablets	• Root bulking and yield • Quality traits (fresh root, product) **Sensors:** • Flower counting Yield • Pest and disease quality scoring (canopy and roots) • Weed management **Ground penetrating radar:** • Yield • Adaptation - drought • Maturity time • Root disease **Mechanizes harvesters for yield**
Variety release and dissemination	• Candidate varieties • SAH	• Incorporate end-user preferences • Integrate social studies (gender)
Genomic resources	• Development of low cost SNP chip • rAmpSeq • genomic selection models – new genome assembly	
Flowering induction	• Grafting • Hormones (STS + BA)	

Potential products	Possible pathways (how)
Intermediate products • Protocol • Technology • Training packages	• Research • Collaboration • Knowledge exchange • Equipment sharing • Databases for exchange • Storage
Final products • Varieties • Trained personnel	• Explore alternatives for better delivery of varieties

Activities for year 5 of Phase I

- NIRS – collaboration and calibrate for more traits
- CASS project – interaction with NextGen project
- Write brochure of technology description
- Optimise GS models for downstream use - GS implementation and tracking GS materials
- Flowering induction records
- Human resources –tracking graduate students to ensure they remain active on cassava research (seed grants?)
- Stakeholder mapping to identify potential product users
- Training on standard phenotyping protocols
- Fast-tracking elite clones for release – PVS

6. NextGen Phase I final year and transition to Phase II

The aim of this stage is to address the implications of the trends and the future demands in view of Phase II and the last year of phase I of NextGen. An overview presentation of Phase II concept and group discussions enabled participants to critically examine the implications of previous analysis of high potential technologies and products, and possible demands and pathways. Participants then identified what needs to be pursued in Phase II, and what needs to be focused on in the remaining time of Phase I.

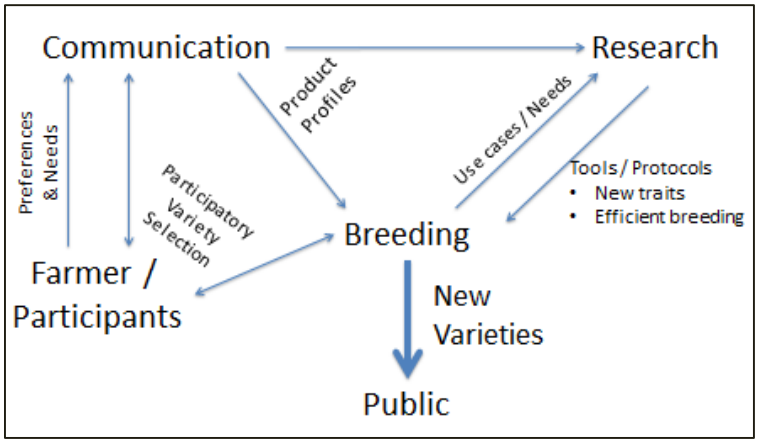
6.1. Introduction to Phase 2 of NextGen

Jean-Luc Jannink gave an overview of Phase II concept note with the following highlights:

What NextGen Does

- Improve cassava through breeding cycles that involve generating and identifying improved progeny that we take through to release.
- Improve our understanding of the gender-responsive product profiles desired by end users through communication with stakeholders.
- Improve our ability to deliver higher-valued varieties rapidly and efficiently by technological advances driven by research.

There are three management divisions: research, breeding, and communication (see diagram below).



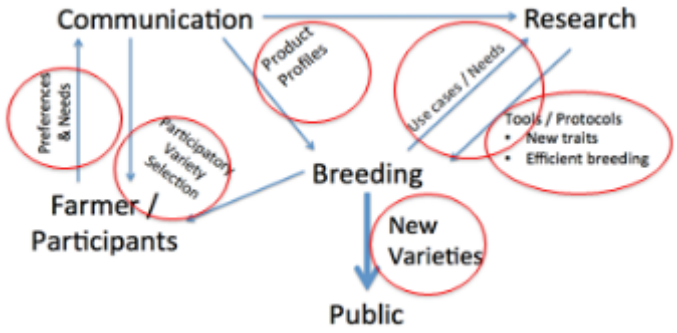
Breeding	Communication	Research
• Variety release pipeline – From CET to UYT and National release trials – Optimized numbers and locations • Population improvement pipeline – 40,000 seeds from 250 to 500 families – 20,000 tissues to MAS – 10,000 DNAs to genomic prediction – Selection in the crossing nursery prior to crossing • Participatory evaluation	• Participatory evaluation • New trait discovery • Equity of opportunity and Sustainable chains • External impact metrics • Project advocacy and communication • Technology outreach • ICT infrastructure • Community of Practice Partnerships (Ghana, Rwanda, Mozambique and D.R. Congo)	• Uniform methods across programs • Root quality traits, CBSV titre, Stake quality • Cassavabase digital ecosystem • PhenoApp integration • Process map: identify and minimize errors • Decision support – Crossing and population management, training population design, Breeding vs. per se value • Whole genome sequence information in prediction

– While there is still diversity (~ 100 clones from AYT) – 10 farmers in each of 20 groups (Mother / Baby)		• Breeding scheme optimization • GxE and selection index in product profiles • Germplasm acquisition • Flowering **More in Africa, less in the US**

The Phase II concept note will be developed in a full proposal. At the moment it is deficient in specificities and research objectives. There will be a need to prioritize on research (it is not possible to carry out everything from the onset). Key activity is to understand points of interaction between research, breeding and communication. Additionally how to enforce compliance in use of the systems.

6.2. SWOT analysis of NextGen Phase II

Six groups were formed based on participants areas of expertise to discovery inter-sectionality between breeding, research, and communication (see diagram below). Thereafter a challenge and offer exercise for specific questions was undertaken.



Questions for challenge and offer model

1. **How do we assemble product profiles?**
2. **How do we create breeding process maps?**
3. **How do we elicit farmer preferences and needs?**
4. **How can research help product development?**

Question one – how do we assemble product profiles?

1. How do we identify key traits weighted by preferences and needs and the feasibility of breeders?
2. How do we balance the different profiles in the assembling of the final products?
3. Are the traits heritable (genetic or processing – dependent)

4. What is a product profile?
5. What are the different levels of end-user (farmer, processor, etc.)
6. what are the end uses
7. How do we measure those traits?

Question two – how do we create breeding process maps?

1. How to identify common traits and proper phenotyping in the breeding process?
2. When and how to initiate the participatory breeding program?
3. What is a breeding process map?
4. What should be the extent of stakeholder engagement? E.g. participatory breeding
5. What selection strategies should we adopt?

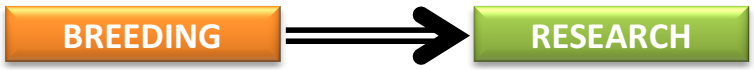
Question three – how do we elicit farmer preferences and needs?

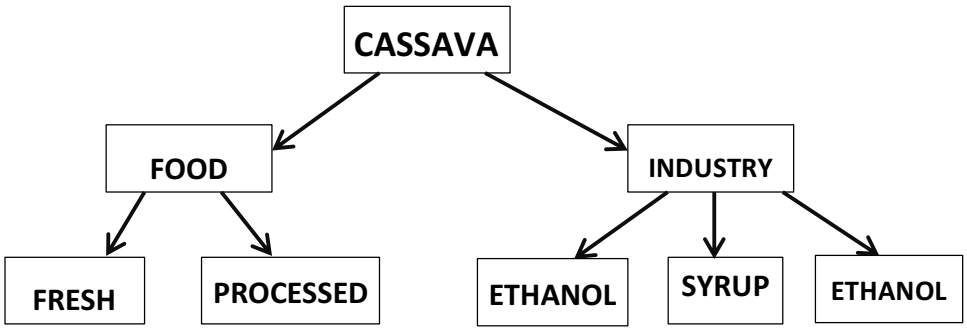
1. How do we develop surveys to gather unbiased farmers preferences and needs across gender, geographic and social-economic groups?
2. Who will be farmer – researcher/breeder liaison? (Social scientist? product manager? breeder? extension officer?)
3. Can we involve farmers in the selection process? (participatory breeding)

Question four – how can research help product development?

1. How can communication improve research?
2. How do we assess our own progress?
3. Who will do the research?
4. What kind of expertise/research is relevant?
5. Can we predict/forecast epidemics and anticipate needs?
6. Can we develop predictive ability to determine the “lifespan” of a product?
7. What problems don’t have solutions yet?

6.2.1. Use cases and needs offers





Question one - how do we assemble product profiles		
Master challenge	**Offer**	**who**
How to balance the different profiles in the assembly of the FINAL PRODUCT	Use surveys of end user preferences and balance with breeder knowledge of what is realistic	Peter Hyde
	Data sharing and mining will allow establishing genetic correlations among traits. This will be helpful in defining "wise" selection indexes	H Ceballos
	Develop variety development pipelines for specific markets	Peter Kulakow
How to identify KEY TRAITS by preference, need and feasibility	• Have series of meetings with farmers and survey • Identify end users and ask for their preferred traits • triangulation of available data and use of understandable and current data analysis tools	
Who are we breeding for? (breeder)	Ensure unbiased sampling of farmer/end-user preferences so that all preferred traits are identified	Peter Hyde
	We are breeding for end-users and stakeholder preferences and needs	OSA
	Surveys to identify the needs and gaps in breeding programs	Paula
	Cassavabase can help clustering the different farmer/consumers	
	Run market surveys	Edema, researcher
	Who are we breeding for? we should target the industries and farmers (end-users)	Nwaogu Ahamefule
	End-users preferences and needs	
What is the cassava market (per country) (social science)	Identify market drivers in relation with cassava traits	DD
	The cassava market must be : ✓ Profitable (roots and products) ✓ Available and accessible to marketers and buyer ✓ Social groups • Culinary traits are key for most end-users • Clustering niche markets and key products in these niches	

What are the different levels of end-user?	Consumption patterns and uses identified by region	DD
What traits are critical for each use?	• Baseline surveys • Assess end user needs	Hale
How do validate (fact check) a new product profile to ensure it contains the right elements?	• participatory breeding and farmer involvement in multi-location trials	Peter Hyde
	• PVS to validate profiles	Hale
How would farmers and end-users prioritize traits for a given product profile (eg gari cassava)	• good processing evaluation with farmers using their current varieties along with new ones • choice experimentation	Hale
	• assess processing ability with farmers and processors	DD

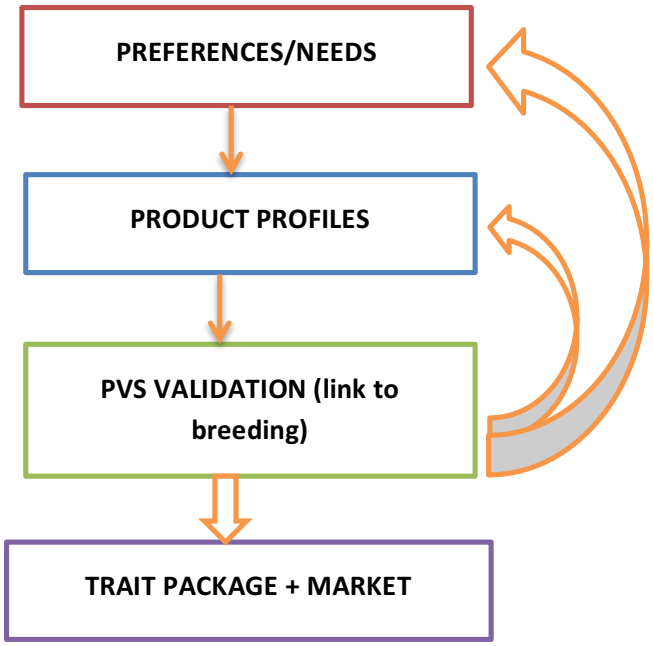
6.2.2. New varieties and efficient breeding

Question 2 - How do we create breeding process maps			
Master challenge		**offer**	**who**
When and How to initiate participatory breeding programmes	• interaction of farmers and scientists in the farms, markets, field days etc. to create awareness and also identify challenges that might hinder adoption of improved product • participatory breeding program can be initiated at the second stage of breed in order to bring end users on board as well as towards the end stage • participatory breeding approach in the early process of identification • farmers should be involved in identification of traits • farmers should be involved in the selection processes • standardize the phenotyping process by use of tools (Cassavabase) • capacity building on data quality management for research	• Participatory breeding could involve end users at multiple steps in the breeding process: ✐ ID key traits early in the process ✐ Multi location yields – late in the process • Structural PVS trials	Peter Hyde Femi A
How to identify common traits and proper phenotyping	• Correlate social perceptions with traits and develop method to measure them		DD

in the breeding process	Use new phenotyping tools – NIRS, PhenoApp	Phenotyping – use more reliable and less suffiticated data	Tessi
		• Efficient phenotyping may require less but more reliable data • Reliable phenotyping achieved by starting with 3 clonal evaluation trails (in 3 ǂ locks) from the same genotypes	H Ceballos
	• Create list of identified traits • Identify the sources of traits genes • Breeding procedures to be used		
How do you get different actors to communicate (work together) (communications)	Proper integration of participating disciplines • let there be exchange programmes e.g. social scientists from Nigeria can participate in Uganda	Adopt and actively use Slack or Basecamp application	Marnin
How do we increase the efficiency of the breeding programme (breeder)	• participatory approach • Exchange of germplasm to increase variation • community of practice • town hall meetings • surveys • feedback dissemination via several platforms • setting up standard procedures • ensuring breeders follow procedures • how do we use breeding process maps to create an institutional culture of continuous process improvement •	Effective field team to execute high quality trails	Peter Kulakow
		Advocate for and implement high quality farm management	Peter Kulakow
		Describe breeding stages in detail for each programme	Peter Kulakow
		Develop detailed breeding schedules for each programme	Peter Kulakow
		Make sure you clearly understand your: Breeding target traits Breeding target environment	D Meyer
		Track all breeding processes in Cassavabase	Lukas
		Chain of custody for phenotypes and genotypes – all meta data and all people associated with data at all times	Marnin
		Track/estimate the accuracy in every cycle	Ramu
		Track QTL in breeding process	Morag
		Develop easy tests for evaluating complex traits (phenotyping)	DD

		Develop plan for workshops/seminars to address institutional culture of continuous improvement	Paul Gibson
		Efficient breeding will benefit if genetic variances are split (somehow) into their components	H Ceballos
How do we maximize useful genetic gain	• Standardize phenotyping protocols • How much genetic source of disease resistance are there in breeding programme • develop protocols for selfing and develop heterotic groups via genomic selection • how much genomic	Write down the generic gain equation and find strategies to optimize all the parts of the equation in your breeding programme, but remember genetic gain does not matter if it is not REALISED in the farmers field	Damian
What variation is present among current selection candidates? (pre-breeding)	• lack of enough genetic diversity for the target trait • develop an interface for users to search and retrieve the best potential parents, given a specific product profile (based on past performance, genetic relatedness and combining ability)	Genotyping and identifying the variation among selected candidates	Ramu
		Efficient screening of already existing germplasm	Smith
What is the target population		Baseline surveys - conduct baseline surveys for the traits of interest	Hale
		Evaluation of genetic resources, trait and marker identification and tracking in populations	Morag
		TPE - once identified and genotype tested, can be evaluated	researcher

6.2.3. Product profiles preferences and needs



Question 3 - How do we elicit farmer preferences and needs			
Master challenge		**offer**	**who**
How do we involve farmers and extension in NextGen phase II (communications)	• Interaction with farmers and extension service providers through social surveys • identifying key extension agent by region and involving them at an earlier stage of phase II	• Participatory variety selection and create discussion platforms	KJM
		• Survey and training	Tessy
How will the farmer/breeder interaction be structured?	• use variety as product processing and evaluation protocols	• feedback mechanisms between farmers, social scientists and breeders	DD Tessy
How do you prioritize preferences and needs (breeder)	• talk to end users (farmers, consumers, industry, women) – then make priority list • use preference based index for selection		
How to develop unbiased surveys to best capture farmer preferences (across gender, geographic and socio economic groups)	• Can we do a baseline survey to capture farmer preferences and needs • How best, cost efficient way can we capture farmer preferences industry model?	• consider using metadata e.g. consumption and market information (data science approach)	Ernest M

	• Baseline survey can start with reading previous reports and papers to understand needs and preferences		
	• design baseline survey • identify niche market sources and track their inputs	• regional survey to capture trait preferences and product development through value chain	Tessy DD
How do we define the group of adopters?	• socio economic characteristics – groups having similar characteristics and needs; groups affected by gender issues	• conduct region specific and gender specific surveys	researcher
Question 4 - How can research help product development			
Master challenge		**offer**	**who**
How can you accelerate breeding for complex traits (simple phenotypic methods and understand genetics) (breeders)		• transcriptomics	Andreas
How can we access/use genetic resources in pre-breeding to concentrate alleles in population improvement (breeders)	• include promising farmer varieties with desired quality traits in pre-breeding process • genotype and database relevant accessions or sequence caasavabase • conduct pre-breeding for different product profiles i.e. disease, good cooking, high quality DMC and starch	• Identify priority parents and produce seed of critical germplasm combination	Peter Kulakow
		• evaluation and characterization of genetic resources, trait marker associations, tracking markers/QTL in population	Morag Kiddo
		• Cassava, Inc requires a genetic resources team – works across countries, runs trials, studies, diversity and genetic architecture considers wild germplasm	Marnin
How do we prioritize the research and allocate resources	• needs assessment	• identify the most important and highly demanded research output and allocate resources that are preferred by farmers	OSA
		• Should be a group/committee including peer	Marnin

		representatives from each division who will (democratically) determine this	
		• can we get more exposure on how industry deals with these challenges? exchanges, more frequent survey by external committee	Guillaume
How do we ensure the varieties released will be a success in the market (communication)	• create a readily accessible and profitable market for the variety released (expert potential) • know the needs and preferences of your farmers/target population and address their concerns • capture farmers/end users preferences during breeding process (participatory breeding) • regular update and consulting the farmers/consumers	• farmers participatory trials	DD
		• early involvement of farmers variety development pipeline – advance yield trials (AYT)	Alfred
Market driven traits	• early communication with key actors in the value chain		
How do our products remain relevant in the seed system	• how do extension agents train farmers to increase productivity and quality of cassava • providing farmers with information on how to connect directly to a constant demand without middlemen that lower the prices	• constant survey of preferred/changing preferences of end users	OSA
How do we ensure that research is driven by breeder needs	• ask what their needs are and try out the products (feel their pain) • breeding and research communication must have regular project meetings • seek and adopt current breeding tools – GS etc	• need a joint workshop/strategy session with key breeders and partners to increase shared knowledge on the challenges/needs of the breeding program and the potential solutions that new technical tools can provide	David Meyer

Can we develop tools to make the breeding process more efficient? (Allowing more time for breeder to ensure trajectory of program is correct)	• increased use of standard databases (Cassavabase) for phenotyping and genotyping processes	• high throughput methods for phenotyping	DD
		• Develop tech-tools (PhenoApp) for standardized measurement	Ernest M
		• PhenoApp – communication between developers and breeders to make sure apps are useful and helpful in increasing efficiency, standardization of phenotyping	Jenna
How can communication improve research	• communication can improve research both internally (project) and externally • Interact more in informal settings (not just annual general meeting dance partners). Maybe more NextGen social events on campuses/research stations or intramural sports • research breeder exchange visits and workshops	• real-time communication	researcher
		• utilize extension agents to improve communication between farmers and researchers	Peter Hyde
		• Strengthen ICT infrastructure across participating programs	Fadil
		• enforce open and honest dialogue between different actors involved in the breeding pipeline	H Ceballos
		• engage the farmers in small group discussions	Femi Alaba
		• Better flexible communication platform (we have slack bilateral meetings) a note for Cassavabase?	Guillaume

Quick comments on challenges and expertise offered

- It is imperative to stop working in silos – the process should be more integrated
- Communication will be central for the quality traits to be used by consumers
- Common understanding - all have to be on the same page and understand one another better

6.3. Planning for year 5

Following the extensive analysis of progress made, high potential technologies and products, future demands and pathways and implications for Phase II and year 5, participants discussed the priorities and modified activities for year 5 where necessary. Eight groups based on the

objectives were formed to plan in detail for the remaining year in the objective groups and come up with updated work plans using guidelines in Box 7 below.

Planning for year 5

- **Clarify again what you want to achieve under your objective area.**
- **Looking at what you really want to achieve, what activities will you carry out to consolidate the success made and address challenges discussed in this workshop?**
- **What activities will you carry out in preparation of phase 2?**
- **Which partners will you be working with and how do you engage with them to better learn and collaborate together?**

Box 4: Planning for year 5

Objective leaders guided the groups in updating their work plans for year 5.

Objective 1: Flowering - Tim Setter

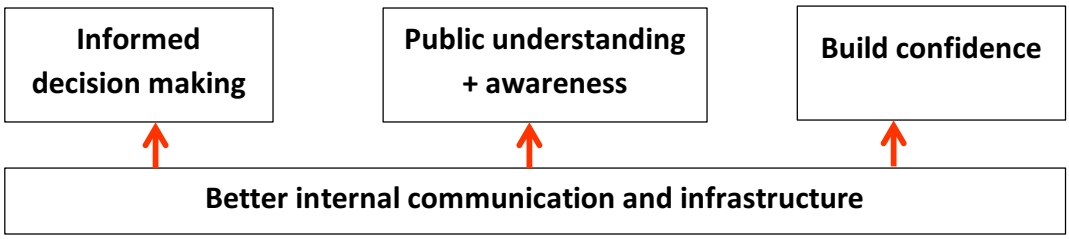
Objective 2: Genomic Selection - Jean-Luc Jannink

Objective 3: Cassavabase - Lukas Mueller

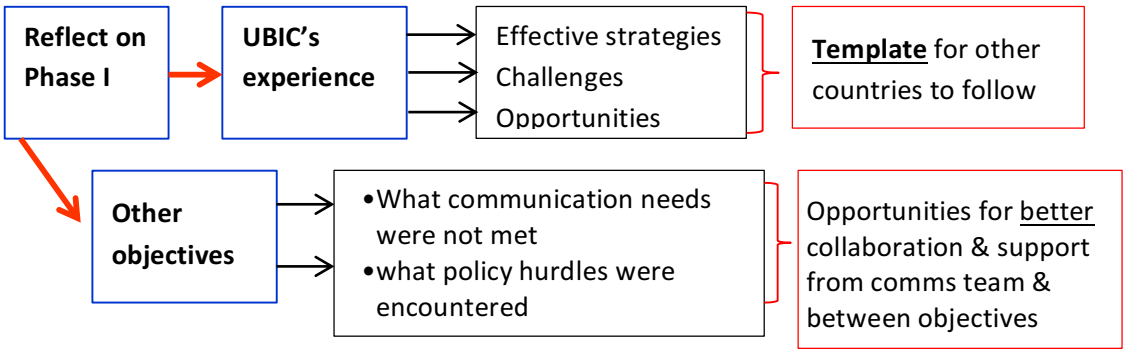
Objective 4: Germplasm Exchange - Peter Kulakow

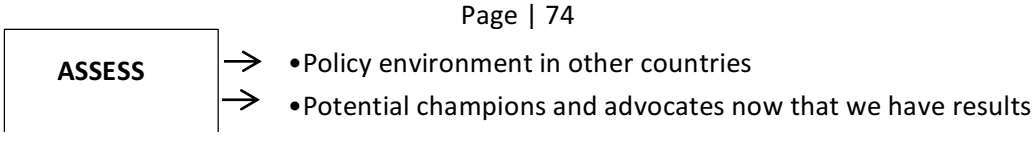
Objective 5: Capacity Building - Richard Edema and Paul Gibson

Objective 6: Biotech/biosafety Communication - Barbara Mugwanya



To consolidate success:





Next Steps (subject to timeline)

1. Protocol for crisis communication (country/project) and internal communications (key people/how to stay in the loop)
2. Identify current communications capabilities/need of each partner including ICT needs
3. Revive the NextGen mailing list and establish quarterly newsletter with regular project updates
4. Use existing materials to create/package communications kits
5. Take stock of public sentiments and policy/political developments in each country

Objective 7: Enhancing of GS through Cassava Genomics - Ramu Punna and Roberto Lonzano

Crosscutting Objective: Gender responsive breeding - Hale Tufan

7. Next steps, workshop evaluation and closing

7.1. Next Steps

The following next steps were discussed and agreed upon in plenary.

What	Who	By when
Workshop report to organizers	PICOTEAM	10th April 2017
Year 5 work plans and notes to include in report and proposal	Project management	7th April 2017
Phase II Proposal	Project management	To be discussed

7.2. Workshop evaluation

At the end of the workshop quick feedback was sought from the participants on what they liked most, what could have been done better, the take home message and recommendations for next phase of NextGen (see box 8).

Table task: workshop evaluation

Reflect on past three days and discuss around your table:

a) What did you like most?

b) What could have been done better?

c) What is the take home message for you?

d) For NextGen next phase we recommend....

Box 5: workshop evaluation

Below is a summary of the evaluation results.

What participants liked most	What participants feel could have been improved
• Time management and maximization– good time for group discussions • Value of seeing all that was accomplished in the three days • Variety and representation of the collaborators/partner institutions. Invitation of external partners provided opportunity to learn and acquire more insights • Having the whole team in one place • Dynamism, interactions and meeting new people - the rotations and discussions around the tables enabled participants to talk with most people. Members of the NextGen team now know one another • Facilitation – that enabled dynamic interaction, participatory contributions, organized processes, no hierarchies/big bosses, lively sessions • Energizers and appreciation/motivation • Information sharing – content, quality and usefulness. Learnt a lot about our project • National varietal release process • Value and display of posters throughout the meeting • Logistics – efficient movement of people across the regions	• Time allocated for presentations – 10 minutes was too short; more time should also be allocated for formal and informal discussions as well as questions and answers • There may be need for an extra day in view of the amount of work and presentations for in-depth discussions • Have all the sub-projects working together beyond the meeting will be excellent • Some instructions were not clear – need to explain complex questions/instructions better • Hard to know in some of the instances how the pieces fit together in terms of the activities and how they relate to the overall workshop • Phase II presentation was rushed and unclear; more time was also needed for planning and prioritization of Phase II – did not have enough time to deliberate on the objectives • Feedback on the challenges - need more challenging/constructive criticism • Feedback of the review was not presented • Needed to hear more from the students • Results from poster session did not come out • Invite farmers (did not talk about them in depth) • Needed more time to prioritize for Phase II + final year?

Participants take home message	**Recommendations for next phase of NextGen**
• Great success has been made in the genetic gains over the 4 years • Work in progress • We are in the right track and making progress, and we should continue working hard building on what we have learned • New varieties and map will be released • High throughput phenotypes focus of Phase II • Lots of work has been done, but there is still even more work to be done in Phase II • Stay focused on the goal of releasing award winning varieties • GS is working – it is not a theory	• Advance technologies – NIRS, PhenoApp, more tools in Cassavabase and good/quality genotyping • Open minds and open phase • Broaden communications • Need M&E unit • More farmer representation • Work harder • By end of next phase there should be a NextGen cassava variety released • Clear mechanisms for bringing all sub-projects together • Feedback to everyone

7.3. Closing remarks

- The facilitator thanked the participants for being wonderful and engaging, thus enabling success of the workshop. He thanked NextGen, Chiedozie and the organizing team for excellent coordination and inviting PICOteam to facilitate the meeting. Edward also thanked the process steering group who reviewed the progress every evening and worked with him in making the necessary adjustments for success of the workshop.

  In concluding Edward wished the participants all the best in implementing their plans noting that based on one's perspective of "**Opportunity is nowhere**". The project team can mourn or take advantage of opportunities available to upscale cassava for great impact.

- Jim Lorenzen in a special way thanked all participants for energy and hard work put in the three days of the meeting as well as the past four years. He was grateful that participants had found time to participate in the workshop. He applauded the objective leaders, researchers and all the teams back in the various countries and stations. He noted NextGen is an exciting project with great potential – there is room for growth and to get even better. He assured the team of continued funding.

- Ben on behalf of EPAC lauded the team for great achievements and reiterated the team was on the right track of changing cassava production in Nigeria, Uganda and before long in Tanzania. He congratulated the people in the field trials, genomics, breeders and all

working in the NextGen project. He appreciated the change in the group over the last four years – has increased in number and dynamics and asked the team to stay and work together as a group. It was wonderful to have students going through the project and getting respectable results. He urged them to continue working on the many areas/objectives, and talk across the fields to be well informed about the whole project.

- Dave was glad to have been involved with all the project staff and noted there are many research areas and issues in cassava. He advocated for vision, passion and scientific excellence – when these three are put together, there is so much power to improve cassava. He reminded that phase II is about bringing impact from work done in phase I. The most important next step is bring the products to the farmers. He asked the participants not shy from asking the question "I am sorry, can you help me understand."

- Chiedozie thanked PICOteam for the facilitation and support noting that though the facilitator was not a scientist he successfully managed to coordinate the team to bring out the necessary information. He also thanked Jürgen who co-facilitated the meeting. Chiedozie commended the EPAC group and members who make NextGen achieve their objectives (do what they are supposed to do). The EPAC team enables the NextGen staff prioritise quality of their work and ensure they are on the right track. The EPAC group provides unique support, and they have passion for cassava in their "blood".

  Chiedozie notified of an event to mark the science achievements of Phase I, and encouraged the participants to continue working with passion. He requested the spirit of togetherness and unity to be endured – agree and walk/run together. He thanked the logistics team for their remarkable work, IITA management, director or roots and tubercrops, executive director of variety release committee, BMGF and DFID and thereafter closed the 5th NextGen cassava meeting.

Appendix one – NextGen attendance list

Full Name	Institution	E-mail Adress
Afolabi Agbona	IITA, Nigeria	A.Afolabi@cgiar.org
Alex Ogbonna	BTI, USA	aco46@cornell.edu
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Alfred Dixon	IITA, Nigeria	a.dixon@cgiar.org
Alfredo Augusto Cunha Alves	Embrapa Cassava and Fruits, Brazil	alfredo.alves@embrapa.br
Andrew Ikpan	IITA, Nigeria	
Ani Elias	Cornell University, USA	aae37@cornell.edu
Barbara Zawedde	Makerere University, Uganda	bmugwanya@gmail.com
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Ben Hayes	Government of Victoria, Australia	b.hayes@uq.edu.au
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Canaan Boyer	Cornell University, USA	ceb363@cornell.edu
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Appendix two - workshop programme

Day 1: Tuesday March 14, 2017

Time	Session
Session 1 8:15 – 9:00	**Welcome and Opening Remarks** Chiedozie / Richard
	Setting the Scene: Interactive introductions, objectives, expectations Edward Chuma, Facilitator
Session 2 9:00 – 10:00	**Analysis of Progress I (Presentations strictly 10 minutes, 10 slides)** 1. Jean-Luc Jannink: GS update 2. Robert Kawuki: NaCRRI update 3. Joseph Onyeka: NRCRI update 4. Ismail Rabbi: IITA update **Table group analysis of presentations**
10:00 – 10:20	*Coffee Break*
Session 3 10:20 – 12:30	**Official Opening Ceremony** • Welcome DG – IITA • Goodwill from BMGF- Jim Lorenzen, Senior Programme Officer, BMGF • Goodwill from NRCRI – Julius Okonkwo • Goodwill from ACAI Project- Abdulai Jalloh, IITA • BASICS Project – Hemant Nitturkar, RTB • SAH Technology – Lava Kumar, IITA • Cassava breeding and varieties of change –Alfred Dixon, Director, Partnerships, IITA • Intro. of Hon. Minister of Agriculture – Nteranya Sanginga, DG, IITA • Formal Opening: Hon. Minister of Agriculture
	Group Photograph/Displays/Exhibitions – Outdoors IITA Conference Center
12:30 – 14:00	*Lunch and interaction*
Session 4 14:00 – 15:30	**Analysis of Progress II: (Presentations strictly 10 minutes, 10 slides)** 5. Tim Setter: Flowering update 6. Simon Prochnik: Cassava genomics consensus mapping update 7. Lukas Mueller: Cassavabase update **Table group analysis of presentations (to incl Session 2)**
15:30 – 16:00	*Coffee Break & Open Space Sharing Opportunity*
Session 5 16:00 – 17:00	**Analysis of Progress III: (Presentations strictly 10 minutes, 10 slides)** 8. Peter Kulakow: Germplasm update/way forward 9. Hale Tufan: Gender-responsive cassava breeding update 10. Ramu Punna: Genetic load in cassava and rAmpSeq **Table group analysis of presentations**
Session 6 17:00 – 18:00	EPAC Meeting
18:30 – 20:00	*cocktail reception*

Day 2: Wednesday March 15

Time	Session
Session 1 8:00 – 10:30	**Analysis of Progress III: (Presentations strictly 10 minutes, 10 slides)** 1. Eder Oliviera: Embrapa NextGen update 2. Hernan Ceballos: CIAT update 3. Barbara Mugwanya: UBIC update **Table group analysis of presentations** **Interactive POSTER SESSION 9:30 to 11:00**
10:30 – 11:00	*Coffee Break & Open Space Sharing Opportunity*
Session 2a 11:00 – 11:50	**Analysis of future trends, high potential technologies and products (Presentations strictly 10 minutes, 10 slides)** 1. Ben Hayes: OHV technology and use in breeding 2. Mike Gore: Improved phenotyping through image analysis 3. Dominique Dufour: NIRS phenotyping and calibration 4. Ng Enghwa: High throughput genotyping and sample tracking 5. Sunday Aladele: Variety release process in Nigeria
Session 2b 11:50 – 13:00	**Analysis of future trends, high potential technologies and products** Group discussions – analysis and report back
13:00 – 14:00	*Lunch*
Session 3 14:00 – 15:30	**Analysis of future demands and pathways** Group discussions – analysis and report back
15:30 – 16:00	*Coffee Break & Open Space Sharing Opportunity*
Session 4 16:00 – 18:00	**Implications and thrusts for phase II and year 5** Group discussions – analysis and report back

Day 3: Thursday March 16

Time	Session
Session 1 8:00 – 10:30	**Way forward in fostering the joint learning and collaboration network** Group discussions, conclusions in plenary
10:30 – 11:00	*Coffee Break & Open Space Sharing Opportunity*
Session 2 11:00 – 13:00	**Planning for year 5** Group discussions in objective groups – major activities for each objective, and cross-objective activities
13:00 – 14:00	*Lunch*
Session 3 14:00 – 15:30	**Planning for year 5** Group discussions in objective groups – major activities for each objective, and cross-objective activities
15:30 – 16:00	*Coffee Break & Open Space Sharing Opportunity*
Session 4 16:00 – 18:00	**Report back on plans** **Next steps** **Evaluation and Closing**

Appendix three – photo gallery

Participants following the proceeding during the workshop

Peter Kulakow seeking clarifications after a presentation

Poster session

Group work sessions

Guidelines on making offers to contribute to a challenge

Energizer – making fufu (there was also a cassava clap, locomotive clap; rain and thunder clap and parliamentarians clap)