

Roots and tubers roadmap summary

The road to sustainable root and tuber growing [2023-2033]



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Root and tuber crops play a major role in food security for the world's poorest people, particularly in Africa, where they are very popular. In a context of rapid population growth and increasing dependence on imported cereals, research must support the development of root and tuber crops and their markets, particularly with a view to supplying urban areas. CIRAD has pinpointed four ambitions that will frame its research in partnership over the coming decade. ■

Roots and tubers (RTs), primarily cassava, sweet potato, yam and taro, are grown for their starch-rich underground organs, but also for their leaves (except for yam). Cassava is by far the most important in terms of production, with a total of 315 million tonnes produced worldwide in 2021 (65% in Africa), followed by sweet potato (89 Mt, 34% in Africa), yam (75 Mt, 98% in Africa) and taro (12 Mt, 80% in Africa). On a global level, average per capita RT consumption is roughly 70 kg/year, although the figure is much higher in some African countries. For instance, people consume 250 and 220 kg of cassava per year in Congo and Ghana respectively, while in Nigeria, they eat almost 120 kg of cassava and 105 kg of yam and in Benin 110 kg of cassava and 155 kg of yam [source: FAOSTAT 2021].

Production on family farms, with very little input use

Except for three yam species, all RTs were introduced into Africa as clones, several centuries ago. Average yields are relatively low, particularly in sub-Saharan Africa (10 t/ha), and there is substantial room for improvement. For want of a seed production sector, due to the complexity of the cropping systems concerned, and no doubt also due to a lack of interest on the part of donors, RTs have received much less research investment than

cereals. Many countries are building intensification pathways based on synthetic inputs and mechanization, particularly in Asia and Latin America. That type of intensification could resolve short-term economic issues and satisfy industrial and food security requirements, but it also means economic, environmental and health risks and agrobiodiversity losses. It would therefore be worth looking into agro-ecological intensification of RT chains.

Processing, a key issue

Given their low dry matter content (20 to 45%), RTs are often processed (dried or fermented), to stabilize the product and make it easier to store and accessible to urban consumers. The original craft techniques have gradually become industrial, and new products with innovative functional and nutritional properties are being developed to respond to rapidly changing consumption habits. Consumers are very demanding in terms of the quality of such products, which must be suitable for local culinary specialities that they see as part of their identity.

Cassava is processed industrially in Asia and Latin America, and also on a relatively limited scale in Africa, to make starch and flour for both food and non-food purposes (biopolymers,

ethanol, etc). Sweet potatoes are also processed in Asia, albeit on a smaller scale, and the leaves are used to feed both animals and humans. These fast-growing agroindustrial value chains call for new types of production and processing systems. As things stand, industrial yam processing is difficult, since yams are both costly, and difficult to peel (they have to be peeled by hand). Taro is not widely processed, except in Asia, where its organoleptic properties are appreciated.

Resilient crops with as yet untapped potential

As regards climate change, most studies see RTs as more resilient than cereals and pulses, and they should therefore see their production zones expand. However, their potential, which is still largely untapped, is threatened by the emergence and spread of new diseases, fostered by the fact that RTs are reproduced by vegetative propagation, and by a lack of reliable seed systems. The need for research to support the development of these value chains is therefore set to grow in the coming years, primarily in Africa, where there is galloping urbanization and diets are moving away from traditional food types, resulting in constant demand for processed, ready-to-eat foods. ■

Promoting the root and tuber production of the future: four ambitions to frame operations

CIRAD began working on yam and cassava agronomy very early on, in West Africa and Madagascar and also in the Asia-Pacific zone. Its research subsequently shifted towards the quality of the foods derived from those various species, to encompass consumer demand. It is now working to develop agroecological cropping systems and new varieties that satisfy both the technological constraints associated with processing methods, and taste preferences. In addition to its long history of research on these plants, CIRAD benefits from a broad network of partners. It has four research units (AGAP, QUALISUD, AIDA and PVBMT) working on roots and tubers, focusing on biological systems (PERSYST department), and the environment and societies (ES department). Its work on roots and tubers in the coming years will be framed by four ambitions.

Ambition 1

Foster root and tuber varietal diversity

For want of specialist seed supply chains, producers are often left to their own devices and have trouble acquiring quality healthy, virus-free planting material. This first ambition on the one hand involves conserving, characterizing, improving and disseminating genetic diversity that responds to demand from end users, which producers need if they are to adapt quickly to climate change. On the other hand, it will also mean developing new tools to allow CIRAD's part-

ners to build their skills in terms of varietal management in their local area.

Ambition 2

Make roots and tubers more productive, through agroecology

Current RT cropping systems are often based on shifting cultivation with no input use, after slash-and-burn. The area cultivated is primarily extended by clearing forest. Developing sedentary systems is therefore a top priority. In this context, CIRAD is working to develop and promote cropping systems that enable better soil fertility and pest management in Africa and Madagascar, Southeast Asia and Latin America. The approach centres on varietal innovation, crop management sequences and agrobiodiversity management (agroforestry, intercropping crops and service plants, fallow, varietal diversity, etc). The resulting technical solutions must be environmentally, socially and economically sustainable, while fitting in with local dynamics (mechanization, markets, farms, etc).

Ambition 3

Contribute to root and tuber market development

RT processing, which is often done on a small scale, by women, serves to promote local products via the development of small, innovative agrifood units working primarily to supply fast-growing cities.

CIRAD's research towards this third ambition will be devoted to determining how to access emerging markets for quality products by combining technological innovations and optimized root and tuber quality control methods (matching physicochemical and sensorial properties to RT consumer and user preferences). Developing end product quality prediction tools will facilitate the market launch of new varieties and their adoption by value chains. Lastly, optimizing the equipment used and its environmental impact will serve to develop eco-friendly processes that will benefit processing and packaging firms. CIRAD will be supporting the development of SMEs specializing in root and tuber processing.

Ambition 4

Build skills and back support policies

CIRAD supervises training for large numbers of PhD students from the global South in its laboratories in Montpellier, Réunion and the West Indies. It is those students who will be conducting tomorrow's RT research and innovation operations. In addition to training through research, CIRAD also intends this ambition to build skills among its partners, by transferring knowledge and techniques, and through co-innovation to respond quickly and effectively to demand from RT users (producers, processors and consumers). ■

Details

Genetic improvement, agroecology, market development, skill building, etc... A look at the key details of the roadmap with Vincent Lebot, breeder, and Dominique Dufour, food technology researcher, CIRAD roots and tubers research coordinators.



DR

Why do roots and tubers call for a specific approach in terms of genetic resources?

Vincent Lebot: Contrary to many crops grown primarily for their fruits or seeds, RTs are grown for their underground organs. Depending on the plant and the country concerned, varieties were introduced either in the form of clones, or found in producers' plots and bred locally. All the traditional varieties are therefore hybrid clones.

Dominique Dufour: Varietal improvement to build resistance to certain diseases and adapt crops to soil and climate conditions is relatively simple, given the range of genetic resources available. However, it is much more difficult to improve the quality of aerial or underground organs, since the operation has to allow for local consumers' wishes and cultural preferences. One of the specificities of

CIRAD's research is that it is working to build an approach and new tools to enable scientists in the global South to develop new varieties that consumers will easily take on board.

How can we boost productivity and satisfy urban demand better?

V.L.: Current cropping systems, with their very low use of inputs, are often based on long fallow cycles. With population growth, it is now vital that we boost yields by adopting sustainable approaches and cutting postharvest losses. Apart from cassava in Asia and Latin America, which has already been intensified (ameliorators, mechanization, etc), in most countries, root and tuber cropping systems benefit from very little in the way of innovations. Competition from weeds is the main constraint, and in view of the limited income generated per unit area, new techniques based on biocontrol and agroecological innovation are eagerly awaited.

D.D.: RTs are often very voluminous and not suited to urban markets. However, they have more flexible harvesting dates than cereals and pulses, with the possibility of storage in the ground. The functional and technological properties specific to RT starch have enabled the development of new global markets, particularly for cassava starch, which is now competing with cereal starch on the world market. Past work on waxy starch from cassava (which does not contain amylose), obtained by crossing, offers new prospects in terms of markets and of developing gluten-free bread products or frozen foods.

What role could private seed firms play?

D.D.: Whereas in temperate countries, the success of potato cropping is down to the development of efficient seed systems, RT producers are often left to their own devices in terms of access to seed. Propagules therefore build up viral loads or infections that threaten the performance of plots right from the outset. Several studies have shown that planting material quality is crucial to the future development of RTs.

V.L.: While new in vitro propagation protocols to ensure healthy plants are being developed in many countries, they are having trouble becoming established, since producers still see RTs as traditional crops whose selling price does not warrant investing in healthy planting material. The private sector has not yet invested in developing such propagation systems, and nothing is really in place yet.

How can we build local skills and provide policy support?

D.D.: The SMEs involved in RT processing are highly diverse, but very responsive and eager to innovate to open up new markets. CIRAD can help identify the equipment best suited to local constraints, not forgetting gender-related safety and labour issues.

V.L.: CIRAD trains large numbers of local researchers within development projects that fund PhD grants. Training through research as part of diploma courses is the preferred approach, but there are other options, such as training seminars focusing on specific issues. ■

Find out more: roots@cirad.fr

Facilitating the adoption of new root, tuber and cooking banana varieties to improve food security - the RTBfoods project

Cassava, yams, sweet potatoes, cooking bananas and potatoes are key to food security in Africa. They are consumed in many forms, and are processed and used differently, depending on food cultures. It is essential that scientists take into account local consumers' and processors' preferences in their programmes to breed improved varieties. This is what the RTBfoods project, implemented by CIRAD from December

2017 to January 2023 with funding from the Bill & Melinda Gates Foundation, set out to do in five African countries (Benin, Cameroon, Ivory Coast, Nigeria and Uganda). According to Jim Lorenzen, Head of RTB breeding operations at the Bill & Melinda Gates Foundation (BMGF): "Thanks to RTBfoods, we now know a lot more about what consumers and processors expect in terms of texture and taste, and in some cases, we have

rapid tests that breeders can use to determine whether candidate varieties have the right properties". This is a success for the BMGF, one of whose major aims in funding RTBfoods was, as Jim Lorenzen recalls, to "allow breeders to learn more about consumer and producer requirements in order to include them in their target product profiles".

For further information:



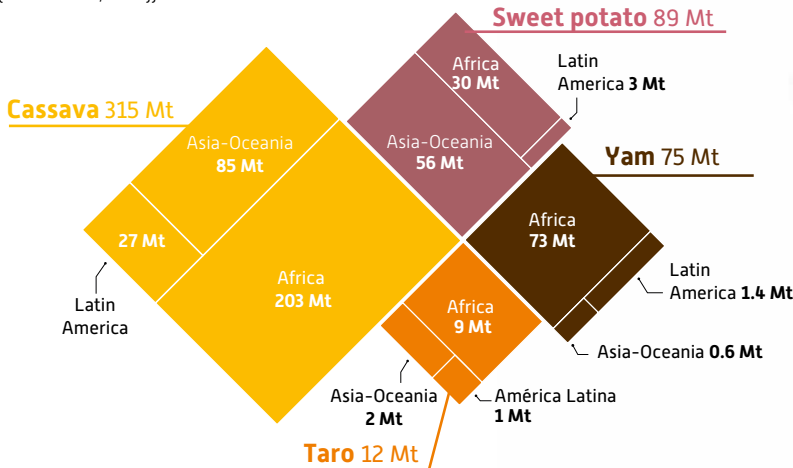
Inventing the roots and tubers sector of the future

CIRAD's work to tackle the challenges facing the value chain

A major sector for food security

Cassava, the most important in production terms

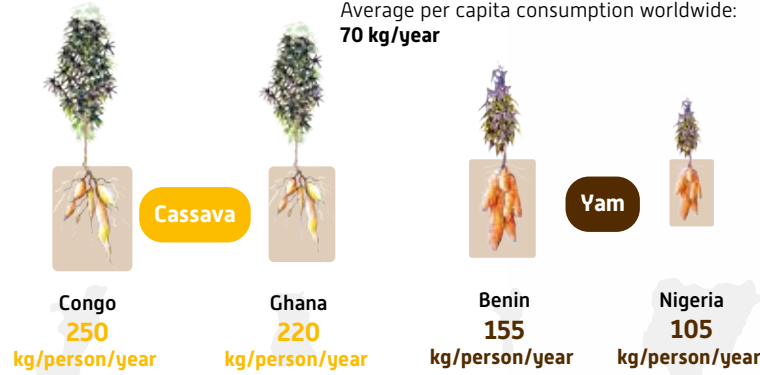
[Source: FAO, 2021]]



Foods that are vital for certain countries [Source: FAO, 2021]

3 billion RT consumers in developing countries

Average per capita consumption worldwide: 70 kg/year



Processing, a key stage

Focus on cassava, a source of human food for local and regional markets and a source of starch and flour for industrial use abroad.

With 20 to 45% dry matter, RTs are highly perishable and require processing, for different uses depending on the continent



Our ambitions ...



Foster root and tuber varietal diversity



Make roots and tubers more productive, through agroecology



Contribute to root and tuber market development



Build skills and back support policies

... in partnership

1 platform in partnership for research and training (dP): BIOCONTRÔLE-OI

CIRAD is a member of several international networks, including:



Our means and resources

37 scientists in 4 research units

5 disciplines involved, from genetics to science of processes

143 publications in peer-reviewed international journals between 2015 and 2022

400 RT accessions (primarily yam) in the BRCs in the West Indies and Réunion

Partnerships, the core of CIRAD's research

CIRAD works with teams on all five continents, and has scientists assigned to national and international research structures worldwide. Those collaborations are initiated from its laboratories in Montpellier and the French overseas regions. This research in partnership is often conducted under the umbrella of joint projects funded by international donors. CIRAD also receives researchers from the

global South within its research structures, for post-doc training or on sabbatical. It works with numerous other French research organizations (IRD, CNRS, Montpellier SupAgro), and universities. In the West Indies, CIRAD works with INRAE, notably on yam, and with the Biological Resource Centre, which holds precious *in vitro* genetic resource collections. ■

A word from our partners



Interview with Jonathan Newby, agricultural and rural development economist, Cassava Programme Leader, Alliance of Bioversity International and CIAT*

What is the history of the partnership between CIRAD and CGIAR on roots and tubers?

The partnership between CIAT and CIRAD has mainly been concerned with cassava and began in the mid-1980s with staff hosted in Colombia and joint activities in Latin America, Asia and Africa. Research on cassava at CIAT has always been demand driven, which has been a key part of the partnerships with CIRAD. While on the production side we have always focused on smallholder farmers, more than ever we need to ensure our products are meeting consumer preferences, emerging industrial requirements and demand from a dynamic food sector. While cassava remains an important food security crop, it is no longer just a poor farmers' subsistence crop. In this context the partnership between CIRAD and CIAT has been a long-lasting and evolving relationship based on complementarities in our skills and geographical presence. It remains demand- and impact-oriented.

What do the CIRAD roadmap and the CGIAR vision on roots and tubers have in common?

The cassava programme at the Alliance is a multidisciplinary team drawing on expertise in six main areas, working to improve the livelihoods of cassava producers by boosting productivity and sustainability. This roughly corresponds to CIRAD's ambitions. For us the work with CIRAD has mainly been around the integration of postharvest and consumer research. I was happy to see that CIRAD is also interested in those broader systems aspects for which we think multidisciplinary teams need to come together. CIRAD also helps us enhance our relevance in West Africa, where CIAT does not really have a strong presence on the ground.

In terms of One CGIAR, CIRAD's ambition 1 centres on genetic innovation initiatives. Ambition 2 relates to the "resilient agrifood systems" initiative. Ambition 3 brings a lot to the partnership, as CGIAR really hasn't focused on postharvest and processing. It is essential to continue to engage with CIRAD on the complementarity of both our research and the geographies in which we work. Ambition 4 is critical in terms of building skills within national programmes. Students from the global South can study in France and French students can learn what is happening on the ground. We hope to continue to host CIRAD staff as part of our teams.

The challenge is how to integrate the four ambitions into a single roadmap, to ensure impact. This calls for expertise embedded in institutions in target countries. I think that's an area where we can look for further collaboration. ■

* CIAT became the Alliance of Bioversity International and CIAT in 2019.



Interview with Bolanle Otegbayo,
PhD in food technology
from the University
of Ibadan, Vice-Provost
of the College of
Postgraduate Studies,
Bowen University, Nigeria

What is the history of the partnership between CIRAD and Bowen University on roots and tubers?

Bowen University's relationship with CIRAD started in 2011, when I was an AWARD programme post-doctoral fellow (African Women in Agriculture for Development, financed by Agropolis Foundation). I spent three months at CIRAD in Montpellier working on "Functional characterization of yam starch for industrial potential". It was an interesting time, as it improved my scientific skills, allowed me to network and enabled me to access equipment that I did not have access to in Nigeria. Then, in 2015, I was given a Bill and Melinda Gates Foundation grant. In 2017, I was invited as yam expert to a meeting organized by the BMGF in order to draft a new project on RTs. The RTBfoods project was born there. This strengthened the part-

nership between CIRAD and Bowen University as I was the focal point for the University.

What do the CIRAD roadmap and the Bowen University vision on RTs have in common?

Bowen University's first priority for its yam project is to enhance the production of value-added products for a rapidly increasing Nigerian urban population (ambition 3). Our second priority is to increase yam productivity in such a way to meet consumer demand, through agroecological processes (ambition 2). Under ambition 2, CIRAD also intends to "reduce labour intensity". I am very excited by the idea, as indeed, yam producers are the most important people in the value chain, and producing yam must be a profitable venture. However, farmers often make little profit in relation to labour input. Increasing yam productivity while reducing labour intensity will therefore go a long way towards enhancing farmers' livelihoods. Our third priority is the identifying the determinants of food quality. In addition, Bowen University also wants to work on the diversity of yam species because in Nigeria most people value *Dioscorea rotundata*. However, as researchers, we want to also work on other species that have industrial potential (ambition 1). Lastly, Bowen University is constantly involved in skill building and institutional strengthening, through training, collaborations, exchange programmes etc (ambition 4). The CIRAD roadmap's ambitions point in the same direction as ours at Bowen University, and I find this very exciting. ■



Interview with Harry Archimede,
Director of Research,
INRAE

What is the history of the partnership between CIRAD and INRAE on roots and tubers?

The partnership between CIRAD and INRAE is a very concrete one. In the French West Indies/French Guiana, we have the Tropical Plants Biological Resource Centre (CRB-PT), with a large number of resources, particularly for yam. This is a tool for conducting joint research, a source of international collaborations and a way of conserving biodiversity. We also have joint projects, particularly within the framework of the RITA networks (yam pathogen resistance capacity). Under the umbrella of the ERDF, INRAE and CIRAD have worked on food crop production, combining agronomy, economic sciences and social science. Over the past decade, our partnership on roots and tubers has expanded.

What do the CIRAD roadmap and the INRAE vision on RTs have in common?

Ambition 1, to foster agrobiodiversity, is vital. Without diversity, we'll be unable to cope with global change. In the West Indies, we have particularly diverse systems with significant genotype-environment interactions. Ambition 2, agroecology, is the guiding thread for all INRAE's operations. It represents the future, although we are not yet in the transitional phase and agrochemicals are still omnipresent. The aim is to give stakeholders the tools to make the agroecological transition. Ambition 3, on the other hand, is not a major line of work for us, although it is part of our activities. The geographical area we cover is only small, and agricultural transformation on this scale means looking at the volume of resources and how to build win-win relationships between producers and processors. Lastly, as far as ambition 4 is concerned, INRAE has a specific scientific department devoted to public policy support. This is therefore a very important aspect for us. We cannot build new systems with the same rules as for the intensive farming of yesteryear. It is vital that we interact on this level too, to make sure that the legislation keeps in step with agroecology. ■



CIRAD is the French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions.

CIRAD works with its partners to build knowledge and solutions and invent resilient farming systems for a more sustainable, inclusive world. It mobilizes science, innovation and training in order to achieve the sustainable development goals. Its expertise supports the entire range of stakeholders, from producers to public policymakers, to foster biodiversity protection, agroecological transitions, food system sustainability, plant, animal and ecosystem health, and sustainable development of rural territories and their resilience to climate change.

CIRAD is a public establishment (EPIC) under the joint authority of the Ministry of Higher Education and Research and the Ministry for Europe and Foreign Affairs.

CIRAD hopes that multi-stakeholder partnerships and alliances will discuss, share and support its four ambitions for sustainable root and tuber growing.

Contact us to find out more: roots@cirad.fr

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CIRAD is a founding member of:

