Cassava Technology Toolkit Catalogue

TAAT Clearinghouse

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Front cover photographic credit: Inspection for disease in improved cassava varieties being grown for cuttings (left), and cassava plantlets cloned using the Semi Autotrophic Hydroponics technique (right). Photo credits: IITA Stock Pictures and KilimOrgano.

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A Report by the Technologies for African Agricultural Transformation Clearinghouse, March 2021

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Purpose and Introduction

This catalogue describes a suite of technologies related to the modernization of cassava production in Africa. It is based upon the combined efforts of the Project Platform for Agricultural Solutions (ProPAS), an information internet site, and the Technologies for African Agricultural Transformation, a large collaborative program that is deploying agricultural solutions across the continent. Both of these activities are based upon the imperative to better connect proven technologies to those who need them but each undertakes this goal in a very different manner. Cassava is one of TAAT’s priority commodities because of its huge importance to food and nutritional security, and rural development in general across Africa. It is also targeted as an agro-industrial crop for processing and trade within world markets. In the course of its compilation, ProPAS has accumulated several technologies that specifically address this commodity and we have compiled them into a “technology toolkit” designed to advance understanding and encourage adoption and investment into the proven agricultural solutions that advance this crop. This is the second of several catalogues that we intend to produce as a joint ProPAS-TAAT activity.

About ProPAS. The Product Platform for Agricultural Solutions (ProPAS) provides a mechanism to compile and access innovations, management technologies and products needed for Africa’s agricultural transformation. The platform provides two pathways: it permits users to enter their proven and promising solutions into a database, and then encourages others to sort through its options to reveal the suite of opportunities that can assist their agricultural objectives. ProPAS results from the recognized need by the International Institute of Tropical Agriculture (IITA) to more systematically compile and access the full range of agricultural solutions available to modernize and transform African agriculture. Its overall goal is to accelerate the process of agricultural transformation in Africa. Many solutions are available to improve and modernize Africa's food systems but those who benefit from them most are often unaware of the best options at hand. In addition, more solutions are in the research and development pipeline that are best advanced through wider exposure and validation. Solution profiles are compiled and released in a systematic manner that involves submission by technology holders, entry into a user-friendly software platform, and use by an expanding base of clients. A small committee of agricultural experts oversees this process, but recognizes that its strength is through open-ended access to a marketplace of solutions. ProPAS is therefore managed through a three-phase process that involves solution submission, database management, and client access. The database allows for solutions to be identified through selection of several search fields related to the form, type, commodity application and target beneficiaries of a given solution, sequentially narrowing the number of platform recommendations.

About TAAT. The Technologies for African Agricultural Transformation (TAAT) is a program led by the International Institute of Tropical Agriculture (IITA) that has pioneered new approaches to the deployment of proven technologies to African farmers. TAAT arose as a common effort of IITA and the African Development Bank (AfDB); and is an important component of the latter's Feed Africa Strategy. TAAT is currently advancing 76 carefully-selected technologies through 88 interventions in 28 countries. It is organized around 15 "Compacts" that represent priorities in terms of achieving Africa's potential in achieving food security and advancing its role in global agricultural trade. Nine of these Compacts relate to specific priority value chains of rice, wheat, maize, sorghum and millet, cassava, sweet potato, bean, fish, and small livestock. Weaknesses in the production of commodities are viewed as responsible for Africa's food insecurity, need for excessive importation of food, and unrealized expansion of Africa's food exports. Together these Compacts design interventions in collaboration with national programs to introduce technologies and management innovations that are designed to meet targets for agricultural development. In many cases, these targets are addressed through the implementation of projects resulting from sovereign country loans awarded by development banks, and TAAT's role in the planning and execution of these loan projects is becoming a vital element of their success.

The TAAT Top 100 Technologies. The Clearinghouse developed a database of the Top 100 Technologies that are transforming African agriculture. It is based upon the approaches of the TAAT Commodity Compacts but also includes those from the CGIAR Collaborative Research Programs that are recently described as ready for next user. These technologies are divided between those involving improved genetics and plant and animal breeding (23%), those based upon the distribution of digital information (3%), production input products of proven efficacy (21%), crop and animal management technologies of utility within agricultural extension messaging and campaigns (27%) and the availability of appropriately designed labour-saving equipment (26%). These technologies have a direct role towards the achievement of the Sustainable Development Goals in relationship to farm productivity, food security and hunger reduction, improved household nutrition and diets, economic growth, climate-smart innovation and improved human equity. These technologies form the basis for selecting entries into ProPAS, including those advancing cassava.

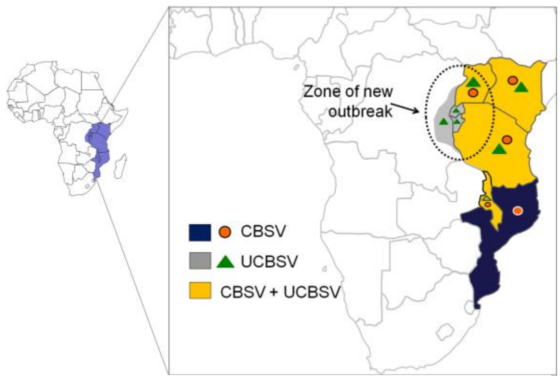
The Top 12 Cassava Technologies. This catalogue presents eleven technologies that serve to modernize production and processing of cassava in Africa. These technologies include: 1) cultivation of disease resistant cassava varieties where needed, 2) golden cassava varieties as more nutritious alternative to common white-fleshed types, 3) high dry matter and starch content varieties for greater economic value and industrial processing, 4) seed-bulking farms for improved supply of planting materials, 5) semi-autotrophic hydroponics for rapid clonal multiplication of elite cassava varieties, 6) use of specially blended fertilizers that are better adjusted to nutrient demand by root and tuber crops, 7) mechanized planting and harvesting for labour savings, 8) stepwise practices to best weed management, 9) manufacturing of high quality flour and industrial starches, 10) processing cassava peels into a source of nutritious livestock feed, 11) mobile processing units for improved value augmentation, and 12) a digital business connector application for value chain coordination. Details on each of these twelve technologies follow.

Technology 1. Resistant Cassava Varieties for Mosaic and Brown-Streak Virus

Summary. Production of cassava by farmers in Sub-Saharan Africa is widely limited by pernicious viruses such as cassava mosaic disease, cassava brown streak disease and several more that cause damage to leaves and thereby reduce photosynthesis, which leads to yield losses and possibly complete crop failure. The most common measures to protect this food crop against infection by pathogens include the removal of symptomatic plants and use of virus-free planting materials but these options are labour intensive, not completely effective and require continuous and long-term interventions. Cassava varieties have been developed and released in African countries that are resistant to major diseases and bring down infection rates and yield losses in stands, as well as prevent rapid spread across growing areas. Use of cultivars that possess genetic defence mechanisms is a viable and efficient avenue to combat viral infections of cassava crops, particularly because farmers tend to favour vigorous and/or symptomless plants when selecting cuttings for new plantings. For more information contact Dr. Edward Kanju of IITA by email at e.kanju@cgiar.org.

Technical Description. It is estimated that farmers in African countries are losing 20% to 95% of cassava yields because of disease, and continent-wide this amounts to 12-23 million ton of fresh roots per year, worth about US $1,200 million to US $2,300 million. Dispersal of cassava mosaic and brown streak viruses in Africa primarily occurs through whiteflies as vectors that feed on leaves, and also by reuse of infected cuttings as planting material in farms. Years of work by African breeding programs has identified several cassava land races that possess natural resistance to common viral diseases, a trait that is ascribed to multiple recessive genes. Transfer of the immune trait from wild types into improved cassava varieties through conventional crossing techniques has been successfully used for developing cultivars that withstand diseases and is relatively low in cost. Genetic markers for resistance to different viruses in African cassava varieties have recently been found which accelerate breeding efforts to obtain immunity against diseases for elite high-yielding types that are well-adapted for specific growing areas. Techniques through which gene expression in cassava plants is modified (e.g. RNA silencing) allow developing varieties that are resistant to common viruses, and they offer advantages over conventional breeding methods because the latter are confounded by the crop inbreeding depression and heterozygosity.

A Cassava Mosaic Disease susceptible variety (left) and resistant variety (right).



Distribution of viruses causing cassava brown streak disease (CBSD)

Uses. Cultivating varieties of cassava that withstand mosaic disease is of critical importance in all major growing areas in Sub-Saharan Africa because the virus has spread widely across the continent, and thus sweeping countermeasures are required to safeguard this staple crop. Brown streak disease resistant lines of cassava are necessary for farmers in regions of East-Africa and the eastern part of the Congo Basin where this virus causes extensive damage to root yield. Producers operating in areas that are plagued by high numbers of whiteflies that transmit the diseases have greatest need for these resistant varieties. Cultivating resistant lines is offering substantial benefits in terms of root yields and the production of virus-free cuttings, and these varieties are cultivated and harvested like any other cassava variety (e.g. following these catalogue guidelines).

Composition. More than 200 improved cassava varieties that are resistant to mosaic disease were released over the past two decades, and are multiplied by programs in 31 African countries for distribution to farmers. In the last five years, breeders have developed cassava varieties that withstand attacks by brown streak disease and were made available to national systems for deployment in heavily impacted regions. There are also a number of elite lines with dual resistance to cassava mosaic and brown streak diseases. Breeding for this resistance was also combined with traits related to high-yields and consumer preference. Many of the varieties that are resistant to cassava mosaic disease or brown streak disease also withstand other major cassava pathogens like bacterial blight, anthracnose, cassava green mite, and cassava mealybug, offering a major advantage for integrated crop health management by farmers. Ongoing programs are making continual efforts to further identify and engineer cassava varieties that withstand common diseases and fulfil agronomic needs.

Application. Disease resistant varieties are multiplied and cultivated in the same way as any other cassava crop, in which cuttings taken from one stand are reused to plant another field. Caution has to be exercised by farmers that planting materials are free of disease symptoms when transfers are made between fields and farms in order to effectively restrict infections and associated yield losses. Planting disease resistant varieties on boundaries of farmer fields or the rows oriented to the dominant wind direction has shown to limit infections of susceptible varieties in the middle. Different modes for planting have to be employed depending on rainfall conditions, cuttings are best placed horizontally and covered entirely with soil in areas with a dry climate, and can be planted vertical or angular in more humid areas. Recommended soil and fertilizer management for particular growing areas and conditions have to be followed to achieve highest root yields. Limitations in the availability of nutrients and water, soil compaction and weed encroachment must be overcome to ensure the full advantage of disease resistant cassava varieties.

(a) Horizontal (b) Vertical (c) Slanting position

Commercialization. These varieties are commercially available in many countries, including from national authorities.

Start-up Requirements. Communities can work together to switch to disease-resistant varieties by: 1) Awareness-raising with multipliers, farmers and food processors about the benefits of disease resistant cassava varieties, 2) Identifying and acquiring elite immune lines that are adapted to conditions and needs in growing areas, and 3) Stakeholder capacity building on propagation of healthy planting material through local delivery hubs.

Production Cost. The purchase price for cuttings or seed of disease resistant cassava varieties is similar to common improved cultivars that are susceptible because the costs of propagation are identical. On local markets in Sub-Saharan Africa, the planting materials of elite cassava varieties that withstand mosaic and brown streak viruses typically range between US $30 to 35 per hectare. The switch from non-improved disease susceptible cassava varieties to those that are resistant requires investments by farmers, so it is important that they understand the resulting benefits.

Customer Segmentation. All cassava producers can benefit from this technology, especially those in disease infested areas including subsistence and commercial cassava producers, and those involved in community-based actions.

Potential Profitability. Studies conducted in the Democratic Republic of Congo and Cameroon demonstrated that incidences of cassava mosaic disease in stands with resistant varieties amounts to only 15-20% compared to nearly 100% incidence for susceptible local varieties. Farm-level root yields in south-western Nigeria were found to measure 40% higher for cassava that withstand mosaic virus infections than for local varieties without resistance, resulting tuber yields of 19 ton per hectare instead of 13 ton/ha. The greater economic yields obtained by cultivating disease resistant cassava are paying back required investments and generate a greater profit for farmers. Elite cassava lines that are resistant to diseases also have a short growth cycle, reaching peak yields in 12 to 15 months, whereas for non-improved susceptible varieties this can take 20 to 24 months. Use of disease resistant varieties therefore mitigates risks of yield losses and crop failure during periods of prolonged drought, which enhances food security and returns on investment.

Licensing Requirements. There is need for certification to multiply and sell cuttings from disease resistant cassava varieties, and requirements vary between countries. Disease resistant cassava varieties are considered a Regional Public Good, and the International Institute of Tropical Agriculture assumes responsibility for breeding and distribution of this commodity through national sector programs.

Technology 2. Golden-Fleshed Cassava with Higher Vitamin A Content

Summary. Millions of people in Sub-Saharan Africa rely on cassava as their main staple yet the varieties they grow contain low levels of vitamins and minerals. This shortcoming contributes to poor nutrition and hidden hunger; with 50% of children between one-half to five years old suffering from vitamin A deficiency according to World Health Organization. Insufficient intake of vitamin A is the leading cause of preventable blindness in children, and it compromises the immune system, increasing the risk of diseases including measles, diarrhoea and respiratory infection. Conventional and advanced breeding approaches resulted in the increase of pro-vitamin A content in cassava that offer a viable avenue to substantially improve nutrition within rural communities. Roots of so-called golden or yellow-fleshed cassava are rich in a beta-carotenoid that give its characteristic colour, and after ingestion these compounds are converted into vitamin A by enzymes in the body, resulting in more balanced nutrition among consumers. A range of golden cassava varieties are now available and entering markets across Sub-Saharan Africa, and through close collaboration between seed companies, farmers, policy makers and researchers, this important nutritional characteristic is becoming successfully scaled within major cassava production areas. For more information contact Dr. Elizabeth Parkes of IITA by email at e.parkes@cgiar.org.

Technical Description. Elite golden cassava varieties were developed by crossing naturally occurring lines containing elevated pro-vitamin A content with elite land races and hybrid lines possessing higher yield potentials and improved agronomic traits such as disease resistance and drought tolerance. This approach resulted in new biofortified varieties. Next, breeding techniques assisted by genetic markers enabled rapid development of golden cassava varieties that contain three times as much pro-vitamin A than this parent material, allowing consumers to meet a large part of their nutritional requirements for vitamin A through consumption of cassava. Further selection was applied to silence the activity of enzymes that result in the breakdown of pro-vitamin A, resulting in a tremendous nutritional breakthrough. More recently, outreach programs extending golden cassava to rural households in some Sub-Saharan African countries were shown to be highly effective in reducing vitamin A deficiency and related health issues in children and adults. At the same time, the multiplication of golden cassava is proving to be an enterprise in itself as demand for these elite varieties grows.

Biofortified 'yellow fleshed' cassava (top) and common white fleshed type (bottom).

Uses. Golden cassava varieties are highly suitable and cost-effective for tackling malnutrition in rural communities that rely on this crop as a staple food. Lines of pro-vitamin A bio-fortified cassava are now available for a wide range of growing areas in Sub-Saharan Africa, and can be adapted to the conditions within a wide range of production systems and agro-ecologies. Studies on public acceptance show that consumers do not object to the colour and enjoy the sweet flavour of pro-vitamin A enriched cassava. There is a range of open pollinating lines of golden cassava that can be multiplied by community and private enterprises that enable rapid scaling and commercialization in growing areas. Hybrid types of pro-vitamin A enriched cassava typically possess other improved traits that make them highly appropriate for farming systems where production is limited by diverse challenges, but are somewhat more expensive to propagate and retain their virus-free status. Different varieties are suitable for major production zones in African countries and achieve similar yields as conventional improved lines under a range of soil and weather conditions. In Nigeria, Togo, and Benin several lines of vitamin A fortified cassava have been successfully released to hundreds of thousands of farmers.

Composition. Golden cassava varieties containing six to 15 micro-grams of beta-carotene per gram are now available. This trait gives the root interiors a yellow colour, with highest concentrations appearing golden. In this way, it is simple to determine if a cassava variety has this important trait. Taste panel testing which compared cassava flour from white and golden varieties have shown that the latter biofortified type is preferred because it adds to the appetites of consumers. The beta-carotene in golden cassava is preserved during storage and processing, unlike common varieties in which most of the pro-vitamin A is oxidized and results in off-flavours, thereby increasing the value in terms of nutritional value and sales.

Application. Yellow-fleshed cassava varieties are multiplied and cultivated in the same way as any other cassava variety, in that cuttings taken from one stand are reused to plant another field. Caution has to be exercised by farmers that planting materials are free of disease symptoms when transfers are made between fields and farms in order to control infections and associated yield losses. Different modes for planting can be employed depending on rainfall conditions, cuttings are best placed horizontally and covered entirely with soil in areas with a dry climate, and can be planted vertical or angular in humid areas with high precipitation. Recommended soil and fertilizer management described elsewhere in this catalogue should be followed to achieve high root yields. Limitations in the availability of nutrients and water, soil compaction and weed encroachment have to be addressed for making sure that the use of disease resistant cassava varieties increases production levels. Because of their high nutritional value, roots from golden cassava varieties are perfectly suited for manufacturing of flour or processed foods, such as bread or crisps, which can be retailed on local and international markets although in most cases these applications have not yet been achieved.

Commercialization. These golden varieties are becoming commercially available but access to them is often best achieved through national programs.

Start-up Requirements. In most cases, entering into golden cassava production simply requires that new varieties be substituted by producers for existing ones. In terms of scaling this innovation there are several steps: 1) Promote the benefits and availability of golden cassava within cassava production areas, particularly those where vitamin A deficiency occurs, 2) Community-based and commercial suppliers of cuttings and plantlets should be provided with the best available golden varieties as a product line and recognize the importance of maintaining disease-free stocks, 3) Cassava producers must be linked to buyers and food processors to create market opportunity, and consumer and nutrition groups should assist in creating further demand, and 4) Financial incentives that support local suppliers of golden cassava varieties should be devised that include extending purchase opportunity to cassava producers, allowing them to incorporate these biofortified varieties into their production systems.

Production Cost. Development of golden cassava varieties initially involved advanced breeding techniques in the laboratory and greenhouse, and extensive testing in the field that required significant investment from the public sector and donors, but this cost should not be passed to commercial applications because the resulting elite varieties are considered Regional Public Goods. Providing these varieties from the public sector technology holders to commercial interests and farmers is largely conducted on a cost recovery basis. The costs associated with producing lines with high carotene levels are not substantially different from more common improved cassava varieties, and the costs of plantlets and cuttings are similar. At the same time, producers must recognize that golden cassava is not a stand-alone technology and they must co-invest in fertilizer inputs and other recommended crop management and post-harvest practices in order for golden cassava to result in effective and sustainable increases of nutrition and income.

Customer Segmentation. Cassava has a highly segmented customer base including small-scale and commercial producers, suppliers of planting materials, and food processors but the biofortication aspect of golden cassava serves to refocus its use among poorer and nutritionally vulnerable households.

Potential Profitability. The sales price for golden cassava roots on markets in Sub-Saharan Africa is up to 20% higher than that of white non-biofortified types. Cultivating pro-vitamin A enriched cassava thus offers a substantial economic advantage over similar yielding varieties and non-improved types, an advantage that makes it attractive to both small-scale farmers and larger commercial interests. Other useful traits that have been incorporated into pro-vitamin A rich varieties include shorter production cycles, and resistance to drought and pests serve to reduce risks of crop failure and lead to larger and more stable incomes. The higher nutritional value of golden cassava varieties make it more feasible to blend it with more expensive cereal products, that in turn reduces costs for manufacturers and improves profit margins.

Licensing Requirements. Hybrid varieties of golden cassava are marketed under a commercial license, while open pollinated varieties are royalty-free for multiplication and sales by farmers, but certification is often required following national compliance with seed system requirements. Golden cassava varieties represent a very important Regional Public Good and the International Institute of Tropical Agriculture shares responsibility for promoting it through national programs and within the larger agricultural transformation process.

Technology 3. Higher Dry Matter and Starch Contents in Cassava

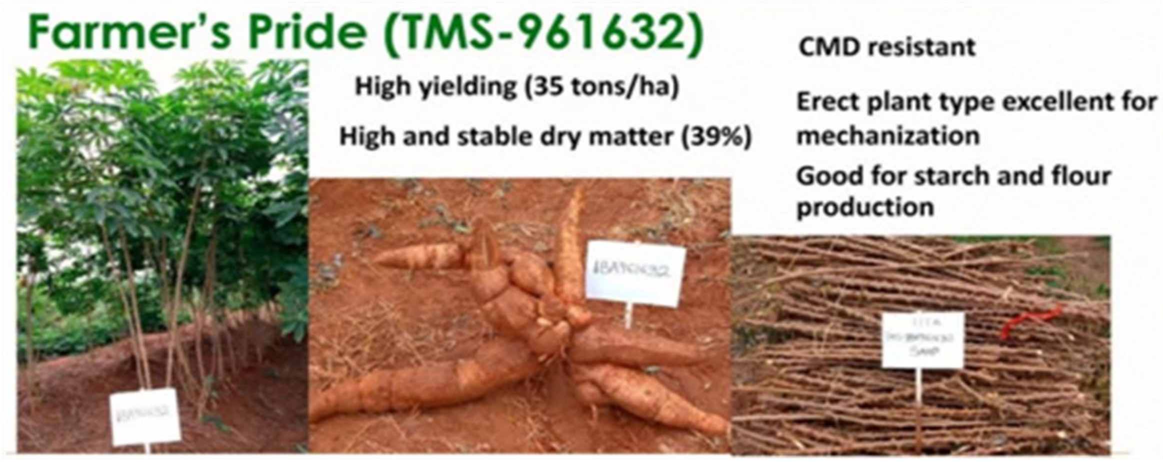
Summary. The amount of dry matter and starch in cassava roots greatly influences their value in terms of agro-processing options including the manufacturing of flour, starch, chips or industrial materials. Cassava crops in Sub-Saharan Africa are associated with a low degree of root filling that in turn affects the accumulation of dry matter and starch, but varieties are now available to reverse this trend. Improvements of root quality represent a major growth market for African cassava in the near future, benefiting food security among rural communities depending upon this crop and as well as accelerated growth of cassava cottage and food processing industries. In this way, breeding cassava for higher dry matter and starch content is important to improve the supply for local and regional markets, and a number of varieties have been developed for African farming systems. The improved quality of harvested cassava roots allows producers to receive greater return from their crop on the same area of land, and thus more food or income. For more information on this topic contact Dr. Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. The bulking of dry matter within cassava roots occurs through accumulation of starch during the latter stages of the crop's growth cycle, and the large degree of root bulking differs between varieties and growing conditions. The total amount of carbohydrates in roots of common African cassava varieties ranges from 20% to 31% of fresh yields, and starch makes up 64% to 72% of the total carbohydrates, and these proportions are considerably improved in these varieties. Breeders have substantially improved the quality of cassava roots by combining traits of cassava varieties with superior root filling characteristics with lines that are resistant to major pests and diseases. These roots with improved quality are suited for fresh consumption as well as processing into flour or starch used as thickener for foods, binders in pharmaceutical products, packaging materials and other industrial goods.

Uses. Cassava varieties with high dry matter and starch content offer a viable technology to enhance the root yields and qualities in all major growing areas of Sub-Saharan Africa because common varieties that are cultivated by millions of farmers achieve modest to poor root bulking. Varieties with improved root quality are available that possess a high degree of resistance to drought and pests, and adaptations to other adverse growing conditions or production objectives; and combinations of traits can be tailored to suit the needs in a specific area. Cassava roots with high dry matter and starch content are useful in subsistence farming systems for enhancing food security and incomes, and commercial agri-businesses as source of low-cost flour and starch for various manufacturing processes. An example of these characteristics is found in the variety Farmer's Pride.

Composition. Cassava varieties are now available that have root dry matter contents of 40% to 45% and starch contents of 80% to 95% (of total carbohydrates); a considerable improvement over conventional varieties. Several of these varieties have been released across Sub-Saharan Africa that also possess necessary agronomic and nutritional traits. These varieties include TMS-961632 (Famers' Pride), TME419 and CR36-5 (Ayaya). There is a medium to high level of heritability for root dry matter content when crossing varieties, enabling further improvement of root quality through localized, conventional breeding.

Application. The multiplication and cultivation of cassava varieties with high dry matter and starch occurs in the same ways as other cassava crops, where cuttings taken from one stand and used to plant another field or farm. Caution must be exercised by farmers that planting materials are free of diseases when these transfers are made between fields. Different types for cutting positions are employed depending on rainfall conditions; cuttings are best placed horizontally and covered entirely with soil in drier areas, but are best positioned vertically or diagonally in more humid conditions. Recommended soil and fertilizer management for a particular growing area should be followed to achieve maximum root yields. Limitations in the availability of nutrients and water, soil compaction and weed encroachment have to be addressed to ensure that the use of these higher dry matter varieties actually increase production levels.



Commercialization. These varieties are becoming commercially available, most often in conjunction with national programs.

Start-up Requirements. In most cases, adopting higher dry matter varieties simply requires that new varieties be substituted by producers for existing ones. In terms of scaling this innovation there are several steps: 1) Identify well adapted cassava varieties with high dry matter and starch content that align with conditions and contexts in the value chain and communicate their advantages to producers, 2) Community-based and commercial suppliers of cuttings and plantlets should be provided with the best available higher dry matter and starch varieties as a product line and recognize the importance of maintaining disease-free stocks, 3) Establish linkages between those cutting suppliers, cassava growers, food processors and consumer groups to create greater demand for cassava-based starch products, and 4) Provide financial incentives to local suppliers and smallholder farmers to stimulate investment and purchases of cassava with improved starch quality.

Production Cost. Cassava breeding for high dry matter and starch content in roots through conventional crossing is a lengthy process that starts in the lab and screen house, and is following by extensive testing of in the field. The costs associated with developing lines of cassava with improved root quality are not substantially different from a common hybrid variety, causing prices for planting materials to be similar. When cultivating cassava crops for high dry matter and starch content farmers must also invest in fertilizer inputs, and crop and soil management practices in order to achieve the desired root quality and yields in a profitable manner.

Customer Segmentation. While cassava stakeholders are highly segmented, increased dry matter and starch varieties appeal most to commercial cassava producers and their food processing buyers.

Potential Profitability. Cultivating varieties with improved root quality offers various financial benefits for farmers and food processors. The high dry matter contents of cassava roots increases the amount of dried roots that are harvested from an area of land, which reduces the land under cultivation and labour requirements for a similar yield. The high starch content in root dry matter translates into a better nutritional value and selling price of dried roots, which improves diets and income of subsistence farmers. Cassava varieties with high dry matter and carbohydrate contents are suited for replacing starch and glucose sources from wheat, barley, maize and rice that are more expensive which reduces costs of raw material supply for food and industrial manufacturers.

Licensing Requirements. Most cassava varieties with high dry matter and starch content that are released in Sub-Saharan Africa are royalty-free for multiplication and sales by farmers but may require certification following national guidelines. Hybrid cassava varieties with improved root quality are sometimes marketed under commercial license. High dry matter and starch content varieties of cassava are an important Regional Public Good, and the International Institute of Tropical Agriculture assists in the distribution of this material through national programs.

Technology 4. Stem Bulking Enterprise for Reliable Supply of Improved Cassava Planting Materials

Summary. Cuttings from cassava stems are the most commonly used planting material by African farmers because this kind of propagule can be gathered from previous crops, it sprouts quickly and reliably, and allows ever-increasing areas of land to be cultivated. Distribution of cassava stem cuttings to growers may prove difficult because these materials can lose vigour when stored, and their sheer volume and weight drive up costs when transported over longer distances. These factors limiting the supplies of improved, disease-resistant cassava planting material across major growing regions, especially among communities in more remote rural areas. Smallholder farmers living in expansive agricultural landscapes of Africa can get much better access to high-quality cassava stem cuttings through seed-bulking farms that are scattered across their communities. This approach allows multiplication of planting materials in closer proximity to the fields where the crop is cultivated, thereby reducing costs of production and transport, and avoiding over-reliance on more distant companies and institutions with limited geographical coverage. Decentralized networks of seed-bulking farms can greatly accelerate the dissemination of improved cassava varieties described elsewhere in this catalogue and make planting materials available to farmers that are free of pests and diseases. Multiplication of cassava cuttings offers opportunities for community-based enterprise development in a win-win manner. For more information on this topic contact Dr. Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Cassava seed-bulking involves multiplication of stem cuttings under well managed conditions in order to obtain true-to-type planting material that is free from pest and disease. Seed-bulking farms allows producers to obtain hardened planting materials closer to the fields, and are particularly effective for accelerating the distribution and then maintaining improved varieties, and controlling pest and disease infestations. The improvement in availability, access and quality of stem cuttings can be realized by decentralizing its production and make it possible to distribute large amounts of cuttings over a short period of time prior to the beginning of a growing seasons. Reductions of transport distances achieved by positioning cassava seed-bulking farms in remote rural communities is hugely benefiting the survival rates of planting materials and crop health throughout its growth, which gives rise to higher yields and resilience of cassava as a food crop and production enterprise.

Example of seed (cutting) bulking of an elite cassava variety in close proximity to production areas.

Uses. Seed-bulking activities for cassava as a means to supply quality planting materials in a timely manner is suitable for all major growing areas in Africa because it can be implemented with simple facilities and limited capital investments. Individual farmers, community-based organizations and business enterprises can establish these fields in close proximity to the fields where farmers cultivate the crop and bring early generation planting materials within reach of remote rural communities that rely on cassava for food and income

Composition. This technology may rely upon certified cuttings from other producers as well as cloned plantlets that are otherwise unavailable to most members of the rural community, thus providing them with more ready access to recently-released varieties described elsewhere in this catalogue. This includes hybrid varieties developed through advanced breeding techniques.

High-yielding, disease-resistant and bio-fortified lines of cassava are the most appropriate for seed-bulking farms because distributing such kind of planting materials creates large impacts on productivity and incomes along the food value chain, and often links to national rural development projects.

Application. To initiate a cassava seed-bulking enterprise, a relatively small number of the certified cuttings or plantlets must be obtained from improved varieties that are suitable for specific growing conditions and that meet preferences of buyers and consumers. Cassava seed-bulking should be done in fields that are fertile and away from crop stands that are heavily infested by diseases and pests in order to promote multiplication and seed quality. Access to irrigation is an advantage as it permits off-season production prior to rain-fed growing seasons. In places where this is not possible the use of specialty blended fertilizers and chemical control agents is required for producing high quality planting materials. Seed-bulking enterprises should be remain free of weeds that may harbour pests and disease. Advanced technologies such as drip irrigation and mechanized tools can shorten harvesting cycles and reduce labor costs. Under optimal crop and soil management, it is possible to multiply cassava cuttings in only six to 10 months' time. Seed-bulking enterprises must be located within communities and proportioned according to the size of the cultivation area. Access to transportation is also an advantage, allowing for sales of cutting to farmers and through agro-dealers within a radius of 20 km or so.

Commercialization. Enterprises devoted to localized distribution of cuttings from improved cassava represent a viable commercial opportunity and may benefit from advisory support by agricultural extension.

Start-up Requirements. Bulking and sales of improved cassava varieties as cuttings can be considered an enterprise separate from field production of roots. Steps in this process include: 1) Identify suitable cassava varieties for local farming conditions, and access their cuttings or plantlets six to 10 months prior to the main growing season, 2) Select production areas based on favourable field conditions and access to customers, announce the pending availability of cuttings to agrodealers, extension agents and other marketing intermediaries, 3) Optimize production of these stems according to recommended cassava practices and maintain these fields under sanitary conditions, and 4) Harvest, cure and bundle cuttings immediately before the normal planting season, with care taken to identify top from bottom, and supply these bundles through pre-arranged market outlets.

Production Cost. Multiplying planting materials of improved cassava varieties through seed-bulking farms is associated with slightly higher costs than the traditional use of cuttings from previous crop phases because it requires to land and inputs for producing high quality seed. The main investments to produce cassava planting materials are the purchase of seed tubers or cuttings from elite cassava varieties, and the labour for establishing, maintaining and harvesting farmer fields where multiplication takes place.

Customer Segmentation. Suppliers of improved cassava planting materials occupy a unique position along cassava value chains, and may operate as either commercial or community-based interests. To maintain a competitive advantage, it is an advantage that they maintain close contacts with national agencies that evaluate and clear new varietal materials, and those who sponsor their registration.

Potential Profitability. Improving the access of African farmers to clean planting materials for elite cassava varieties through seed-bulking enterprise close to the fields and farms where the crop is grown is a viable opportunity. In general, each cutting may be produced and marketed for as little as US $0.02 each, and sold for up to US $0.04 each, and up to 24 cuttings may be produced on 1 m^2 over six to ten months, resulting in revenues of US $4,800/ha. Another factor in favour of profitable operations is that cassava grown for cuttings is planted at higher densities than those for roots, allowing for greater cutting yields and more favourable seed to production area ratios. Also, after cutting, stems can re-grow and roots develop providing additional revenue streams. In this way, seed-bulking enterprises represent an important avenue for enterprise development and employment in rural communities.

Licensing Requirements. A certificate may be required to multiply and sell planting materials for cassava in some countries, but in others this service is unregulated. Those producing cuttings intended for sale must familiarize themselves with local regulations. In some cases, community-based operations remain unregulated while commercial ones are. This concept of cassava cutting enterprise development is offered as a public good, and further information on it is available from the International Institute of Tropical Agriculture.

Technology 5. Semi Autotrophic Hydroponics for Cassava Multiplication

Summary. In most areas of Sub-Saharan Africa, stem cuttings are used to establish cassava fields, a practice that is simple to understand and perform. The previous technology described in this catalogue describes how the production and supply of these cuttings may be established as a business enterprise or community-based activity. This process is, however, limited in terms of the rate at which new varieties may be multiplied because each plant produces a relatively low number of propagules over an extended period of time, so the speed at which new improved varieties can be released to large number of farmers requires years before sufficient volumes of planting materials can be produced. This process is also prone to contamination with pests and diseases. A solution to this constraint is found through accelerated initial propagation as plantlets through a technology known Semi Autotrophic Hydroponics. This approach resembles tissue culture, but is simplified and less expensive. It features high multiplication ratio and allows propagating true-to-type and pathogen-free plantlets. It is particularly effective during the early stages of new variety release by providing packages of plantlets to those who then raise them for stem cuttings and further distribution. For more information on this topic contact Elohor Mercy Diebiru-Ojo of IITA by email at e.diebiru-ojo@cgiar.org.

Technical Description Semi Autotrophic Hydroponic (SAH) systems for crop multiplication were first developed for potatoes but were later adapted for cassava. The SAH technique conducted in a laboratory and then a greenhouse, and involves turning small cuttings of plant roots into small plants (plantlets). First, small root cuttings are placed in clean media where they grow and differentiate into entire plants. Infrastructure requirements and costs of production for SAH are comparatively low, but the skill levels and initial investment are high, making this technology difficult to replicate at a small scale across farming communities. At the same time, this technology results in plantlets with well-developed shoots and roots ready to be transplanted that free of pests and diseases, unlike traditional cassava stem cuttings methods. A medium-scale SAH propagation facility for cassava was designed that permits the production of about 7 million plantlets per year, and includes simultaneous multiplication of several elite cassava varieties.

A tray of cassava plantlets produced by SAH multiplication ready for planting.

Process: In vitro → SAH Lab → Field

Uses. SAH technology is suitable for rapid dispersal of improved cassava varieties across Africa through its adoption within biotechnology and advanced seed companies. In this sense it requires limited additional capital investment but is likely too difficult for establishment by community-based organizations as is espoused by others. That the SAH technique results in disease-free and high-quality cassava planting materials that are readily transportable is a major advantage of this technology. Evidence suggests that planting materials produced using the SAH technique have a greater resistance to pathogens in the field than those obtained from stem cuttings, and thus presents a viable strategy for combating virus infestations. In addition, with the production of disease-free SAH plantlets, transfers of planting materials between countries becomes more feasible.

Composition. The requirements for SAH multiplication of cassava include basic growth chambers or sealed greenhouses with climate control systems. Shelves are installed to hold trays with a clean growth media made of combinations of peat, rock wool, vermiculite or perlite that provide anchorage and plant support, retain up plant nutrients and water, and allow air gas exchange between the roots and the atmosphere. A tray of ready to market product typically contains 12 to 48 plantlets that can be covered, stacked and packaged for transport.

Application. At the start of the SAH process, tissue cultured (in vitro) plantlets are produced under semi-hydroponic and semi-controlled environmental conditions, which are then cut into mother plants that are transferred into trays with growth media and placed in the growth chamber. After two to three weeks, these "mother plants" are divided making two plantlets from one, which are then placed into growing racks for 6-8 weeks to develop rooted plants. Trays can transported in perforated cardboard boxes for over 48 hours, after which these can directly be planted in open fields for production or into pots for the production of larger plants.

Commercialization. Materials and equipment necessary for the production of SAH plantlets are commercially available although many must be imported from elsewhere.

Scaled-up semi-autotrophic hydroponic production of cassava seedlings in screenhouses by GoSeed at the Business Incubation Platform from IITA.

Start-up Requirements. To start an SAH processing unit, the following steps are required: 1) Inform cassava multipliers about the benefits of the SAH plantlets as planting material, 2) Obtain in-vitro mother plants from improved cassava varieties that are free of pathogens, 3) Construct growth chamber or sealed green houses and install shelves and growth media for propagation, and 4) Organize marketing and delivery of SAH plantlets through existing suppliers within the cassava value chain including sales through local seed companies and agro-dealers.

Production Cost. A SAH facility with an area of 40 square meters, which can produce 75,000 SAH plantlets per month (sufficient for cultivating 16 hectare of land), has an estimated setup cost of up to US $10,000. Operational cost for the production of 75,000 plantlets through the SAH technology is about US $3,408, i.e., US $0.05 per piece. These costs are slightly reduced for scaled-up production of cassava seedlings in screenhouses, as is being performed by GoSeed at the Business Incubation Platform from IITA. Shipment and handling of trays to farmers attracts transport expenses.

Customer Segmentation. This technology is intended for commercial and public sector multipliers of cassava, particularly biotechnology companies and public sector laboratories.

Potential Profitability. SAH propagated plantlets may be sold for about US $0.12 each, at a profit of US $0.07 each. In this way, the 40 m^2 facility producing 75,000 plantlets per month operates at a profit of about US $5,250. SAH allows multipliers to supply large number of cassava plants in a shorter time than tissue culture methods at a price that is seven times less. Farmers who cultivate cassava multiplied through the SAH technology must be prepared to pay about three-times more for the convenience.

Licensing Requirements. The design of SAH facilities and its procedures are considered a public good, although producers tend to develop trade secrets over time. Propagation of cassava through SAH and marketing to farmers are eligible to meet full national phyto-sanitary requirements and multipliers require a license and face periodic inspection in many countries. Further information about the SAH technology is available from the International Institute of Tropical Agriculture that is actively engaged in expanding its application.

Technology 6. Production and Use of Specially Blended Fertilizers

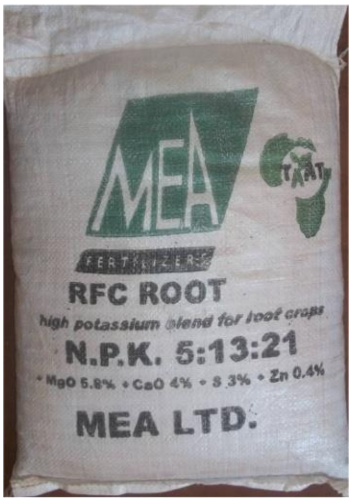
Summary. Mixes of common inorganic fertilizers have been specifically developed for cassava and other root crops that create balanced availability of nutrients for the crop's belowground production. These kinds of fertilizers supply elements like nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) that are insufficiently available in soils across many landscapes and farmer fields of Sub-Saharan Africa. Fertilizing cassava crops with the correct balance of nutrients at the right time and placement can greatly enhance the productivity and quality of tubers, and strengthen resilience to drought, and pests and diseases, while avoiding undesired losses to the environment. Readily accessible types of fertilizers and manufacturing facilities across Sub-Saharan Africa can be used to prepare appropriate blends of nutrients for cassava and other root and tuber crops. For more information on this topic contact Dr. Paul L. Woomer of the TAAT Clearinghouse by email at plwoomer@gmail.com.

A fertilizer blend suitable for root

Technical Description. Application of inorganic fertilizers that are specially formulated for cassava and other root crops ensures an adequate and balanced supply of essential nutrients that are needed for maintaining a healthy stand and harvesting large tubers. Blended fertilizers create a regime in which cassava crops utilize nutrients efficiently and sustainably as such inputs replenish stocks in soils. Inputs of phosphate and potassium particularly benefit root development and tuber filling by cassava, and input of sulphate improves the regulation of photosynthesis and transpiration of crops. Specialty fertilizer that are appropriately blended and applied at the right time and place, often in conjunction with organic inputs, boost the crop's ability to withstand disease, pests and drought stress.

Uses. Specialty blended fertilizers applied at the rate of 100 to 150 kg/ha to cassava over split applications correct various nutrient deficiencies and imbalances in soils that are limiting the production of cassava. Insufficient nutrients result from highly weathered soils, pH imbalances, and intensive cultivation. Inorganic fertilizers are best used on improved varieties of cassava as the nutrient demand and agronomic efficiency is larger than that of the non-improved crop.

Composition. Specific nutrient formulas can be made by blending a wide range of solid granular types of "primary" fertilizers like urea, calcium ammonium nitrate, potassium chloride, single or triple super phosphate and sulphate. Micronutrients like zinc, boron and cupper, amongst others can be added in solid form or impregnated as liquid.



A commercial fertilizer blend designed for root crops.

Application. Information about the nutrient deficiency and imbalance in specific growing areas contained within soil maps and past agronomic trials is sufficient for developing blended formulations, subject to the availability of different primary fertilizers. Manufacturing of specialty blended fertilizer is done using a dry rotary system available in medium to large sizes. Fertilizers will be applied two or more times in split applications during the growing cycle of cassava depending on nutrient availabilities in soils and rainfall conditions.

Commercialization. Fertilizer blends designed specifically for root crops are commercially available across Africa but their specific composition is only known to the blenders. Different compositions, however, may be inferred from their accompanying nutrient contents. In some cases, the specific formulation and means of combination are protected by trade secrets.

Start-up Requirements. To produce a new blended fertilizer, the following steps are required: 1) Derive the formula of blended fertilizers based upon nutrient demands and the soil fertility conditions requirements across a large production area, 2) Establish manufacturing protocols for mixing different sources of fertilizer and packaging the blend, 3) Sensitize agro-dealers about the benefits and profitability of specialty fertilizer blends and provide customer information about them, 4) Provide these branded fertilizers at affordable prices on local markets and monitor their sales, and 5) Conduct demonstrations and trials to assess the efficacy of a blend compared to other management options, and refine the formulation and branding campaigns over time as necessary.

Equipment used in smaller-scale fertilizer blending.

Production Cost. Designing a new fertilizer blend need not be expensive as it can be based upon desk study from a wealth of secondary information, including the composition of similar products. Refining that blend over time based upon agronomic trials and plant and soil analysis is considerably more expensive. Manufacturing specialty blended fertilizers bears a considerable start-up cost for based upon capital investment for on multi-channel dry rotary systems and automated packaging. There is also the cost of assembling the primary fertilizers to be blended. These costs are considerably reduced for fertilizer companies with existing blending capacity that is seeking to expand their product lines. Smaller, more labour-intensive blending systems may be developed for localized operations, and even operated as a community-based operation once specific formulations are known.

Customer Segmentation. Blended fertilizers are intended for use by cassava producers through distribution via agro-dealer networks. Note that blended fertilizers intended for root crops may also benefit other root crops, flowers and fruits. This versatility should be incorporated into promotional campaigns.

Potential Profitability. The profitability of fertilizer blending is not based upon crop response to individual component fertilizers, but rather their improved response to strategic combinations of those ingredients and that customers are prepared to pay for this synergetic benefit**.** Basically, blended fertilizers should offer returns that are greater than the sum of the ingredient parts. Combining two or more needed fertilizers offers more efficient labour operations as well. The profitability of fertilizer use varies with crop and growing conditions, but it is likely that the use of a blended fertilizer can increase returns by 50%. In some cases where nutrients are extremely limited, application of combined nutrients can result in a 10- to 16-fold return on investment.

Licensing Requirements. The formulations of fertilizer blends may be subject to licensing but are more often protected as trade secrets. Those with knowledge of fertilizer composition may easily calculate desired blend proportions from different primary fertilizer materials. Responses to fertilizer application and combination are abundantly available as published information, particular when performed by research institutions as Regional Public Goods.

Technology 7. Mechanized Cassava Planting and Harvesting

Summary. In order to obtain greater cassava yields and economic benefits, improved practices for cultivating the crop are required. Mechanization of the cassava production system, combined with reliance upon fertilizers, control of weeds, and the use of improved varieties can increase the yield of cassava to 25 t/ha. The planting and harvesting operations of cassava are most often performed by manual labour, causing operations to be expensive and time consuming. For example, it requires takes 8 to 10 persons to plant one hectare of land by hand in a day; compared to using a two-row mechanical planter that can plant 7 to 10 ha daily, making it much faster and less expensive than manual planting. Similarly, manual harvesting is slow and associated with drudgery and high root damage. Manual harvesting of cassava is a massive undertaking that requires between 40 and 60 persons to harvest one hectare of cassava in a day compared to a two-row mechanical lifter that can harvest up to 3 to 5 ha of cassava farm in a day. For more information on this topic contact Dr. Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. A two-row cassava planter (Model 2AMSU) for planting on flat ground can plant over 0.5 ha per hour at preset row spacing. It must be drawn by a tractor at least 90 hp. Cuttings are planted in the horizontal position at adjustable depths. As they are planted, cuttings are produced from longer stems by a saw using the tractor's power take-off. This equipment costs between US $7,000 to US $10,000. Mechanical harvesters range in complexity from simple, multipurpose lifters to tractor attachments that lift, shake and gather roots from multiple rows. An intermediate mechanical two-row harvester option requires a more powerful tractor (e.g. minimum 120 hp) and operates at adjustable forward speeds and lifting depths. The harvesting rate can exceed 0.3 ha per hour. In most cases, the cassava stems are cut and harvested before the roots are recovered. These lifters cost between US $1,500 and US $2,000 depending on their width and penetration.

Uses. Mechanical planting and harvesting can greatly reduce labour bottlenecks that undermine cassava production and increase its profitability assuming that the proper equipment and maintenance infrastructure is in place. Opportunity exists to provide and maintain these equipment as well.

Composition and Field Applications. This equipment is driven by a tractor of specific horsepower depending on the model of the planter or harvester. Stakes (cassava stems) are loaded to synchronize with the speed of the tractor in order to achieve the predetermined plant spacing. Similarly, a harvester is also powered by a tractor. In addition, labour must be trained in the safe operations of these equipment. Prior to the use of mechanical planting, land and seedbeds must be prepared as these are not simultaneous operations. The two-row or four-row planter was designed to plant cassava on flat ground with a planting rate of 0.5 - 0.8 ha/hr at 700 mm row spacing. This planter is drawn by a 90 hp (67 kW) tractor. A power take-off (PTO) driven circular saw is installed to cut stakes to cuttings of 14 ± 3 cm to 149 ± 3 cm. Cuttings are planted in a horizontal position and planting depths may be adjusted ranging between 60 and 100 mm below the soil surface. No ridges are needed for this model of planter. Mechanical harvesting is performed using a two-row or four-row harvester. This attachment requires a 120 hp (90 kW) tractor at a forward speed range of 2.1 to 6.7 km/hr and operates at a lifting depth range of 300 to 400 mm. The harvesting rate of the mechanical harvester is between 0.3 and 0.5 ha/hr.

The Model 2AMSU two-row cassava planter being prepared for operations in Nigeria.

Harvesting attachments useful for cassava root lifting: An attachment from China (left) and a lifter in operation in Nigeria.

Commercialization. Mechanical planters and harvesters for cassava are commercially available in some African countries and are becoming more so with time as farmers recognize their advantage.

Start-up Requirements. Entering into mechanical planting and harvesting requires initial investment that is recovered over time through the resulting less expensive field operations. Start-up requires that investors: 1) Determine appropriate specifications of mechanical planter and harvester based on operational footprint and available funds, 2) Train operators in the maintenance and safe use of these equipment, and 3) Monitor the advantages and disadvantages associated with conversion from manual to mechanized field operations including the survival of planted cuttings and the damage to harvested roots. As with all other farm equipment, these ones require periodic maintenance.

Production Cost and Profitability. Once purchased, the recurrent investment for mechanized planting (US $13/ha) is less than half that of manual planting (US $29/ha). Harvesting cost under mechanized operations (US $25/ha) is also less than half than under manual operation (US $61/ ha). The total cost of cassava production using mechanical method is US $367/ha representing about US $17 per ton of roots while the total cost using manual method can exceed US $21/ton of roots.

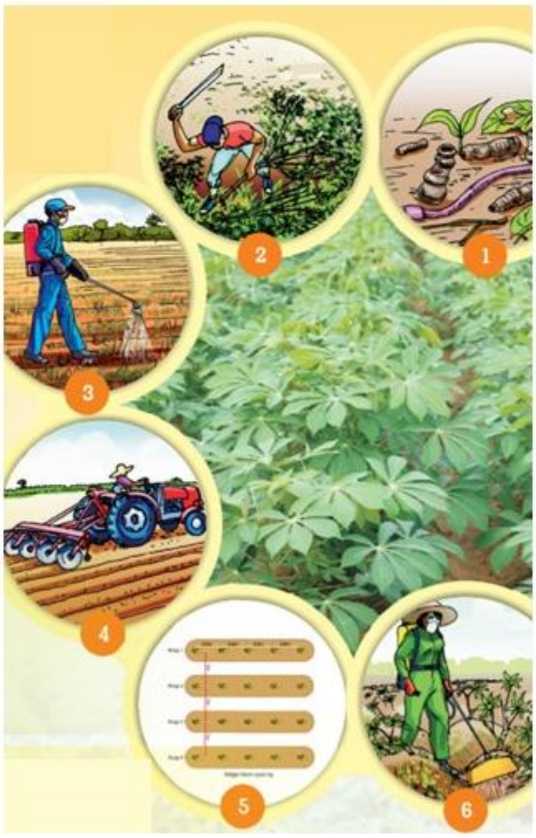
Client Segmentation. Mechanized customers are largely limited to large-scale commercial cassava producers and cassava farmer associations. These equipment are intended for use in flat fields not in sloped areas. The supply, maintenance and contracted use of these equipment also offer a business opportunity.

Licensing Requirements. These equipment are in most cases protected by patents, particularly cassava planters and more complex harvesters. In other cases, root lifters of simple design may be fabricated locally without patent infringement. Licensing protection also opens opportunity for franchise distribution and product representation by local agribusinesses. As these equipment are manufactured and distributed by the private sector, including multi-national companies, their technologies are not considered to be Regional Public Goods although sometimes research institutions may assist in their design and evaluation.

Technology 8. “Six Steps” Cassava Weed Management

Summary. Weeds pose a major constraint in the production of cassava across Sub-Saharan Africa because farmers generally do not take adequate and timely measures to control encroachment. The wide spacing and its slow initial canopy development make this crop particularly susceptible to weeds during the first 10-16 weeks of cultivation. When weeds are abundant on farms they consume large amounts of both nutrients and water from the soil, which can severely reduce the yield of cassava roots. The “Six Steps” approach is a complete package for weed management that addresses multiple key control measures, including site selection, weed identification, herbicide application, tillage operations, plant spacing, and post-emergence weeding. Cassava farmers in Nigeria who were trained in Six Steps weed management by large-scale dissemination programs have been harvesting fresh yield root yields of more than 20 ton/ha in comparison to the national average of 9 ton/ha. For more information on this topic contact Dr. Alfred Dixon of IITA by email at a.dixon@cgiar.org.

Technical Description. Six Steps cassava weed management offers a decision support framework and recommendations on various control measures in line with prevalent conditions that assists farmers to keep their cassava fields free of weeds and realize higher root yields. The specific steps involve: 1) site selection, 2) slashing of vegetation, 3) land clearing with herbicides, 4) ploughing and ridging of fields, 5) planting and pre-emergence herbicide application, and 6) post-emergence manual and chemical weed control.



Overview of the practices in the Six Steps approach.

Uses. The Six Steps weed management strategy is tailored to the agricultural contexts and available resources of small-scale farmers, and can be applied in all cassava growing areas of Sub-Saharan Africa – from sub-humid savannahs and highlands to humid lowlands. Multiple forms of weed encroachment, i.e., grasses, broad leaves, and woody shrubs), each with different levels of coverage and height, are addressed in the stepwise approach that provides cassava producers the opportunity to better align practices with prevalent conditions on their cropland.

Composition. Different types of equipment and herbicides are needed for implementing the Six Steps weed management strategy. Farmers can use simple, low-cost types of gear like slashers, hand hoes and manual knapsack sprayers, or, if available, tractor mounted attachments for land clearing and herbicide application.

Weeds in cassava greatly reduce yields but technologies are available that assure control.

Application. The Six Steps strategy is implemented using a compact, two-page document which takes farmers through a series of questions that guides them to the appropriate weed management and planting practices for cassava production under diverse conditions on farms. Procedures for land clearing, tillage, planting, and pre- and post-emergence weed control are described in detail through pictures and text that make it easier to follow. Site selection and land clearing typically starts two weeks before planting, and weed control through chemical and physical measures is carried out until the cassava canopy is fully developed, providing little opportunity to understory weeds. This stage requires about 20 to 24 weeks after planting. To determine the suitable type of herbicide product, and its application rate and method, farmers can make use of the freely-available calculator applications for cassava crops (featured on the ProPAS web portal). Note that inputs of nitrogen, phosphorus and potassium fertilizers have to be applied at recommended dosages and times during cultivation for achieving full root yield potential (see Technology 6) and this application can coincide with manual weed control.

Commercialization. The tool for Six Steps cassava weed management and planting has been successfully released in major growing areas of Nigeria, and the same is under way in other countries across SSA. Necessary herbicides and equipment are marketed by commercial agro-dealers in all counties of SSA, often times at the local agrodealer level although small-scale power equipment may be more difficult to obtain.

Start-up Requirements. Widespread uptake of the Six Steps approach is achieved by: 1) Raising awareness about its benefits on cassava root yields, input efficiency and resilience, 2) Disseminating the decision support tool and recommendations via farmers own lines of communication or local extension agencies, and 3) Ensuring access to small loans that help offset initial investments for herbicide application and labour.

Example of mechanized weeder for cassava.

Production Cost. The Six Steps toolkit offering decision support and recommendations for weed management and planting practices can be downloaded free-of-charge from the internet. Substantial investments from farmers are needed to keep cassava crops free of weeds, with removal taking up 30-50% of total labour costs at respectively US $28-46 per hectare, and herbicide applications with manual knapsack sprayers usually costing US $20-30 per hectare.

Client Segmentation. Both subsistence and commercial cassava growers benefit from this technology, and it may be incorporated into the extension campaigns of agricultural service providers and innovation platforms.

Potential Profitability. The Six Steps toolkit ensures that farmers are taking adequate and timely measures to control weed encroachment, and warrants larger returns on labour and herbicide investments for cassava production. A well-weeded cassava farm can achieve a 30-50% greater root yield than a poorly weeded farm, and the efficiencies of fertilizer inputs and water use are also significantly enhanced by following the good practices for weed management and planting.

Licensing Requirements. Farmers do not require licenses for manual and mechanized removal of weeds, while the application of herbicide on farms is subject to environmental regulations and permissions in some countries of SSA. The manuals and tutorials for implementing the Six Steps weed management and planting practices in cassava production are developed and disseminated as a regional public good by the International Institute of Tropical Agriculture.

Technology 9. High Quality Flour and Industrial Starches from Cassava

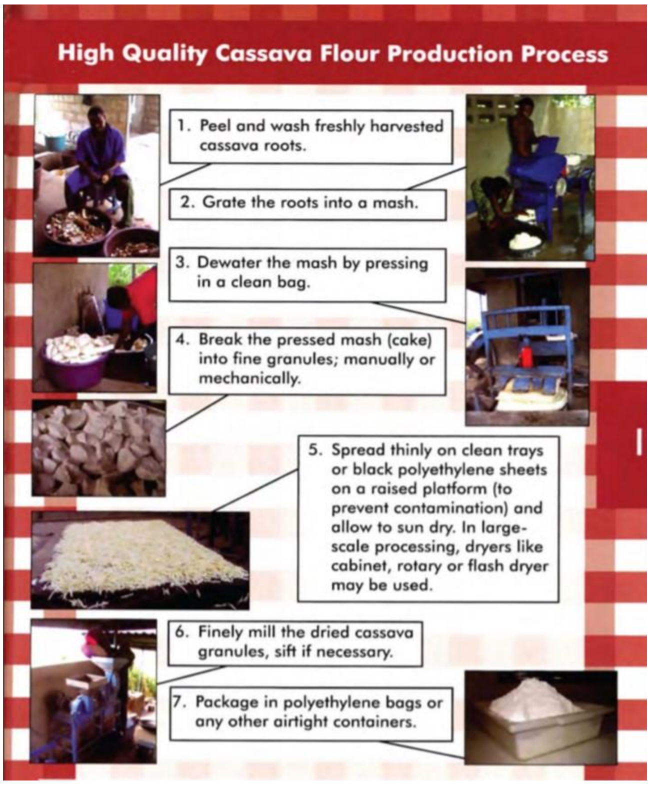
Summary. Fresh cassava roots are very quick to perish because of their high water content, thereby posing a major challenge for farmers to store them as food or sell them within markets. African communities growing cassava have always processed roots in one way or another to extend the shelf life and reduce toxic cyanide compounds, usually by chopping, washing and drying, or by fermentation. The techniques that are traditionally used for producing cassava flour do not provide significant market opportunities to the cassava farmers operating at commercial scales. High quality cassava flour (HQCF) is made through a series of steps, but is not fermented like some traditional foods, making it odourless and giving it a white or off-white colour. The main advantages of processing fresh roots into HQCF are the reduction in transport costs from farms to factories, and the longer shelf life of the raw food product. HQCF and derived starches are suitable for manufacturing into a wide range of foods and goods, and to partially substitute for wheat or other imported foods. Building capacity in rural communities for the processing of cassava into flour and starch boosts the performance, value addition and competitiveness along the entire cassava value chain, and thus strengthens the advantages of modernized cassava production. For more information on this topic contact Dr. Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Manufacturing HQCF is done using fresh roots with high dry matter and starch content, and lower levels of bitter tasting cyanides as featured in this catalogue, and needs to take place within a day or two after harvest. The key steps in producing HQCF are: raw material selection, peeling, washing, grating, pressing, drying, milling, screening, packaging, and storage. Either chipping or grating can be performed prior to drying and milling.

Detoxification of cassava roots in this process happens through grating, dewatering, and drying, and does not result in a bitter taste and odour. Extraction of starch from cassava follows a similar process except that it requires wet milling of grits or chipping, followed by physical separation of fibers. HQCF is a gluten-free product, making it ideally suited for manufacturing of non-allergenic foods, a property that attracts a growing global market.

Uses. HQCF is suitable for manufacturing a large range of food products including soups, bread, sweet syrups and alcohol. The proportion of HQCF acceptable within wheat-based bakery products ranges between 10% to 35%, and many consumers prefer the heavy "cake structure" that cassava produces at higher concentrations. Through the use of commercially available enzymes, it is possible to convert of HQCF into sugar syrups that are similar to common dextrose products and meet different sweetener requirements. In further steps, the sugar syrup derived from cassava can be industrially fermented into alcohol for potable and industrial use. When blending HQCF with salt and soda it can be used as adhesive for paper board and plywood glues, and extracted starches as filler for cosmetic, pharmaceutical and regular products, or as textile stiffener. These applications are important to Africa's industrial growth as a replacement to imported materials.

Composition. The nutritional and chemical properties of HQCF or derived starches are dependent on the cassava variety, freshness of roots, and processing steps; all of which must be harmonized within product and customer requirements. The typical quality standards of HQCF are: moisture content 13%, fibre 2%, ash 3%, fine flour (<0.6 mm) 90%, hydrocyanic acid 10 mg/kg, ash 0.5%, starch content 65 - 70%, protein content 1.3 - 2.0%, crude fat content 0.3 - 0.5%, and total acidity 1%. Pro-vitamin A or beta-carotenoids levels measure 0.06 µg/g for HQCF that is made from white fleshed cassava, whereas this goes up to 11 µg/g when biofortified yellow fleshed cassava is used to prepare HQCF (see Technology 2). The moisture content of flour determines its storage stability, as the lower the flour moisture, the higher the storage stability. The cyanide content for HQCF is very low (2 to 48 ppm) and falls within a safe level for human consumption. Foaming and emulsion capacity of HQCF is low while its bulk density, and water and oil absorption capacities are high.



Application. Manufacturing of HQCF can be performed using simple cottage style equipment that are manually operated, similar to that already used for gari processing (a traditional fermented food). Large automated systems are also available for industrial-scale processing of cassava roots into flour. The minimal infrastructure required for manufacturing of HQCF includes: a grater for size reduction, a press for dewatering, a solar or flash dryer for drying, a pin mill and a stitching machine or sealer for packaging. For production of starch there is need to remove cellulose fibres that are released during wet milling, and this is performed by a jet extractor or perforated-basket centrifuge. Reliable supply of electricity must be in place because this process requires an uninterrupted power supply.

Commercialization. Cassava flour and starch production technologies are commercially available in various African countries although some equipment must be imported or modified. Industrial-scale operations require considerable investment but may be modified around other existing food processing approaches. Localized enterprise options based upon traditional knowledge are also available.

Start-up Requirements. In order to enter into cassava flour and starch production, the following general steps must be followed: 1) Raise awareness with cassava farmers, agri-food companies and investors concerning economic opportunities related to HQCF and starch, 2) Identify profitable, durable and equitable integration of HQCF and starch into markets, both national and export, 3) Organize reliable supply of cassava roots with high dry matter and starch content close to the processing plant, 4) Set up processing methods and simple energy-efficient and labour-saving equipment such as graters and flash dryers, and 5) Train machine operators and workers on safety and quality adherence throughout the manufacturing process.

Production Cost. The cost of cassava fresh roots at the factory gate, including transportation, is a major determinant of the economic viability of manufacturing HQCF and derived starches. Producing 1 ton of HQCF requires on average 5.5 ton of fresh cassava roots. About 60% of the capital investment that is required to set up a processing plant is going to machinery and equipment, while the rest to construction. A demonstration carried out in Madagascar showed that processing 288 MT of fresh cassava roots into HQCF over a year costed US $17,238, which corresponds to a production cost of US $60/ton fresh root product. Production of starch is more capital intensive and requires higher levels of inputs compared to HQCF, thus larger investments are needed to enter that market.

Client Segmentation. This technology is applicable to smallholder industrial flour processors and food manufacturers, and may be modified to suit the needs of more localized processors and community-based activities. It also requires that consumers accept the products resulting from blended flours.

Potential Profitability. A study in Uganda on production of HQCF found that a net margin of US $79/ton can be achieved when starting from dried chips, which suggests a real potential for enterprise development in rural communities. HQCF is currently sold at US $550 to US $650/ton. Substitution with cassava flower offers a potential 25% reduction in raw material costs for bakeries that now use mostly-imported wheat flour. For example, if producer of biscuits processes 200MT flour per month, the substitution of wheat flour by HQCF can lead to an annual saving of US $130,560 per year. The higher value of HQCF and starch offers incentive to agro-processing, particularly in conjunction with the production higher dry matter cassava varieties (Technology 3).

Licensing Requirements. Producers of HQCF and starch must comply with food safety regulations. Most of the simple cottage style machinery and equipment can be fabricated free of license, while industrial systems fall under intellectual property protection. Technologies for production of HQCF and starch are a public good, and The International Institute of Tropical Agriculture is actively involved in disseminating this information across Sub-Saharan Africa.

Technology 10. Cassava Peels for Animal Feed Production

Summary. Processing cassava roots into food or starch products results in massive amounts of peels that were previously regarded as a waste product. Typically, 1 ton of fresh cassava roots results in 200 to 300 kg of peels, with a staggering total of 40 million metric ton peels being generated annually across Sub-Saharan Africa. In contrast, cassava peels can be used as a feed and fibre source for livestock and fish, but it is often unused because of difficulties in transport, drying, possible contamination by aflatoxin and poor storability of feed resulting feed products. Simple equipment can be relied upon to mechanize the conversion of cassava peels into animal feeds that not only result in a saleable product but also provides a nucleus for employment. This opportunity literally creates a market for the fresh peels themselves, positioning cassava producers and food manufacturers as suppliers of nutritious animal feeds. Scaling mechanized processing of cassava peels into wet cakes and dry mashes clearly presents many opportunities for business development across Africa wherever cassava is processed, and business models are available toward that end. For additional information about this topic, contact Dr. Iheanacho Okike of the International Livestock Research Institute by email at i.okike@cgiar.org.

Technical Description. Low-tech approaches for processing wet cassava peels into safe and hygienic animal feed sources have been developed that can be powered by small generators and carried out in small-scale farming communities with limited road connectivity and electrification. Using mechanized graters and presses, this processing makes it possible to remove five hundred litres of water from a ton of fresh peels in only 30 minutes, and reduce the drying time of peels to 6-8 hours instead of 2-3 days for traditional methods. The major savings in labour and time achieved through these simple equipment allow for large volumes of cassava peels to be processed into animal feed production in a cost-effective manner. With this technology, harmful substances like cyanides and aflatoxins do not accumulate in the final wet cake or dry mash product, thus safeguarding the health of animals and consumers of their produce along the food chain. Farmers and processors can organize timely and low-cost supply of cassava peels through data applications like 'Peel Tracker'; a virtual market place in which the location, quality and amount of resources can be shared. Animal feed production from cassava peels creates additional sources of income for farmers growing the crop, and brings down prices of feed ingredients for manufacturers and livestock owners.

Uses. Simple mechanized processing of cassava peels into animal feeds can be deployed in all cassava growing areas of Africa as it does not require large infrastructure and can be performed by farmers with limited technical training. Animal feed ingredients from cassava peelings can replace maize and wheat that are more expensive, and thus very suitable for areas in Africa that suffer from shortage of affordable, high-quality animal feed. Wet cakes, obtained after one round of grating and pressing cassava peels, have a shelf life of one week and can be fed in pure form to cattle, sheep, goats, and pigs. Mashes that underwent fuller processing and drying can be stored for 4 to 6 months, and are suitable for feeding to all types of livestock, poultry and fish. These high-quality cassava peel feeds can fulfil up to 40% of the dietary needs of pigs, 27% of broody hens and 15% of broiler chickens. Cassava peels are energy-rich but have relatively low levels of protein, which requires that diets are adequately supplemented with crude proteins, particularly those containing the amino acids methionine and lysine available from soybean and maize.

Composition. The crude protein content of cassava peel animal feeds is low, amounting to only 4% to 6% for wet meal, 3.1% for coarse mashes, and 2.6% for fine mashes. Crude fat contents of mashes are low at 1.7% but the starch content is 77-78%. This results in an energy-rich feed that contains insufficient protein. Fine fractions of dry mashes are higher in energy content and lower in fibre content, whereas the coarse fractions have a lower energy content and higher fibre content. When cassava peel processing is done appropriately, the hydrogen cyanide concentrations of animal feed products fall below 10 parts per million (tolerable limit: 100 ppm), and aflatoxins presence is well under the permissible 18-20 parts per billion. Wet cakes made from cassava peels typically contain 38−42% of moisture after one round of grating and dewatering, while dry mashes should have 10-12% moisture before packaging to achieve safe storage.

Application. Before processing of cassava peels, all remnants of soil must be removed for protecting the grater from damage and avoiding spoilage of feed products. As a first step, the peels are grated up to three times to reduce their particle size, and then packed into sacks that are placed in a hydraulic press for dewatering. The resultant wet cake is left in the sacks overnight to ferment which causes hydrogen cyanides in the product break down. As a next step, wet cakes are grated again to further reduce particle sizes, and then sieved to separate fine and coarse fractions. Mashes can be dried in direct sunlight by spreading the product thinly over clean plastic and metal sheeting or cement slab, and stirring the materials at hourly intervals. The mashes can also be dried overheat if need be. In more industrial settings they may be flash dried. All machines and processing areas must be kept in hygienic conditions after each run to restrict microbial contamination, particularly aflatoxin-producing fungi. Disposal of process waste water should be done through seepage tanks that avoid pollutants from entering surface waters.

Commercialization. Hand and mechanical equipment to prepare animal feed from cassava peels are commercially available in all African countries allowing for this technology to be adopted widely.

Start-up Requirements. Commercializing the processing of cassava peels into animal feeds requires several steps: 1) Raise awareness of cassava farmers and processors about the advantage of animal feed production from cassava peeling wastes, 2) Identify processing equipment and facilities appropriate to the scale of intended cassava peel processing that match expected throughput volumes, 3) Tailor operational protocols and business plans for processing and marketing of cassava peel animal feed products, and 4) Adjust operations to the different forms of cassava peel feeds and their required supplementary materials, and brand and market the resulting products.

Production Cost. The base equipment required for small-scale processing of cassava peels into animal feeds requires an investment of approximately US $3,400 including a motorized grater for US $1,000, a hydraulic press for US $600, a motorized pulveriser for US $850, a mechanical sieve for US $400, and a supplemental dryer for US $550. In addition, a backup generator is needed in areas with unreliable power supply. Once this equipment is assembled, the approximate total cost of producing one ton of dry mash is about US $114 including production of wet cake at US $20, grating at US $18, dewatering by the hydraulic press at US $6, drying at US $40, fuel costs at US $17, and other miscellaneous costs.

Customer Segmentation. This technology targets small- to medium-scale animal feed processors operating in areas where abundant wastes of cassava peels occur, and where strong demand for animal feeds exists, particularly where current feeds are considered unaffordable.

Potential Profitability. The market price for one ton of dry mash in Nigeria is US $210 and if it costs US $114 to produce then potential a profit margin of 84% exists. This is quite high for industrially produced bulk products, so it is likely that as more processors are attracted to the market the value of “peel meal” will be reduced. At the same time, feeding poultry a diet of 50% cassava peels instead of 100% maize reduces feed costs by over 20%. Substituting maize with cassava peels serves to overcome shortages of animal feeds in Africa, and at the same time increases profit margins for livestock, poultry and fish producers. In this way, the use of cassava peels is able to release millions of tons of maize meal toward human consumption that is otherwise used for animal feed; significantly increasing food security. When cassava peels are exploited to the fullest, it is possible to produce at least 4 million ton of high-quality animal feed ingredients per year across Africa, valued at around US $600 million.

Licensing Requirements. Phytosanitary certificates may be required to produce and sell animal feeds made from cassava peels in many African countries that are based in part upon regular testing for aflatoxins. Technologies for feed production from cassava peels are a readily available Regional Public Good and The International Livestock Research Institute disseminates it across Africa.

Technology 11. Mobile Processing Unit for Improved Cassava Value Addition

Summary. The commercialization of cassava value chains in Africa is faced with a double-edged problem: farmers located in rural areas lack market access to sell their harvests partly due to poor transportation networks, while industrial processors located in the cities experience scarcity of fresh cassava roots to operate their processing operations. The rural sector lacks the necessary utility infrastructure and labour to attract investments in processing factories. Since cassava is very perishable and bulky, the risk of postharvest losses and cost of transporting cassava roots to factories located in urban areas is high. Hence, most cassava processing factories in Sub-Saharan Africa operate at only partial capacity, stifling further investment in them. A Mobile Cassava Processing Plant was developed by IITA as an alternative investment approach for the private sector to avoid the problems associated with stationary processing factories, inconsistent and inadequate supply of raw materials, high cost of transporting bulky fresh roots to the city-based factories, and the loss in both the quality and quantity of roots that reach the factory. For more information on this topic contact Dr. Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. Fresh cassava roots spoil quickly because of their large moisture content and this susceptibility results in major post-harvest losses of this crop across Africa. A specially designed Mobile Cassava Processing Plant (MCPP) consists of modern processing machinery and an electricity generator housed on a large truck that is equipped with a loader crane and processing equipment. These units can be modified for manufacturing a range of cassava products including dry chips, high-quality gari, flour or starch. The setup and size of this equipment can be tailored according to throughput volumes and market objectives. Mechanization of cassava

processing made possible through mobile plants gives rise to large savings on both transportation and labour costs, and major gains in the efficiency of converting raw materials into finished products, including less waste from peeling (see Technology 9). Medium-sized designs are available that process up to eight tons of fresh cassava roots daily into dry cake, and units for gari production can process 2.5 ton of fresh roots every day into roasted product. The quality of foods and industrial products from cassava that are manufactured by mobile units is much comparable to that of stationary and traditional processing, and is acceptable to consumers.

Uses. Mobile cassava processing units are highly suitable for cassava growing regions with poor road infrastructure that undermines reliable delivery of fresh roots, as well as areas facing irregular supply of electricity to factories; both factors that limits the throughput of food produce. This situation affects a majority of smallholder cassava producers across Africa who live in sparsely populated areas. Equipment configuration of these mobile processing units can be readily adjusted to specific conditions and objectives, making it possible to bring mechanized approaches for manufacturing of cassava products to an increased number of cassava growing communities.

Composition. A variety of base and auxiliary equipment is fitted on mobile cassava processing units, including a chipper, grater, press, dryer, sifter, and roaster, with the specific configuration being tailored to the throughput volume and desired end-products. By default, sun drying systems are included for most remote applications but a flash dryer may be added for increasing the amount and quality of products that are processed. Diesel powered electricity generators can also be substituted by renewable technologies such as solar panels and battery storage, or bio-digestion units installed for utilization of cassava peels.

Application. The MCPP can be driven to the farm-gate or collection point where produce is being harvested and marketed, or placed at existing processing sites, and may also be moved between different locations in line with harvesting schedules. This decentralized strategy for cassava processing can be connected to an attractive forward-contracting scheme that gives farmers a guaranteed market. All of the steps for processing of cassava roots into high-quality products carried out in containerized mobile units are the same as in a large factory. Once dry chips, cake or flour are produced in rural areas, they can be transported more easily, after which these can be sold on markets for direct consumption, or supplied to food industries for making bread, beverages, packaging materials, cosmetics and many other products.

Commercialization. The equipment for building a MCPP is commercially available in most African countries and the approach holds commercial potential although currently this technology exists as a pilot activity.

Start-up Requirements. General steps required to develop a MCPP enterprise include: 1) Sensitize cassava processors on the benefits of mobile units for reducing post-harvest losses and increasing market access, 2) Identify suitable setup and size of a containerized processing factory, 3) Establish reliable supply of quality cassava roots by drawing up contracts and delivery schedules for farmers, and 4) Provide loans to allow interested parties to construct and operate these mobile units.

Production Cost. The capital investment for a medium sized mobile processing unit that produces dry cake is about US $47,000. When set up for gari production this increases to US $53,000. Nearly half of this fixed cost is for purchasing a truck on which the equipment is installed. The assumption is that the mobility of the facility compensates for it higher capital cost. The initial investment for a mobile unit that has the capacity to process up to 48 ton of fresh roots per week into high quality starch flour or cake worth US $5,600. Among the main operational expenses for the mobile factories are the wages of trained personnel to run the plant, and diesel fuel for transportation and generating electricity. Drying the cassava product is a major cost in the processing chain, either requiring labour for desiccation with direct sunlight or as fuel for flash dryer.

Customer Segmentation. This technology is intended for investors seeking new opportunities in cassava processing including producer associations and private cassava processors.

Potential Profitability. Mobile processing units offer cassava farmers in remote communities the opportunity to sell more of their produce and earn larger amounts of cash while using less labour or money for transport. A pilot with medium sized processing units in Nigeria has found that annual net revenues after deducing operation costs and taxes, amount to US $78,000 for dry cake production and US $84,000 for gari production, achieving a return on investment of approximately 155% within three years. The introduction of decentralized cassava processing is furthermore making farmers plant and harvest more cassava each year due to the certainty of the price and demand, and for one case in Nigeria it has led to a 2.6-fold increase of harvested roots over a five year period. The improved production of high-quality cassava flour and starch that can be achieved in rural areas of Africa with mobile processing units helps to replace imported grains at a lower cost and thereby raise the competitiveness of businesses.

Licensing Requirements. Processing of cassava with mobile units must comply with national regulations and standards for manufacturing of food and non-food products in order to reliably access markets. The MCPP was conceptualized, designed and constructed as a Regional Public Good and the International Institute of Tropical Agriculture is responsible for its dissemination in Africa.

Technology 12. Cassava Business Connector Application

Summary. The cassava value chain is characterized by a serious communication gaps among value chain actors, leading to weak market linkage. Producers often do not know about buyers, and vice versa. This weak market linkage often creates an artificial gap in supply and demand, and sometimes unnecessary gluts. Resolving this problem requires efficient integration of value chain actors to improve communication and coordination, and requires greater visibility of producers, input suppliers, processors, and end-users. Conventional procedures used for value chain promotion are an expensive and time-consuming process, and they often result in creating market linkage for a specific product or economic elites. The Cassava Business Connector is a digital innovation for cassava value chain integration to enhance market access. The application creates virtual value chain networks that enable a seamless integration across market linkages, with an ultimate aim to enhance fair income generating opportunities to all. For more information on this application contact Dr. Adebayo Abass of IITA by email at a.abass@cgiar.org.

Technical Description. The Cassava Business Connector is an ICT app available through the link http://taat-cbc.org that is useful to map and register various stakeholders, including producers, aggregators, processors, service providers and others in order to create a virtual platform in each country. This system assists real-time status tracking, communication, coordination of information and management decisions. It allows for the creation of a database or repository of activities and records. It enables digital data collection, submission, and access using a smartphone or any internet-enabled devices. It includes a powerful map-based navigation tool for easy access to other actors for products or information. It includes an alert system and advertisement features for sharing product information and establishing direct linkages with users available on the platform.

Uses. The Cassava Business Connector helps the coordination of material flow from fields to end-users, allows decentralized monitoring of production, real-time information exchange between the users, and offers secure accounts to each user. Individual users are protected by login and password for their information safety.

Composition. The Cassava Business Connector web application involves building of a database of value chain actors, the products, services, geolocation, quantity, quality, certification, price, date of availability and other market information. Typically, users contribute market information and access the online database through computers or smartphones from any location and interact at any time with other value chain actors registered on the platform.

Application. This digital application offers a wide range of Information on products and services to all stakeholders.

Commercialization. CBC is available anywhere, and is currently active in eight Sub-Saharan Africa countries.

Start-up Requirements. As with other digital applications, the Cassava Business Connector requires that users register and familiarize themselves with its use as follows: 1) Registration via an ICT device for access to market linkages and other information, and 2) Input and extract information from the application as needed.

Production Cost. The application is downloaded and used free-of-charge.

Customer Segmentation. The application is available and useful to all cassava value chain stakeholders.

Licensing Requirements. There are no licensing requirements for the use of the Cassava Business Connector but users must register with it and it is operated by IITA is a Regional Public Good.

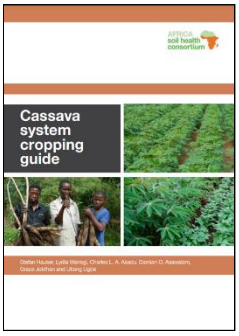
Conclusions

This catalogue provides a wide variety of options for modernizing cassava production and processing in Africa. It identifies means to improve yield and nutritional value of this important root crop, and to grow varieties that resist drought and disease. It provides better options for vegetative propagation of these new varieties, particularly by raising cutting materials under vector-free conditions, both under controlled and field conditions. It advances field production by signalling the importance of mechanized cultivation and better mineral nutrition from specially-blended fertilizers. It does not feature recent breakthroughs in pest and weed management of cassava and its intercropping with legumes, and these will be added to the catalogue with time. Cassava peels are also described as a valuable component of animal feeds. Several other options for adding value to cassava roots are offered. While cassava is an important human food, it may also be processed into a wide variety of products and the preparation of high quality flour and industrial starches is presented as one means to introduce African cassava into world trade.

This catalogue was prepared with a variety of users in mind whether they be producers, agents of agricultural development or private sector investors. Farmers can use many of these catalogue items as production guidelines. Those from the public sector can utilize the catalogue as a whole and design agricultural projects involving cassava around its toolkit of modernizing technologies. Members of the private sector, including propagators, input manufacturers, processors and investors also benefit from the contents of this catalogue. Indeed, the Technologies for African Agricultural Transformation Program’s Clearinghouse welcomes feedback on its contents.

Information Sources

TAAT Clearinghouse. 2018. TAAT **Technology Toolkits and their Strategic Deployment.** Clearinghouse Technical Report Series 001, Technologies for African Agricultural Transformation, Clearinghouse Office, Cotonou, Benin. 18 pp.



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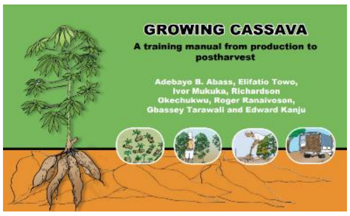

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Technologies for African Agricultural Transformation (TAAT) and its Clearinghouse Office

The developmental objective of TAAT is to rapidly expand access of smallholder farmers to high yielding agricultural technologies that improve their food production, assure food security and raise rural incomes. This goal is achieved by delivering regional public goods for rapidly scaling up agricultural technologies across similar agro-ecological zones. This result is achieved through three principal mechanisms; 1) creating an enabling environment for technology adoption by farmers, 2) facilitating effective delivery of these technologies to farmers through a structured Regional Technology Delivery Infrastructure and 3) raising agricultural production and productivity through strategic interventions that include improved crop varieties and animal breeds, accompanying good management practices and vigorous farmer outreach campaigns at the Regional Member Country (RMC) level. The important roles of sound policies, empowering women and youth, strengthening extension systems and engaging with the private sector is implicit within this strategy. The Clearinghouse is the body within TAAT that decides which technologies should be disseminated. Moreover, it is tasked with the responsibility to guide the deployment of proven agricultural technologies to scale in a commercially sustainable fashion through the establishment of partnerships that provide access to expertise required to design, implement, and monitor the progress of technology dissemination campaigns. In this way, the Clearinghouse is essentially an agricultural transformation incubation platform, aimed at facilitating partnerships and strengthening national agricultural development programs to reach millions of farmers with appropriate agricultural technologies.

Dr. Innocent Musabyimana, Head of the TAAT Clearinghouse

Back cover photographic credit: This mechanized two-row cassava planter helps break the labour bottleneck that undermines the large-scale production of cassava. Photo credit: IITA Stock Pictures.

Cassava Technology Toolkit Catalogue

In collaboration with