Maize Technology Toolkit Catalogue

TAAT Clearinghouse

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The Technologies for African Agricultural Transformation (TAAT) is funded through a grant from the African Development Bank and is implemented by the International Institute of Tropical Agriculture (IITA) in close collaboration with other centers of the Consultative Group for International Agricultural Research (CGIAR) and specialized institutions such as the African Agricultural Technology Foundation (AATF), the Forum for Agricultural Research in Africa (FARA), the International Fertilizer Development Center (IFDC) and others. For more information, email contact: i.musabyimana@cgiar.org or plwoomer@gmail.com.

Front cover photos: Contrast in small ear size of improved maize and large ear size of drought tolerant variety (left), and tractor-mounted driller for N topdressing to better meet crop nutrient demand (right). Photographic credits: International Maize and Wheat Improvement Center (CIMMYT) and QKNOWBooks.github.io.

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Purpose and Introduction

This catalogue describes a suite of technologies related to the modernization of maize 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. Maize is one of TAAT's priority commodities because of its huge importance to food and nutritional security, as well as rural development in general across Africa. It is also targeted as an agro-industrial crop for processing and trade within world markets. During 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 fourth 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.

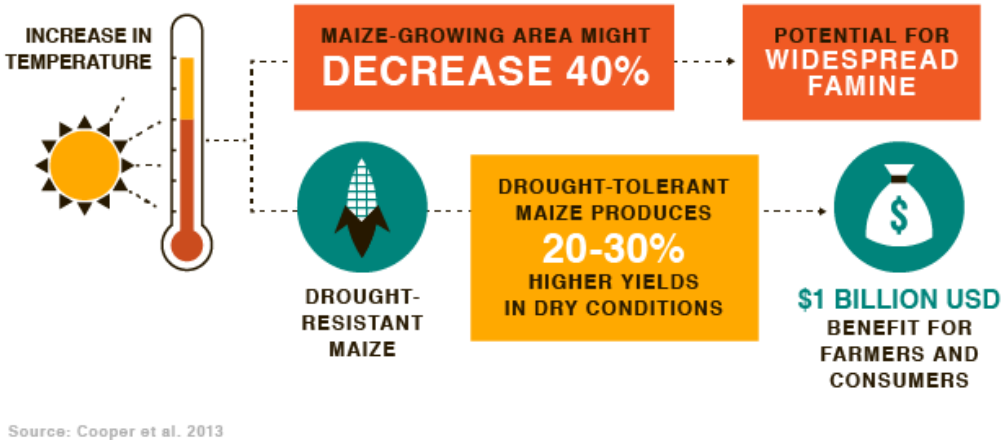
About TAAT. The Technologies for African Agricultural Transformation (TAAT) is a program led by IITA that has pioneered new approaches to the deployment of proven technologies to African farmers. TAAT arose as a common effort of IITA and the African Development Bank (AfDB); and is an important component 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 advocacy (27%) and the availability of appropriately designed labour-saving equipment (26%). These technologies have a direct role towards the achievement of the United Nation's 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.

The Top 10 Maize Technologies. This catalogue presents ten technologies that serve to modernize production and post-harvest processing of maize in Africa. These technologies include: 1) drought tolerant maize varieties to strengthen the resilience of food production, 2) imazapyr resistant maize varieties that withstand parasitic *Striga* weeds, 3) golden maize varieties with pro-vitamin A biofortification for better nutrition, 4) streamlined licensing mechanism for commercial multiplication of hybrid maize varieties, 5) information platforms offering access to contracting of mechanized farm services, 6) pre-plant fertilizer blends and nitrogen topdressing for balanced nutrient supply, 7) legume rotation and intercropping with maize to improve soil fertility and economic yields, 8) herbicides for pre-emergence and post-emergence treatment that avoid early and late season weed encroachment, 9) control of the fall armyworm (FAW) invasion through systemic pesticides applied to seeds and sprayed on the crop, and 10) prevention of aflatoxin contamination with biological agents. Details on each of these ten technologies are given followed by a strategy to include TAAT in technology brokerage.

Technology 1. Drought tolerant maize varieties

Summary. Maize varieties are now available that permit satisfactory grain yields under short-term or moderate drought conditions. Conventional breeding, marker-assisted breeding, and biotechnological modification are used by local and international breeders for making drought tolerant maize varieties that are adapted to specific conditions in growing areas. Seed technology is a valuable asset towards mitigating the impact of dry spells and low rainfall which are limiting production ever more frequently occasioned by climate change; and it has widely been shown to increase productivity, improve yield stability, and reduce the risk of complete crop failure in maize production zones of Sub-Saharan Africa. For more information contact Dr. Tahirou Abdoulaye of IITA by email at t.abdoulaye@cgiar.org.



Maize production in Africa under future climate change and benefits of drought tolerant varieties.

Technical Description.
Unfavorable rainfall conditions are an important cause of maize yield gaps and losses in farming systems of Sub-Saharan Africa as more than 90% are rainfed rather than irrigated; causing productivity of maize to be highly susceptible to seasonal rainfall. The two main solutions on the market are drought tolerant maize (DTMA) that has enhanced ability to withstand periods of acute soil drying, and water efficient maize (WEMA) that is adapted to growing under low supply of water. Breeders developed these seed technologies, so they outperform common non-tolerant varieties under severe to modest levels of water stress that occur routinely in dry climates and intermittently in moist climates. Scaling programs that have taken place for DTMA and WEMA in several major African growing areas have generated large increases of maize grain production and resilience of crops to dry spells and low rainfall. Progress in access to meteorological and market information for farmers on the continent, together with local knowledge, offer powerful means for supporting the decision when to invest in drought tolerant maize.

Uses. Drought tolerant maize varieties provide a safeguard for farmers when unfavorable rainfall conditions occur and are useful in all growing areas of Sub-Saharan Africa as periodic dry spells and low rainfall occur widely. Water efficient maize varieties are particularly developed for semi-arid and dry sub-humid climates where levels of precipitation are chronically low and sandy soils have low moisture holding capacity. As of 2016, more than two million farmers in Africa were reportedly growing drought tolerant maize varieties showing there are high levels of costumer trust and demand for the solution. The use of DTMA and WEMA presents major opportunities to mitigate the short- and long-term challenges of African farmers that arise due to climate change, such as expansion of drylands and increased frequency and severity of seasons with poor rainfall. Also, these seed technologies can be used to grow maize in semi-arid regions with less irrigation water, allowing farmers and national programs to tap into non-traditional growing areas.

Composition. There is a wide range of drought tolerant and water efficient maize varieties available to African farmers that are adapted to specific growing conditions. More than 200 distinct lines of DTMA have been released in 13 sub-Saharan countries up to date, and over 120 hybrids of WEMA in seven countries. DTMA include both hybrid varieties that require parent seed and licensing, as well as open-pollinated varieties (OPV). The OPVs allow for royalty-free purchase and multiplication through a wider range of mechanisms, including farmer's own and community-based seed production, but in general are less productive than commercial hybrids.

Performance of DTMA variety (left) and drought sensitive variety (right).

Application. The decisions by farmers to invest in drought tolerant maize varieties are ideally guided through warnings and likelihood scenarios drawn from rainfall prediction and local experience, and various platforms are now available that provide recommendations on their use to ensure positive results. Seed of DTMA and WEMA varieties are planted as any normal maize crop following best soil and fertilizer management prescribed for particular growing areas and seasons. Appropriate inputs and formulations of inorganic fertilizers are widely shown to provide farmers higher yields from drought tolerant maize because the applied nutrients are addressing limitations in soils that allow the crop to respond more productively to available moisture, but the level of inputs are best adjusted to the target yields. On croplands with low soil fertility, particularly in highly degraded and sandy soils common across Africa, the use of DTMA and WEMA varieties should be combined with legume intercropping, manure application and mulching in order to improve better synchronized nutrient release and more complete water retention.

Commercialization and Start-up Requirements. DTMA and WEMA varieties are commercially available in many countries, including from private seed companies. Scaling the cultivation of drought tolerant varieties requires that: 1) Producers of maize seed identify and secure access to drought tolerant varieties that are adapted to other conditions in growing areas, 2) Awareness-raising with farmers about benefits of drought tolerant maize on food production in terms of risk mitigation, and 3) Creating equitable access and financial support for local suppliers and smallholder farmers that catalyzes investments and purchases of DTMA and WEMA seed.

Production Cost. Development of drought tolerant and water efficient maize varieties involves advanced selection in the lab and greenhouse, and extensive testing of varieties in the field. This effort requires significant investment by both public and private sector breeders. The costs associated with producing DTMA and WEMA are not substantially different from common non-tolerant maize varieties and hybrids, and large agro-input suppliers are currently selling these resilient seed technologies at US $0.8 to $1.2 per kilogram for OPVs and US $2.0 to $2.5 per kilogram for hybrids.

Customer Segmentation and Potential Profitability. Small-scale and commercial maize producers, and seed companies and community-based seed producers all stand to benefit from DTMA and WEMA varieties, especially in areas under growing threat of drought. Evidence from major growing seasons in Sub-Saharan Africa shows that drought tolerant maize varieties have a 20% to 35% larger grain harvest than non-tolerant crop types under severe to moderate drought conditions, respectively. A study in Zimbabwe on the use of DTMA has demonstrated that economic yields increased on average by 0.6 ton/ha compared to the previously cultivated varieties, and that the change of maize seeds provided US $240 per hectare additional income. This yield increase is roughly equivalent to household food demand for nine months, offering a strong argument for

adoption from the standpoint of food security. Risk-mitigating technologies such as DTMA and WEMA are leading to stable production and income levels in the face of shocks and offer a risk reduction dividend. By reducing risks, seed technologies have the potential to catalyze investments in production and achieve higher returns from accompanying technologies as well.

Licensing Requirements. Hybrid varieties from DTMA and WEMA are marketed under a humanitarian-use license, while open pollinating varieties can be multiplied and sold by farmers. Seed marketing requires certification following national compliance. IITA, CIMMYT and AATF are responsible for the development of drought tolerant and water efficient varieties that are released royalty-free, without payment of technology fees, while seed companies will multiply and distribute the seed to farmers at a cost.

Technology 2. Imazapyr resistant maize for Striga management

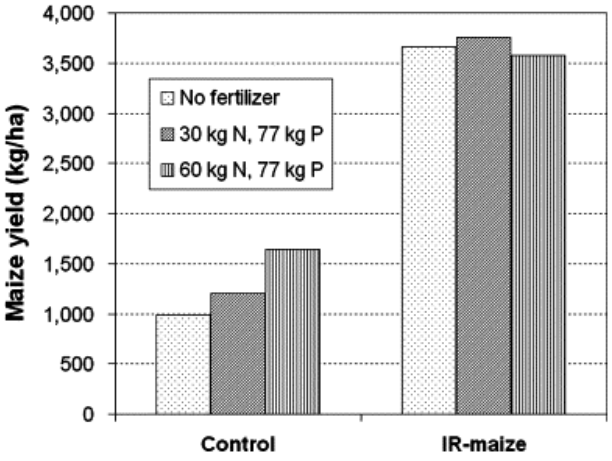
Summary. Parasitic Striga sp., also known as witchweed, attach the root systems of cereals and extracts nutrients and water away from the host plants. Maize has little resistance to striga, and the parasite can reduce yields by 30% to 80%, resulting in plant stunting, twisted growth and diminutive ears. Commercial seed manufacturers are now marketing improved maize varieties that are resistant to the effects of imazapyr, a herbicide that protects the crop against parasitic Striga. Using imazapyr resistant (IR) maize seed coated with the herbicide instead, as an alternative to other hybrid varieties that do not afford protection against Striga is proven to enhance grain yields and reduce further dispersal of the pest on farmlands, particularly when combined with other appropriate Striga control technologies. IR maize is treated with very low levels of imazapyr (e.g. 30 to 45 g per ha) and application rates are critical because maize germination can be affected by seed treatment over time. But this is a very strategic seed dressing because it places the agent right to where it is needed to kill striga as it attempts to invade the young roots at critical stages of crop establishment. IR maize lines are becoming available in some areas in Sub-Saharan Africa where production is severely affected by Striga. More information about this technology is available from Dr. Alpha Kamara of IITA by email at a.kamara@cgiar.org.

Technical Description. Breeders reinforced maize resistance to imazapyr herbicides by screening large number of varieties and reinforcing this trait by marker assisted breeding. Resistance was then combined with other needed traits, particularly disease resistance, and then distributed as both open pollinated and hybrid maize lines. Seed coating of herbicide gives protection to roots for many weeks into the growing season, having the greater impact during the first eight weeks after planting in which maize crops can grow without being subject to parasitism and the toxins that the parasite produces. The tiny germinating seeds of Striga are killed by the herbicide when they attempt to parasitize the host, resulting in a depletion of the seed banks resident in soil. The herbicide has a non-selective formulation meaning that the growth and negative effect of other common types of weeds are also reduced by use of IR maize. Protection against Striga parasitism is boosting grain and stover productivity of maize, and its nutrient and water use efficiency. Use of IR varieties has led to significant improvements of food self-sufficiency and economic returns in the maize value chain across major growing areas of Sub-Saharan Africa. Seed manufacturers are furthermore marketing maize varieties that combine imazapyr resistance with other improved traits such as drought tolerance and bio-fortification.

Field with a high level of Striga infestation.

Uses. Cultivating IR maize varieties is highly advantageous on Striga infested farmlands of millions of subsistence farmers in Sub-Saharan Africa that suffer major grain yield losses every season due to the insidious plant parasite. IR technology results in not only increased yields of maize in fields infested by striga, but also a steady decline in the number of dormant striga seeds in soil, resulting in both immediate and longer-term benefits. Use of IR maize on degraded fields with low soil fertility status necessarily has to be combined with the appropriate supply of inorganic fertilizers and organic resources for the intervention to increase grain production and food security.

Composition. The active ingredient of imazapyr herbicides is imidazoline, and is mixed with salt and other compounds to form a powder that is stable. Imazapyr is a powerful amino-acid inhibitor that is nontoxic to bees and soil-dwelling fauna, especially when applied in micro-doses through IR technology. Herbicides are coated onto maize seeds by means of a binding agent such as gum arabic by vaporizing over the material and allowing it to mix and dry in a rotary mixer. Note that when applied at higher levels to weeds and soils this herbicide has a fairly long-term and non-specific effect, keeping sprayed areas free of plants. Note that one system to treat seeds is patented under the term StrigAway.



Grain yield of imazapyr resistant variety (right) and non-treated maize (left) in Striga infested fields

Application. Seed of IR maize are planted as any normal maize crop following best soil and fertilizer management prescribed for particular growing areas and conditions. Imazapyr is non-toxic to mammals but it is often mixed with more insecticides so care should be taken to wear gloves or wash hands when seed is planted manually. To ensure the herbicide reaches the surrounding of the seed, the surface of soils is best tamped down well. Inputs of inorganic fertilizers, especially nitrogen, are widely applied after planting. Infestation of Striga can be further reduced by intercropping or rotating food legumes like soybean or cowpea, or forage legume like greenleaf desmodium, as in the Push-Pull system. Evidence suggests that urea is a better topdressing for maize in Striga-infested fields because maize can assimilate this form of nitrogen but Striga cannot.

Commercialization and Start-up Requirements. IR maize varieties are becoming commercially available but the spread of this technology across Africa has been slower than expected given the scope of the problem. National programs should encourage the registration and adoption of this technology, but it is best deployed through the private sector. In terms of scaling herbicide-coated IR maize there are several steps: 1) Producers of maize seed must identify the IR-maize varieties and hybrids best suited to their respective service areas, 2) Awareness-raising with farmers about benefits of IR maize on production and *Striga* control, and 3) Creating equitable access and financial support for local suppliers and smallholder farmers that catalyzes purchases of IR maize.

Production Cost. Seed companies should be prepared to invest to produce, treat and market IR maize seed. Imazapyr herbicides are relatively inexpensive but its coating onto seeds requires specialized equipment and additional labor. Care must be taken to ensure that imazapyr does not come into contact with other, non-IR seeds. Certified IR maize seed is higher priced than a similar hybrid variety that has not been treated with imazapyr herbicide, typically costing 25% to 40% more, but under striga-infested field conditions this investment is recovered several folds. Large agro-input suppliers are currently selling seed of IR maize varieties at US $1.5 to $2.5 per kilogram in Nigeria, Malawi, Kenya, Tanzania and Uganda.

Customer Segmentation and Potential Profitability. There is a highly segmented customer base for IR maize varieties including small-scale producers and seed companies. Hybridization for herbicide resistance also attracts buy-in from national seed systems. Compared to improved varieties that are not protected by imazapyr herbicides, yield gains of 1.0 to 3.0 ton grain per hectare have been achieved by use of IR maize in eastern and southern African countries where Striga infestation is severe. At common market value in these regions the added maize grain obtained from planting IR maize is equal to US $200 to $1,100 per hectare and thus will ensure the cost of the intervention is paid back with profit each growing season. The reduced dispersal of Striga by planting IR maize in major production zones will deplete the number of seeds of the weed in soils and over time diminish the need for use of herbicide and other control measures, eventually leading to eradication of Striga from croplands.

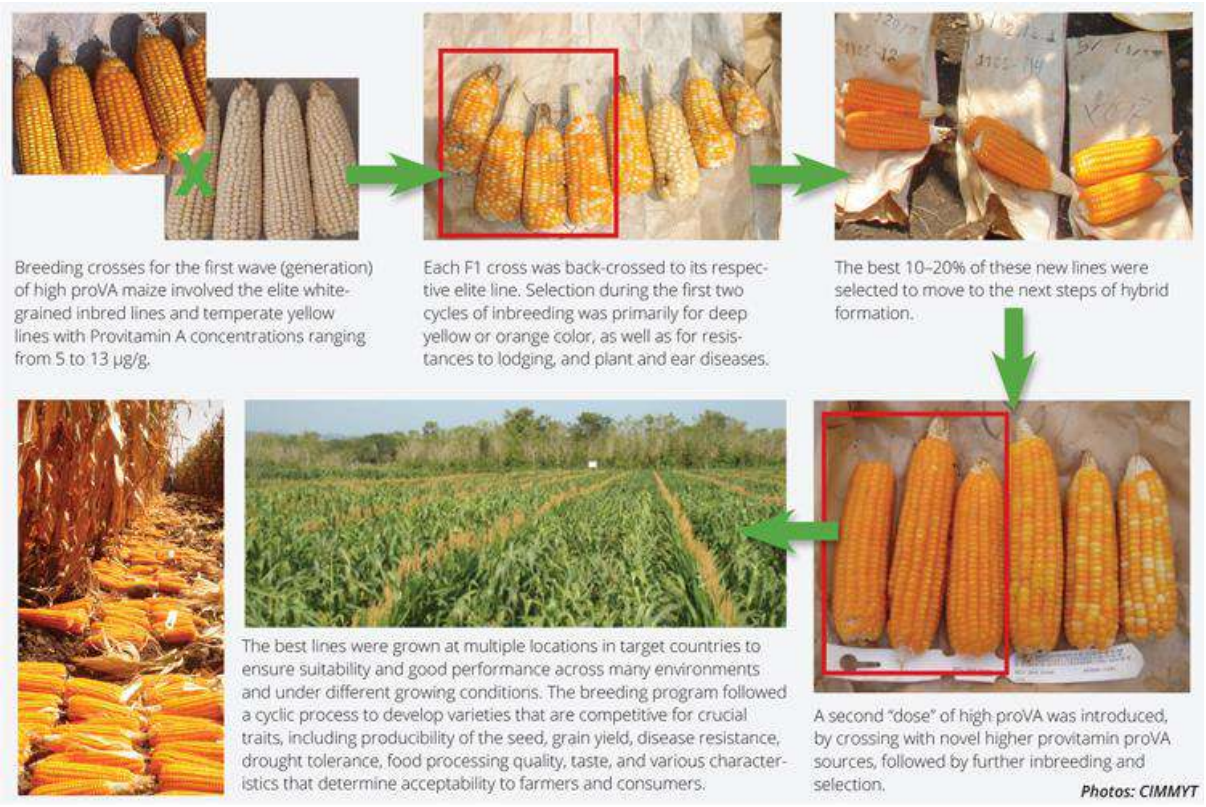
A commercially available Imazapyr-Resistant (IR) maize variety.

Licensing Requirements. Farmers do not need a commercial or environmental license to plant IR maize seed. The intellectual property connected to IR maize is owned commercially by seed manufacturers. One international company successfully patents and licenses the distribution of seed coating technology. IITA and CIMMTY are responsible for the development and dissemination of IR maize across Sub-Saharan Africa.

Technology 3. Biofortified maize that is high in vitamin A

Summary. Biofortified maize varieties rich in Vitamin A are now available. Maize is the preferred staple food for over 300 millions of people in Sub-Saharan Africa but the most commonly grown varieties contain sub-optimal levels of vitamins and minerals. According to World Health Organization, this situation contributes to hidden hunger on the continent with 50% of children between one-half to 5 years suffering from vitamin A deficiency. Insufficient intake of vitamin A is the leading cause of preventable blindness in children, it compromises the immune system, and increases the risk of death from diseases like measles, diarrhea and respiratory infections. Conventional breeding techniques have increased the level of provitamin A in maize crops and offer a viable avenue to sustainably improve nutrition in rural communities. Kernels of golden maize are packed with beta-carotene which gives it a characteristic orange color, and after ingestion these compounds are converted into vitamin A by enzymes as needed by the body. A large range of golden maize varieties have been released and are marketed in Sub-Saharan Africa, and through close collaboration between seed companies, farmers, policy makers and researchers this seed technology has been successfully scaled in major growing areas. For more information on this topic contact Dr. Abebe Menkir of IITA at a.menkir@cgiar.org.

Biofortified maize (center) and conventional varieties (top/bottom).



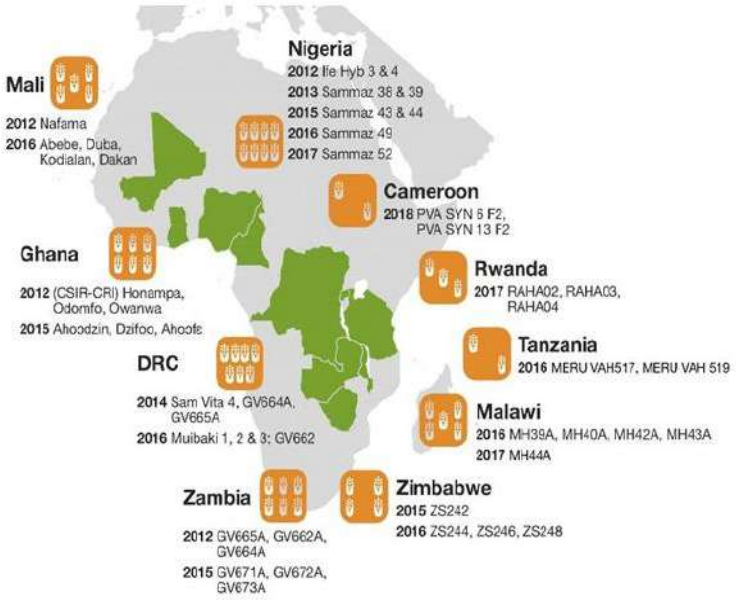
Pathway of breeding golden maize varieties with high beta-carotene.

Technical Description. Golden maize varieties were first developed using lines from Central and South America that are naturally rich in pro-vitamin A and then crossing these lines with elite natural land races and hybrid lines of maize with improved agronomic traits such as disease resistance and drought tolerance. The beta-carotene in golden maize is preserved during storage and processing, unlike common varieties of maize in which scarce pro-vitamin A is typically oxidized and forms off-flavors before the food is consumed. Novel breeding techniques enable rapid development of golden maize varieties that contain 2 to 3 times more pro-vitamin A than the original parent material from which it was developed, reaching levels able to fulfill a large part or all the nutritional requirement for this vitamin. Scaling programs for golden maize in Sub-Saharan African countries are highly effective in reducing vitamin A deficiency and related health issues in children and adults, and have boosted maize value chains at local and regional scale by increasing the production and value of maize grain.

Uses. Pro-vitamin A biofortified maize varieties offer a cost-effective approach to tackle malnutrition in regions where people consume maize, providing substantially to the daily vitamin A requirement. Suitable varieties of golden maize are available for all major growing areas in Sub-Saharan Africa that are ready to be scaled for both addressing malnutrition and increasing producer's profits margins. Acceptability studies have shown that consumers do not object to the color and enjoy the flavor of pro-vitamin A enriched maize. There is a range of hybrid golden maize varieties that can be multiplied by community and private enterprises that enable to rapid scaling and commercialization in growing areas. Hybrid types of pro-vitamin A enriched maize typically possess other improved traits that make them suitable for farming systems where production is limited by diverse challenges, and where other improved maize varieties may be difficult to obtain.

Composition. Breeders have released more than 50 varieties of golden maize in Sub-Saharan Africa that contain high levels of pro-vitamin A, i.e., 8 to 15 parts per million, allowing for more complete intake of health-protecting antioxidants. There are specific lines of golden maize that are adapted

for cultivation in mid-altitude highlands and lowlands within humid to semi-arid climate regimes, and that possess desired agronomic traits for growing areas. These lines provide similar yields as non-biofortified hybrids. Golden maize varieties that are tolerant to dry spells and low rainfall, and resistant to common pests and diseases, or chemical control agents, are developed from parent materials with those traits using novel breeding techniques. There are many multipliers and private seed companies that are marketing open pollinating and hybrid golden maize varieties in multiple countries across Sub-Saharan Africa which have proven to increase food sufficiency and dispensable incomes of farmers.



Available varieties of provitamin A biofortified maize.

Application. Golden maize varieties are cultivated following best planting methods, and soil and fertilizer management prescribed for the particular growing areas and conditions. Appropriate inputs and formulations of inorganic fertilizers secure higher yields from biofortified maize. On farmlands with low soil fertility status, it is recommended that the golden maize be combined with grain legumes through intercropping or rotation, and to combine manure application and mulching to improve availability of nutrients and water for the crop.

Commercialization and Start-up Requirements. Biofortified maize varieties with high levels of pro-vitamin A are becoming commercially available, most often in conjunction with national programs. Scaling this technology requires: 1) Clearly defining quality parameters, norms and screening methods for golden maize varieties from the viewpoints of all actors in the maize value chains, 2) Multipliers and seed companies in the region need to produce and market high quality seed that get the same or higher maize grain yield as non-biofortified varieties, 3) Link seed suppliers, maize growers, food processors and consumer groups to create demand for naturally nutrient enriched food, and 4) Provide financial support for local suppliers and smallholder farmers that catalyzes investments and purchases of golden maize seed. In some cases, promotional advocacy may be required to secure market acceptance of this brightly colored maize meal.

Production Cost. Development of golden maize varieties involves advanced breeding techniques in the lab and screen house, and extensive testing in the field that require significant investment from commercial and non-commercial breeders. The costs associated with producing seed of maize with high carotene levels are not substantially different from a common hybrid variety that is not biofortified. Large agro-input suppliers are selling golden maize seed to farmers in Sub-Saharan African countries at US $0.8 to $1.2 per kilogram for OPVs. Farmers need to co-invest in fertilizer inputs, and crop and soil management practices for golden maize to result in effective and sustainable increases in nutrition and income.

Customer Segmentation and Profitability. Pro-vitamin A enriched maize varieties appeal both to small-scale and commercial producers as well as food processing companies and livestock feed industry. The value of grains from golden maize in markets in Sub-Saharan Africa is 10% to 20%

higher than that of white non-biofortified hybrid maize. Cultivating pro-vitamin A enriched maize thus offers a substantial economic advantage over similar yielding varieties and non-improved types which makes it attractive for commercial and subsistence farmers. Other traits of pro-vitamin A rich varieties include short duration growth cycle and tolerance to drought and pests, thereby reducing risks of crop failure that lead to more stable incomes. Scaling programs in several countries have shown there is a very high degree of acceptance and widespread demand for pro-vitamin A enriched maize by farming households, commercial growers, food processors, livestock feed industry, and consumers across both local and regional markets.

Licensing Requirements. Hybrid varieties of golden maize are marketed under a commercial license, while open pollinating varieties are royalty-free for multiplication by farmers but require certification following national compliance for seed quality. IITA and CIMMYT are responsible for the public development of golden maize varieties that are being steadily released to countries in Sub-Saharan Africa.

Technology 4. Commercial licensing of seed through TEGO® and TELA®

Summary. Improved maize varieties often do not reach the hands of farmers in Sub-Saharan African countries due to limited investments in the seed production sector. The African Agricultural Technology Foundation (AATF) has successfully addressed this situation by establishing a series of public-private ventures for commercial multiplication of high yielding, drought tolerant TEGO® (conventional) and insect protected TELA® (transgenic) maize hybrids. Enterprises in seven African countries now produce seed of these elite varieties and supply millions of farmers via this mechanism, supported by a licensing model and business training. This multiplication process of certified seed includes precautions that ensure true-to-type seed with a high germination rate is produced from parent materials. Hybrid maize varieties attract a high market value and provide great opportunity for businesses to generate returns on investments from seed multiplication and the development of new, improved lines. Major increases of food and nutritional security and farm incomes have been realized in areas where commercial seed systems for TEGO® and TELA® maize were put in place since these varieties produce higher grain yield and quality than commonly cultivated lines under both normal and lower rainfall. For more information on this solution, contact Dr. Jonga Munyaradzi of AATF via email at j.munyaradzi@aatf-africa.org.

TEGO® maize produced under a commercial license.

Technical Description. New improved traits in maize varieties developed by breeders and public institutions can only be made available to farmers by royalty-free licensing their production and distributing them as product lines via commercial transfer rights between businesses. This involves an agreement between the holder of intellectual properties for maize varieties, or a representative dealership, and a legally eligible person from the enterprise that intends to multiply and sell these seed commercially. AATF and its partners work together to create an enabling environment for regulatory approval of new, advanced varieties and commercial multiplication of their seed by private seed companies involved in seed production and trade. These linkages benefit from facilitation by relevant government agencies. From 2013 to 2020, a total of 7,032 tons of recently approved DroughtTEGO® and 161 tons of TELA® hybrid seeds were sold and planted on an estimated 287,720 hectares of cropland, to produce over 1 million tons of grains valued at USD 236 million, which benefited roughly 4.3 million people by enhancing grain harvest for household purposes and

sales. At the end of 2020, variety licenses were signed with 38 seed companies from seven countries to commercialize these elite TEGO® and TELA® maize hybrids as well as test new lines. In this way, the legal framework for intellectual property and breeder rights that is built into commercial variety licensing ensures safe market entry and attractive returns on investment for hybrid maize breeders.

Uses. Commercializing the multiplication of hybrid maize seed has proven to offer a dependable and accelerated route for bringing new and high-yielding varieties to the market in geographically and socially diverse areas; ranging from the cultivated drylands to the humid tropics, and to benefit both smallholders and larger-scale production. Some countries in SSA have well-established plant variety protection legislation and plant breeder rights in place that provide an opportunity for licensing hybrid seed multiplication to private seed companies. The geographic scope of licensing also varies, the most common domain in a commercial agreement is that of a single country, but it can also be part of a country, or more countries, or an entire region. There are more than 120 hybrids of conventionally bred DroughtTEGO® and 5 hybrids of transgenic TELA® maize that suit a large range of climate and soil conditions found across SSA and means for them to reach farmers have been greatly improved by facilitation of licensing arrangements.

Composition. Variety license agreements have two main parts; the first existing of clauses dealing with specific rights and obligations of the parties and the conditions that form the framework of the license, such as exclusivity, territorial domain, evaluation of the licensed material, protection of germplasm, national registration and plant variety protection, effect of termination, and reporting to licensor. In these clauses the standards for business cooperation and commercial objectives are set. The second section has standard clauses with details about legal processes for arbitration, relevant law, legality, warranty, and force majeure that are generally applied to such agreements.

Application. The multiplication of hybrid maize under a commercial license starts from foundation seed which is supplied under strict quality control standards established by 'Excellence Through Stewardship' that involves full life cycle management of agricultural biotechnology products. Once licensed, seed companies can multiply the improved maize variety as is and are also able to cross the inbred lines with their own variety for developing drought and pest resistant hybrids that are better adapted to specific local conditions. For quality control purposes and general uptake monitoring, the seed companies must report on the annual production and sales of the variety to their owner or broker. In the case of TEGO® and TELA® hybrids, this is AATF. Genetic purity of the traits in hybrid maize is tested through laboratory analyses and must be discarded if a batch does not meet quality standards. Seed companies review their commercial contracts and operating procedures on a continuous basis to ensure that obligations and standards are met. This approach provides a guarantee that farmers receive high quality seeds they expect.

Seed production of TEGO® maize.

Commercialization and Start-up Requirements. The licensing mechanisms and legal frameworks for commercial multiplication of TEGO® and TELA® maize are established in many African countries and are under development in others. Steps for entering into seed production for hybrid maize varieties include: 1) Conduct field tests to identify suitable hybrid maize varieties that addresses pertinent challenges faced by the crop in a specific growing area, 2) Develop a commercial variety license with the breeding company or institution that stipulates contractual obligations and operating procedures, 3) Select an area of land for multiplication that is fertile, properly irrigated and freely

draining, and free of weeds and pests, and 4) Market the hybrid maize seed with local agrodealers and organize cost-effective production and timely delivery.

Production Cost. The registration of a new maize variety with regulatory authorities in countries attracts a cost for seed companies but in most cases this fee is already covered by AATF as part of their programs. Usually, no royalties are paid to the variety owner for seed production under commercial variety licenses. Substantial labour expenses are incurred for the general management of crop stands, pollination and detasseling of the female parent to produce hybrid maize seed. To certify hybrid seed, the multiplier company must pay for quality control assurance of genetic purity by accredited laboratories, but these costs are relatively low and depend on the number of genetic traits and their complexity. All these factors are included within TEGO® and TELA® facilitation.

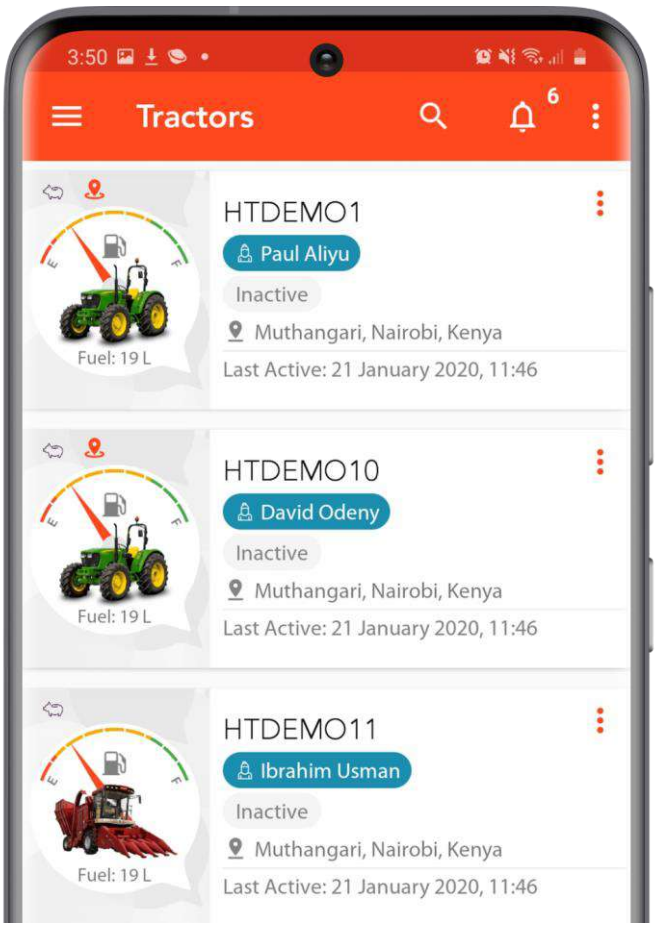
Customer Segmentation and Potential Profitability. The commercial multiplication of hybrid maize varieties is intended for private companies, cooperative associations and individual farmers. In the case of TEGO® and TELA®, variety licenses allow seed companies to broaden and enrich their product portfolio with sought after traits including drought tolerance and insect protection. Certification of seed offers the benefit of increasing sales because farmers know what they buy and are willing to pay a premium price as an investment toward greater yields. At a macro-economic level, the commercialization of the seed sector through TEGO® and TELA® increases competitiveness and transparency that in turn accelerates farmers' access to new improved varieties. At the level of farm enterprises, the access to hybrid maize varieties with drought tolerant and pest resistance traits is reducing risks and improving yields, which contributes to greater food security and incomes for households and commercial purposes. Cultivating maize varieties that naturally withstand episodic dry spells and pest invasions also costs less as opposed to common lines because these reduce the need for deficit irrigation and pesticide application.

Licensing Requirements. The TEGO® and TELA® mechanism is intended to streamline the licensing process for elite, climate-smart maize. At the same time, seed companies entering into the multiplication of certified hybrid seed must comply with national regulations around plant health and food safety that are in place across different African countries. TEGO® maize was developed through the Water Efficient Maize for Africa (WEMA) Program and TELA® maize was developed by TELA Maize Project in partnership with Bayer Crop Science, CIMMYT and NARS, coordinated by AATF all with the aim to address major challenges in African farming systems, and as such represent Regional Public Goods. The dissemination of these elite hybrid lines and brokerage of commercial licenses for these goods are then performed by AATF.

Technology 5. Contract mechanization services and applications

Summary. A growing number of service companies and private owners in Sub-Saharan Africa offer mechanized agricultural equipment for rental to farmers. Yet, such contracted use of modern technologies has remained limited among small-scale producers because contracting businesses face major challenges to inform lower-income communities of their services and convince them of its value. At the same time, contracted services provide mechanized operations using equipment that is otherwise beyond the purchasing power of small-scale farmers. Phone-based data systems provide unique opportunities for accessing this equipment by making it possible for clients to take better informed decisions and equipment providers to reach them as customers. One of the success stories in this arena is Hello Tractor, a power equipment sharing application that connects tractor owners and African smallholder farmers. This digital platform promotes collaborative consumption of mechanized field operations by creating a market place for equipment owners and companies where farmers can request and pay for services via messaging services and mobile wallets, as and when needed. The application allows for service provision to match seasonal demand for mechanization services and linked cash flows, and also supports credit scoring for risk management and loan repayment. For more information contact Jehiel Oliver of Hello Tractor at hello@hellotractor.com.

Technical Description. Digital information and communication technology is making it possible for equipment owners to track movement and use of assets, expand their serviceable geography, and manage payments in a timely and transparent way. For farmers, phone-based information and communication is creating equitable access to agricultural mechanization that improves crop productivity, reduces labour costs and grows incomes from farming. The Hello Tractor application embeds advanced financial analytic tools that minimize the costs and risks of using tractors and other power equipment on farms which increases confidence and modest investments in mechanization. It provides small-scale farmers with wider options for service provision beyond the most local tractor owners, making those services more competitive. Sensor technology lies at the heart of collecting intelligence on the internal workings of two-wheel and four-wheel tractors, and combine harvesters. Hello Tractor integrates multiple telematics solutions for commercial vehicles like GPS tracking, fuel management, driver management, maintenance and servicing, fleet management, fraud prevention and customer booking; which are operated via an easy-to-use dashboard available via smart phone. In this way, equipment owners can add value to their business and ensure sustainability of agricultural mechanization, both are very important factors for widespread scaling to link smallholder farming communities to mechanization.



Dashboard of the Hello Tractor app available via smart phone.

Uses. Digital applications offer major opportunities for promoting and managing use of agricultural power equipment in all types of crop and livestock production systems, both among small-scale farmers and commercial agribusinesses. Hello Tractor, in particular, is available as a mobile and web application, and has extended offline capability for the various modules to allow operations in more remote rural areas. The digital platform for contracting agricultural equipment can be used anywhere since it has the ability to roam different telecom networks, and achieves a GPS accuracy of up to 2 meters. To date, more than 3,000 dealers, fleet owners and banks in SSA make use of Hello Tractor to scale their business for contracted mechanization services on farms.

Composition. Platforms for contracted use of commercial vehicles and other agricultural equipment are integrating different telecommunication and information systems. Devices fitted on tractors to monitor operations are rugged in design, have high sensitivity, and are tamper-proof and weather-resistant. Hello Tractor, like other platforms, is based on the Internet in ways that that creates a network for physical objects through software applications, and embeds a pay-as-you-go system. Machine learning and artificial intelligence are widely employed by the applications for conducting tasks related to the optimization of equipment movement and analysis of performance data. This feature allows neighbors to combine their equipment needs in cost-effective manners.

Application. For equipment owners and service providers to make use of digital contracting applications, they need to have smart devices installed onto machines by an accredited technician. These owners then offer services directly to farmers, or may work through booking agents that aggregate demand within their community, or a combination of the two. Farmers who seek contract mechanization services must request, schedule and prepay for them via the SMS messaging or mobile applications that places them in touch with equipment owners or booking agents. A trained operator then brings the equipment to the field and performs the task after consultation with the farmer. Once a job is completed the balance of payment is settled through the digital system. Equipment owners and investors get detailed reports about the user and cost-effectiveness which allows them to improve business models and access financing for new equipment.

Start-up Requirements. To enter into contracting platforms for mechanized farming services the following steps are required: 1) Purchase and install smart devices for tracking equipment, and download the Hello Tractor application from Google Play Store, 2) Upload tractor specifications, trained operators and booking agents to your account, 3) Service farmers within the area of operation through booking agents, and 4) Track movement and performance of tractors, operators and booking agents to ensure maximum machine uptime, profits and reduced fraud.

Production Cost. Digital applications that help manage contracted use of agricultural power equipment can be downloaded for free by equipment owners, farmers and investors. Aside from the capital for equipment acquisition, owners must also invest in smart mobile devices and their installation by accredited technicians so that critical information about its performance can be regularly collected. The base cost of renting a four-wheel tractor for half a day (4 hours) typically amounts to US $60-70, and farmers making use of the service also need to pay the salary of the trained operator. Contracts for agricultural mechanization set up through a booking agent incur a commission that is paid by the farmer.

Customer Segmentation and Potential Profitability. This technology is intended for tractor and power equipment owners, agricultural service companies, and small-scale and commercial farmers. Digital technology for contracted agricultural mechanization monitors equipment health, fuel, and functionality in ways that reduces operational costs and maintains asset value. Route optimization ensures that tractors spend more time on the field making money and less time on the road travelling between locations. Digitization of asset management and service contracting assists equipment owners to reduce transaction costs. Ultimately, equipment dealers market more machinery as demand for mechanized services grows. Monitoring the performance and risks of shared power equipment usage through mobile data applications enhances transparency which allows farmers, owners and dealers to secure more financing from lenders. The success of Hello Tractor in Nigeria has shown that access to agricultural

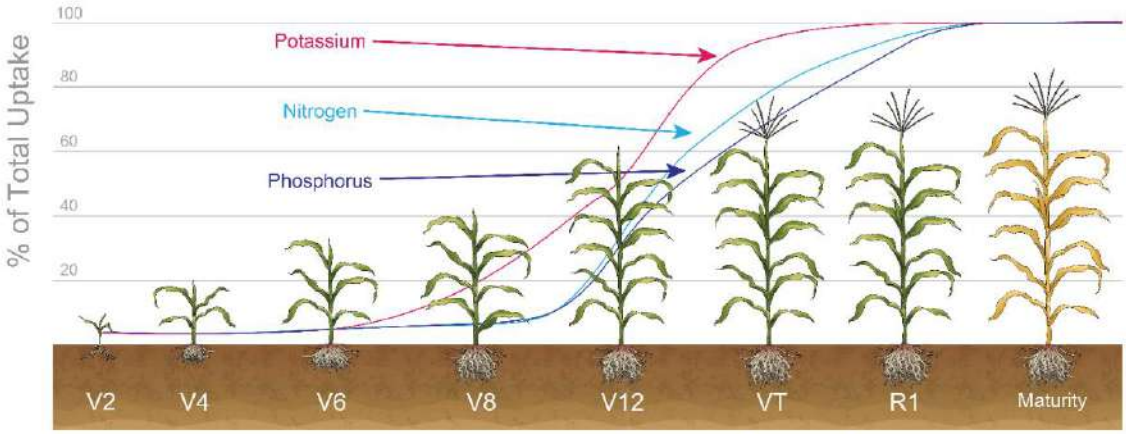
Linkages between the modules for fleet management, payments and business analytics within the Hello Tractor application.

mechanization at the lowest possible price by integration of digital technology enables smallholder farmers to drastically increase crop yields and save on labour costs in comparison to manual practices of the past.

Licensing Requirements. Digital applications for contracted use of power equipment, such as Hello Tractor, are free of commercial licenses and royalties. Sensors and other tools need to comply with operating standards and environmental regulations may require permits to import, assemble and market depending on the regulations of different countries. The Hello Tractor platform was developed as a regional public good for farmers but their intellectual property rights are held by the parent company. The example established by Hello Tractor warrants replication throughout Africa.

Technology 6. Pre-plant blended fertilizers and nitrogen topdressing

Summary. For maize to achieve high grain yields there is need of applying the right fertilizers at the right rate and at the right time following best agronomic practices. Shortages of nutrients such as nitrogen (N), phosphorus (P) and potassium (K) result in a weaker root system, crop stunting, disease vulnerability, low photosynthetic activity, fewer ears, less kernels, and incomplete grain filling. Many farmers in Sub-Saharan Africa do not use appropriate formulations, dosages and schedules of mineral fertilizers and this leads to reduced grain yields, low profitability and nutrient depletion of soils. Specialty mixes of common fertilizers that contain N, P, K, and other nutrients such as sulfur, magnesium and zinc are developed for basal application to maize crops as pre-plant applications that result in balanced availability of nutrients. N fertilizer inputs represent one of the largest investments for maize farmers, and its application is undermined by drought or excessive rainfall, and these extremes occur with increasing frequency. To overcome this inefficiency, it is widely recommended that N fertilizers are applied as split applications, with a special top-dressing later in the growing season. This practice ensures adequate supply of N for crops throughout the growth cycle and mitigates financial risks for farmers. Get more information from Dr. Jonga Munyaradzi of AATF via email at j.munyaradzi@aatf-africa.org.



Requirements of N, P and K by maize at different stages of the growth cycle

Technical Description. Use of "single" formulation fertilizers containing unbalanced formulations of N, P, K and other nutrients causes farmers to apply suboptimal and inconsistent supplies of nutrients that undermines maize production, often resulting in unsatisfactory returns on investments. This situation then discourages future fertilize use. On the other hand, blended pre-plant fertilizers are easy to prepare by mixing two or more single fertilizers using carefully measured formulas that address nutrient deficiencies, ensure no wastage and reduce costs of application to croplands. Agro-input suppliers and manufacturers offer specially designed pre-plant fertilizer blends for maize

which promote early crop development, stress resilience and grain production by efficiently supplying nutrients throughout the growing season. Top dressing N fertilizer later in the season better matches the availability in soils to the demand pattern of maize crops. The optimum time for top dressing N fertilizer is at the stage when maize crops have 6 to 8 fully developed leaves. It is widely demonstrated that African farmers can obtain higher maize yields with lower rates of nutrient inputs when using blended fertilizers at planting instead of single fertilizers, and splitting applications of nitrogen instead of a one-time input. At the same time, different soils contain varying amounts of nutrients. To maximize efficiency and profitability of pre-plant and top-dress fertilizer application it is necessary to account for residual nutrient stocks in soils and deficiencies in crops through visual inspection of stands and standard laboratory analysis.

Uses. Pre-plant fertilizers with specialty nutrient blends and split application of nitrogen by topdressing are recommended for maize production in all types of growing areas from SSA, this includes regions with dry, sub-humid or humid climates and in soils that are sandy, loamy or clayey. These fertilizer technologies offer particularly large benefits for smallholder farming systems where low amounts of mineral nutrients are applied, and degraded croplands where availabilities in soils are very low and imbalanced. Commercial maize farmers stand to reduce fertilizer costs and enhance profit margins through increased levels of fertilizer use efficiency that are achieved by pre-plant fertilizer blends and subsequent N top-dressing. The use of balanced fertilization for maize works well in conjunction with legume intercropping and rotation since the residual mineral nutrient inputs also benefit the accompanying crop and nitrogen fixation by legumes has residual value.

Composition. Specific nutrient formulas that fulfill requirements of maize can be made by blending a wide range of solid granular types of fertilizers like urea, calcium ammonium nitrate, potassium chloride, single or triple super phosphate and different sulfates. Micronutrients like zinc, boron and copper, amongst others can be added in solid form or impregnated as liquid. Readily accessible types of fertilizers and manufacturing facilities across Sub-Saharan Africa can be used to prepare appropriate blends of nutrients for maize crops. The rates of nutrients applied by pre-plant fertilizer blends and N top-dressing are based on specific yield targets and recommendations aligned with local conditions. It is not uncommon to apply pre-plant fertilizer blends at 250 to 350 kg/ha, and N top dressing at 100 to 150 kg/ha, depending upon fertilizer formulation and soil requirements.

Application. Formulations of specialty pre-plant blended fertilizers for maize crops are developed based on information about the nutrient deficiency and imbalance in specific growing areas contained within soil maps, extension advice and past agronomic experience. A dry rotary drum available in medium to large sizes is useful for mixing different single fertilizers that are sourced locally subject to availability. It is best for blended pre-plant fertilizers to be placed at the bottom of sowing holes by hand or planting equipment, but they can also be broadcast shortly before bed preparation and planting. For N topdressing, the most common fertilizers are urea or calcium ammonium nitrate, and there is a recent trend of using supergranules or slow release agents to improve uptake. Applications of the fertilizer on top of soils can be done at the base of maize plants by manual placement and using side dressers, or can also be broadcast by hand or using spinners. Foliar spraying of liquid N

Tractor-mounted driller for N topdressing.

fertilizer can also be used which is fast and has reduced losses through leaching and volatilization, but is prone to scorch and leaf damage if not properly applied. The timing for applying the second dose of N depends on nutrient availabilities in soils and rainfall conditions, for dry granules this must be done before a rain event to move the nitrogen into the soil, or just before final weeding for shallow incorporation into the soil. Note that maize, unlike many other crops is able to assimilate urea, making this lower-cost fertilizer suitable for many locations. At the same time, urea cannot be used by parasitic Striga (see Technology 2), lending advantage to the crop.

Dry rotary system used in fertilizer blending.

Commercialization and Start-up Requirements. Specialty fertilizer blends for pre-plant application with maize 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. A number of steps need to be taken for scaling the improved fertilizer technologies: 1) Identify appropriate formulations of blended fertilizers based upon balanced nutrient demands and soil fertility conditions for a specific maize growing area, 2) Develop protocols for mixing different single fertilizer and packaging the blend with agro-inputs manufacturers and suppliers, 3) Broker market entries for specialty pre-plant fertilizer mixes and N top-dress fertilizers at affordable prices and monitor sales, and 4) Conduct demonstrations on farmer fields that showcase the benefits of known fertilizer blends and N top-dressing for maize production. To remain competitive, fertilizer blenders must continue to refine their formulations and branding advocacy over time. One problem with some blends is settling, where denser fertilizers tend to sink within bags, a problem that is overcome through the manufacture of composite, pelleted fertilizers.

Production Cost. The initial development of specialty pre-plant fertilizer blends for maize is not expensive as it is based upon desk study from a wealth of secondary information, including the composition of similar products. Refining the formulation of blends is considerably more expensive for this requires agronomic trials and plant and soil analysis. Manufacturing specialty-blended fertilizers bears relatively large capital investments for multi-channel dry rotary systems and automated packaging. There is also the cost of assembling or purchasing the primary single 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 are available that can be operated by community-based groups once specific formulations are known. The manufacture of composite fertilizers is considerably more expensive than just blending single fertilizers as all their ingredients must be pulverized and reconstituted, but composite granules have the advantage of releasing all of their nutrients in a more uniform manner.

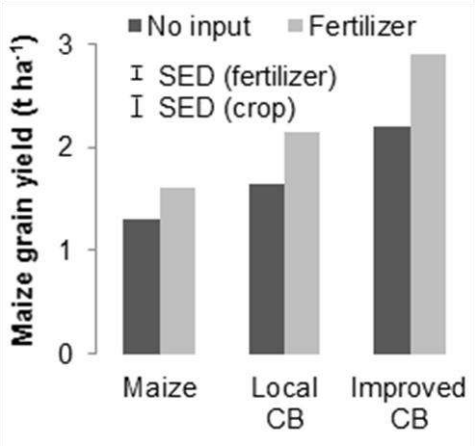
Customer Segmentation and Potential Profitability. Balanced nutrient management for maize crops through specialty pre-plant fertilizer blends and N topdressing is suitable for both small-scale and commercial producers. Manufacturing appropriate fertilizer mixes falls under the responsibility of large and medium-sized fertilizer manufacturers. Blended fertilizers offer multiple practical advantages for applications to croplands as these are made of homogenous mixes that do not coagulate and thus can be dosed directly from bags, thereby saving time and ensuring crops receive the right formula. Field trials in Ethiopia have shown that application of blended fertilizers with NPKS resulted in a grain yield that is 0.3-0.5 ton/ha higher compared to common NP fertilizer. In the same study, uptake of N and P from blended fertilizers with K and S added was found to be respectively

30% and 57% higher compared to that of applying NP only, because higher grain and stover yields were achieved with lower rates of N and P fertilizer. Split application of N fertilizer via top-dressing drastically increases the cost-effectiveness of input investments as the practice ensures that nutrient supply is aligned with crop demand, and diffuses risks of fertilizer losses that may arise from fluctuating weather conditions.

Licensing Requirements. The formulations of pre-plant blended fertilizer for maize crops may be subject to licensing but are more often protected as trade secrets. In cases when the fertilizer composition is publicly known the desired blend proportions can be easily calculated from different primary fertilizer materials. Responses to fertilizer application and combination are abundantly available as published information, particularly when performed by research institutions as Regional Public Goods. The International Center for Fertilizer Development (IFDC) is responsible for development and dissemination of balanced fertilizer practices for maize across Africa.

Technology 7. Maize-legume rotation and intercropping

Summary. Cultivating maize and legumes on the same piece of land simultaneously or in rotation offers multiple advantages as compared to growing the cereal as a continuous monocrop. Legumes enhance the amount of nitrogen (N) in soils during and after its cultivation which can be used to tackle constraints on cereal yields posed by nitrogen imitation, a widespread soil condition, and to reduce costs of mineral fertilizer inputs. Rotation and intercropping of maize with legumes make it possible to achieve a high level of land, nutrient and water use efficiency due to synergistic effects between the two different crops. Mixing of maize and legumes also reduces the infestation rate of weeds, pests and diseases on farmer fields which benefits the productivity of both crops and slows down the spread of organisms that are harmful to agriculture. Rotational and intercropped maize-legume systems are practiced by large numbers of farmers in major maize production areas across Sub-Saharan Africa, giving rise to substantial increases of maize and legume yields, and total harvests from an area of land. The cultivation of a high-carbohydrate crop (maize) and high-protein crop (grain legumes) on the same piece of farmland results in more nutritious diets among small-scale farmers, and also mitigates the risk of a hunger season when one of the crops may fail because of drought or pest attacks. For more information on this topic contact Dr. Frederick Baijukia by email at f.baijukya@cgiar.org.

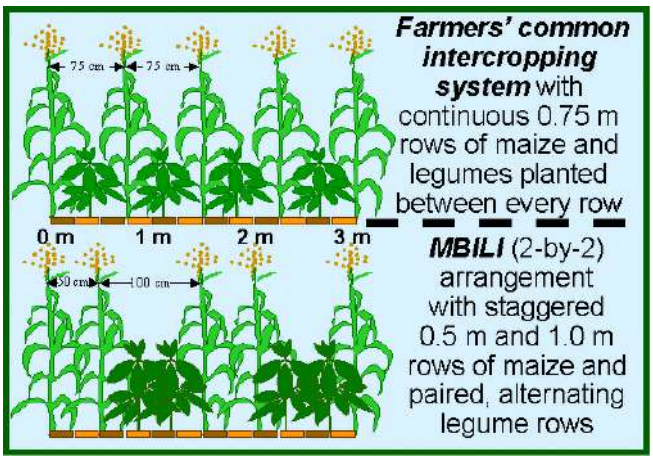


Yield benefit of rotating maize with climbing bean (CB) compared to continuous monocrop (Maize).

Technical Description. The benefits of intercropping and rotation are many. Biological nitrogen fixation taking place in the roots of legumes benefits the productivity of maize crops that are rotated or intercropped on the same field because part of the assimilated nitrogen is transferred between the crops through residual soil processes. Mineral fertilizer application in mixed cropping systems are used very efficiently since either of the crops can benefit from residual nutrients that might have otherwise been lost, due in part to the different root architectures of maize and legumes. Intercropping of maize and legumes is especially helpful in reducing weed infestation, soil erosion and run-off as the method of cultivation keeps more land covered and protected throughout the growing season. Some grain legumes such as soybeans and cowpea are known to decrease infestations of parasitic Striga weeds in maize crops since these crops will induce germination of

Striga seeds but do not become infected by them; with direct effect during intercropping, and residual benefits via rotation. Taller statured maize help to better regulate the temperature of the soil through shading. Understory legumes better utilize light, water and nutrients. In comparison to monocrop cultures, intercropping typically generates larger returns from labor, and like for maize-legume rotation enhances the profitability of mineral fertilizer and organic matter inputs. One difficulty with intercropping. However, is that some field operations become complicated, particularly mechanized and chemical weeding.

Uses. Intercropping and rotation is suitable for all maize and legume growing areas in Sub-Saharan Africa, as long as the variety and type of crops is appropriately selected for prevalent conditions. The mixed cultivation method is particularly advantageous in regions with less fertile soil. At the same time, continuous cropping of monoculture maize leads to soil nutrient depletion. In intensive maize production systems, intercropping and rotation of legumes has benefits on yields and profits over both the short and long term through reductions in fertilizer use and increased environmental quality. Intercropping of maize and legumes is very effective for rural communities where the availability of labor is limited as less time is spent on weed management. Indeed, the improvement of soil fertility and crop nutrition that is realized in mixed maize-legume systems contributes to strengthening the climate resilience of food systems and the communities that draw income from them.



Some recommended configurations of maize-legume intercropping.

Composition. Rotation and intercropping of maize can involve a large range of food legumes such as common beans, pigeon peas, cowpeas, groundnuts and soybeans, as well as legumes grown for animal fodder like desmodium, velvet beans and jack beans. The type of legume that is mixed with maize can be chosen by farmers in line with agro-ecological conditions, marketing opportunity, production needs, and eating habits. Improved varieties of both crops that are well adapted to specific conditions in growing areas should be used to derive maximal benefits.

Application. The approaches used for cultivating a maize-legume rotation or intercrop are the same as when growing a monocrop culture. For intercropping, the two crops can be planted simultaneously or in relay so their growth and harvest are aligned with farmer conditions and needs. Different layouts can be used for intercropping, with maize and legumes planted on alternating rows, in strips of 2-3 rows or randomly scrambled across rows. If mixed with common beans, cowpeas or peas, the maize crop can be planted at its usual density and the legume in between, while for legumes that requires greater direct light the spacing of maize crops needs to be adjusted. In many cases, legume crops should be inoculated with an elite strain of N-fixing microorganisms to maximize carry-over effects on maize. In many cultivated drylands, maize should not be grown intercropped with legumes, but rather strip cropping or rotation should be practiced.

Commercialization, Start-up Requirements and Production Costs. Information is available with regard to suitable approaches for combining maize and legume crops under different conditions on farmer fields, and farmers recognize the advantages of the practices. Scaling the mixed cultivation of maize and legume requires: 1) Educate farmers about the benefits of maize-legume rotation and intercropping, 2) Advise farmers on suitable methods for mixed cultivation and varieties to be grown depending on local contexts, 3) Mobilize high quality seed of maize and legumes, and 4) Secure

fertilizers and legume inoculants. Legume cultivation is associated with higher labor costs compared to maize, which makes that mixing the two crops provides an avenue to balance and diminish investment needs. Intercropping systems of maize and legumes usually have greater planting density than monocrop cultures and thus bears a greater cost of seed and fertilizer per hectare for farmers.

Client Segmentation and Potential Profitability. Intercropping and rotation of legumes with maize is attractive to small-scale and commercial farmers alike. Economic maize grain yields are increased by 0.5 to 1 ton/ha when cultivating after a legume rotation as compared to continuous maize. Yields of maize on croplands with a high infestation rate of Striga weeds increase by 90% when planted after a soybean rotation. Between 30 and 70 kilogram of nitrogen is carried over from soybean to maize crops when grown as a rotation. Mixed maize-legume cultures are able to maintain a high level of agricultural productivity for many years, which results in greater sustainability over time.

Licensing Requirements. No commercial or environmental licenses are needed for mixed maize-legume cultivation. Knowhow connected with intercropping and rotation of maize with legumes is considered an important Regional Public Good being advanced by IITA and AATF.

Technology 8. Weed management through pre-emergent herbicides

Summary. Weeds pose a threat to maize croplands because they compete for finite amounts of water and nutrients in soils. Failure to control weeds thereby reduces yields and limits returns on agro-input investments. It is critical to maintain control of weeds in maize stands, especially during its early establishment and vegetative growth stages, up to 10 weeks after planting. Without effective control of weeds, potential grain yield of maize is reduced by about 50% on average, and if no measures are taken by farmers the yield losses reach 80%. Most maize grown by smallholder farmers is weeded by the use of hand tools and is very labor-intensive because it must be repeated 2 or 3 times for effective control. This difficulty is caused in part because agitation of soils by shallow hoeing and harrowing promotes other weeds to germinate. Pre-emergence herbicides prevent weeds from developing making it possible to maintain fields largely free of weeds during the critical stages of crop establishment, an effect that carries over until the maize canopy shades the ground and weeds become suppressed. This class of herbicides is applied shortly before or at the time of planting maize and after the soil has been tilled which then prevents weed seedlings from establishing, but requires access to the proper chemicals and application equipment. For more information on this topic contact Dr. Jonga Munyaradzi of AATF at j.munyaradzi@aatf-africa.org.

Technical Description. Maize is most sensitive to weed competition between the stages of emergence up to the time when six leaves are unfurled. During this time maize's fibrous root system is under development and its shoots may become outcompeted by faster growing plant. Pre-emergence herbicides provide target crops a competitive advantage by eliminating competition for light, nutrients and moisture when it is most vulnerable during its early growth, and

Maize crop encroached by tall grass weeds.

thereby accelerate the development of roots and shoots. Major advantages are offered by use of pre-emergence herbicides in comparison to other weed control strategies such as manual and mechanical removal or post-emergence control of weeds that have sprouted using contact fertilizers. For one, the pre-emergent solution virtually eliminates seed dispersal from weeds that gives rise to long-term reductions in weed seed banks within the soil, and recurrent savings weed control over time. In general, one year of poor weed control requires seven years of later suppression through chemical control. Also, in fields with severe weed encroachment there is need for multiple control measures using both pre-emergence and post-emergence herbicides throughout the growing season, and in such cases the early-stage control that is achieved through the pre-emergence approach has shown to increase the effectiveness of later control efforts. Also, weeds may harbor pests and diseases that affect maize.

Uses. Application of pre-emergence herbicides is suitable for weed management in all maize growing areas of Sub-Saharan Africa, especially in farmer communities where availability of labor for manual removal is limited. Studies across the continent have shown that application of pre-emergence herbicides is effective on fields with a wide range of weed encroachment and under humid to semi-arid climates. The sort of weeds in farmlands, seasonal weather patterns and timing of other management practices are dictating the exact formulation of chemical agents and moment of application that is necessary for pre-emergence weed killing. In general, the seeds of perennial grasses pose a particular hazard to maize fields. Use of the chemical control technology must be combined with the appropriate input of inorganic fertilizers and organic resources to farmlands for the intervention to increase grain production and food security, especially on degraded fields with low soil fertility status. Pre-emergence weed control strategies have proven to be more effective than post-emergence responses which are most often used by farmers in Sub-Saharan Africa, thus providing a direct entry point for improving agriculture. Common broadleaf weeds in maize include Blackjack (*Bidens pilosa*), Wandering Jew (*Commelina benghalensis*), Striga (*Striga spp*), Mexican marigold (*Tagetes minuta*), Cocklebur (*Xanthium strumarium*), Thorn apple (*Datura stramonium*), Pig weed (*Amaranthus spp*) and Oxalis (*Oxalis spp*). Grassy weeds include Love grass (*Setaria spp*), Star grass (*Cynodon spp*), Couch grass (*Digitaria spp*), Wild oats (*Avena spp*), Bermuda grass (*Cynodon dactylon*), Yellow nutsedge (*Cyperus esculentus*), Purple nutsedge (*Cyperus rotundus*), and Guinea fowl grass (*Rottboellia cochinchinensis*). Some weeds are useful. They have edible leaves and may be the first food of any season (e.g. Amaranth and nightshade (*Solanum*). In other cases weeds are medicinal or may repel pests. It is important to remember that a weed is a plant which grows where it is not wanted and in some cases a weed is a plant whose use has not yet been discovered.

Manual weed control in maize fields is arduous and time-consuming.

Composition. Herbicides for broadleaf (dicots) weeds are usually made of atrazine, phenoxy (MCPA) or terbutryn compounds, whereas for grassy weeds (monocots) the most common herbicides are made of metolachlor, acetochlor or alachlor compounds. Further to this, adjuvants are added to pre-made formulations or spray tanks for enhancing herbicidal activity or application characteristics, such as better mixing and handling, greater droplet coverage, spray retention and droplet drying, improved herbicide cuticle penetration and cellular accumulation which minimize leaching of the chemical agents through the soil profile. Depending on the prevalent sorts of weed and type of maize cultivation, i.e., monocrop, rotation or intercrop, the pre-emergence herbicide needs to be

adjusted. Some herbicides (e.g. Dual Gold or S-metolachlor) affect plants based upon the size of seeds, meaning that control for both maize and intercropped legumes may be achieved by killing the multitude of small seeded weeds in soils.

Application. Concentrated pre-mixed or singular herbicides are diluted in water to activate the chemical agents following the prescribed ratio and safety precautions. The solutions are applied to fields using backpack systems with one or two spraying nozzles or by tractor-mounted systems with many spraying nozzles. Different application methods consider available equipment, intended placement, effectiveness on target weeds and labour requirements, including applicator skill sets. Protective clothing should be worn by workers that apply the herbicides to avoid contact with chemical agents. Soils should be moist, not too wet or too dry, when fields are sprayed thus requiring the time of application to be synchronized with rainfall, being carried out one week after tillage of croplands and latest before maize is 10 cm tall. Chemical weed control management technologies should be prioritized on fields with the highest level of weed encroachment and the more difficult to control weeds to maximize returns, with the intention to steadily decrease weed seed banks of the farms.

A properly equipped spraying service provider prepares to apply pre-emergence herbicide to a field.

Commercialization, Start-up Requirements and Production Costs. Agro-input companies market a range of pre-emergence herbicides that contain different chemical agents and are designed for eradicating specific kinds of weeds occurring in maize crops. Sprayer equipment is available from agro-dealers in major maize production areas. Widespread adoption by farmers of this weed management technology can be achieved by: 1) Agro-input dealers popularize and market pre-emergence herbicides in growing areas that are appropriate for common weeds, 2) Awareness-raising with farmers about benefits of chemical control strategy on food production and risk mitigation, and 3) Provide financial support for local suppliers and smallholder farmers that catalyzes investments on herbicides. Spraying pre-emergence herbicides requires some investment by farmers to purchase herbicides and access spraying equipment. Pre-emergence herbicide and the labor to apply these costs about US $27 per hectare.

Well managed, weed-free understory of vegetative maize plants.

Client Segmentation and Potential Profitability. Use of pre-emergence herbicides for weed management is intended for small-scale and commercial maize growers, with chemical products and spraying services being delivered by agro-input suppliers and local enterprises. The control of weeds with pre-emergence herbicides in fertilized maize crops raises gross margins by US $84 to $433 per hectare. Preventing weed encroachment of maize crops also enhances the palatability and nutritional content of grains which results in a greater value for farmers on local markets. Farmers must never consider the use of Paraquat (also known as Methyl Viologen) as this previously recommended herbicide is extremely toxic to humans and animals.

Licensing Requirements. Countries in Sub-Saharan Africa have specific regulations in place for compliance and use of chemical agents to eradicate weeds in croplands which have to be obtained by agro-input companies supplying local markets. The development and scaling of pre-emergence herbicides is done primarily by private companies, often in collaboration with independent research institutes. In some cases, import "dumping" of pesticides not approved elsewhere may occur.

Technology 9. Fall armyworm control with FORTENZA™ Duo

Summary. Fall Armyworm (FAW) has recently invaded Africa and is causing damage to maize and many other crops. Chemical control agents for FAW known to be effective in protecting maize crops from the pest but the pest has nonetheless spread across the continent and is threatening millions of farmers in major production zones.

Severe damage to maize by Fall Armyworm, a recent invasive pest in Africa.

A range of insecticide products are marketed on the continent by agro-input suppliers that kill larvae of FAW inside the soil and on the plant; including FORTENZA™ Duo seed coating chemical from Syngenta which is demonstrated to be a powerful control agent for the pest. Coating of maize seeds with insecticides protects the young maize plant from pest attack by enhancing seed survival, germination rates and initial growth stages after planting. Use of insecticide as a seed treatment offers several advantages compared to foliar applications as the approach makes it possible to apply smaller amounts of the control agent and is positioned into the soil where eggs of FAW are deposited and hatched. More information about this technology is available from Dr. Peter Chinwada of IITA via email at p.chinwada@cgiar.org.

Technical Description. FAW are the destructive caterpillars of the invasive species *Spodoptera frugiperda* and this pest is quickly spreading establishing itself across Sub-Saharan Africa. Infestations of farmlands by the pest are caused by eggs deposited in soil and on the plant coming from adult moths that are able to fly and cover large distances. The larvae of FAW are causing extensive damage to maize crops at all stages of their life cycle by eating the whorl (apex), leaves and cobs and have led to between 50% yield loss and complete crop failure. Insecticides like FORTENZA™ Duo are providing systemic protection to affected crops and are applied by seed coating. This form of application keeps maize free of FAW during the very early stages of cultivation. Other control approaches involve foliar sprays of other pesticides at later stages of maize development. Large reductions of fall armyworm infestation and damage to maize result from the use of maize seed treated with Fortenza™ Duo. Furthermore, planting insecticide-treated maize seed reduces the number of sprays needed at later growth stages.

Uses. Chemical control of FAW is suitable for all types of maize growing areas in Sub-Saharan Africa and can be dispatched to fields in a short time making it a good option to combat the rapid advance of the pest and reduce yield losses because of it. National Programs and seed companies in Zimbabwe and Zambia managed to distribute 6,598 tons of FORTENZA™ Duo treated seeds to over 650,000 farmers in two seasons, through which they protected about 264,000 hectare of farmland from damage to maize by FAW. Seed treatment may require follow-on sprays with insecticide to avoid later attack by larger larvae as they must consume much higher concentrations of chemical before succumbing to it. This explains some of the greater damage to leaves, whorls and ears seen at later stages of maize development.

Composition. FORTENZA™ Duo used for seed treatment has two active ingredients – Cyantraniliprole and Thiamethoxam – which protects maize from a range of insect pests. The insecticides are coated onto maize seeds by mixing it with a binding agent like Arabic gum, then vaporizing it over the material and letting in mix and dry in a rotary blending system. Insecticides recommended for use as foliar spray later in the growing season are Ampligo® (chlorantraniliprole+lamba cyhalothrin), DenimFit® (emamectin benzoate+lufenuron) or Neconeem® (neem), and are usually applied every few weeks or in response to symptomatic damage to the plant.

Maize crops with (left) and without (right) Fortenza™ Duo seed treatment on a farm in Zambia.

Application. Seeds coated with FAW insecticide are planted as any normal maize crop following best soil and fertilizer management prescribed for particular growing areas and conditions. Fortenza Duo is quickly taken up by the roots and moves up the plant controlling broad range of below and above ground pests including FAW larvae. Foliar spraying of the crop with chemical control agents at later growth stages is performed using common backpack or tractor-mounted sprayers. Applicators must wear protective gear including gloves, suits and face mask when handling these chemical agents to avoid contact with these toxic substances. Despite this emphasis on pesticides, controlling FAW requires an integrated approach – there is not one product that will silence the pest indefinitely. Seed treatment and foliar spraying of insecticide, along with improved varieties and good agronomic practices are all part of the solution. Inputs of inorganic fertilizers need to be applied for addressing nutrient limitations in soils so the crop grows strong. Infestations of FAW can be further reduced by intercropping crops that push and pull the pest away from maize crops such as brachiaria and tuft grass, and rattlepod legumes (*Crotalaria sp.*).

Commercialization and Start-up Requirements. Pesticide-coated maize seed is commercially available in many countries across Africa and others are rapidly following suite. Industrial-scale treatment of seed materials with chemical control agents can be embedded with existing production processes. FAW control through smart pesticide technologies can be widely promoted by following these steps: 1) Manufacturers coat insecticide onto seed of maize varieties that are adapted to

conditions in growing areas, 2) Awareness-raising with farmers about benefits of chemical control agents for FAW on food production and risk mitigation, and 3) Creating equitable access and financial support for local suppliers and smallholder farmers that catalyze investments and purchases of insecticide treated seed and foliar spraying.

Production Cost. For treating maize seed with FORTENZA™ Duo the required dosage is 6 milliliter per kilogram of seed, with an approximate cost of US $0.30 for the insecticide alone. Agrodealers in SSA are selling insecticide treated maize seeds at US $2.0 to $2.5 per kilogram. Hiring skilled labour equipped with knapsack sprayers to apply the pesticide onto the canopy of maize at later stages of crop development costs about US $25-30 per ha.

Youth spraying maize with insecticide to control FAW.

Client Segmentation, Potential Profitability and Licensing Requirements. Use of pesticide-treated maize seed and spraying of crop stands is intended for both small-scale and commercial farmers. African countries were quick to recognize the threat posed by FAW to food security and were quick to fast-track regulatory approval of control measures and to provide financial stimulus to control efforts. Use of insecticide treated maize seed and foliar spraying during the growing season ensures higher grain yields and avoids that the crop would be completely lost when farmlands are attacked by FAW pests. Protecting the crop through insecticide applications makes sure that investments of farmers are not lost and increases their profitability across growing areas that are infested by FAW. Agrodealers may require a phytosanitory and product safety license to distribute insecticides. The intellectual property related to the composition of chemical control agents is commercially owned.

Technology 10. Aflatoxin management

Summary. Common species of the soil-dwelling fungus *Aspergillus flavus* infest farmers' crops and foods, producing a highly toxic, cancer-causing poison called "aflatoxin". There is widespread and severe aflatoxin contamination of key staple crops, animal feeds and processed foods across Africa owing to conducive weather conditions, presence of extremely potent fungal strains, and substandard post-harvest handling and storage practices. In Africa, aflatoxin occurs in maize, groundnut, cassava, sorghum and rice, among others. When contaminated food is consumed by humans or livestock the aflatoxin accumulates inside the body and causes major damage to organs and blood. This toxin causes liver cancer, makes people weaker against other diseases and stunts children's growth. Animals like cows, pigs and chickens get sick from this poison as well, and their milk, meat and eggs can get contaminated with high levels of aflatoxin. The silent aflatoxin pandemic in Africa has massive

Maize cob (left) and kernels (right) affected by fungi producing dangerous aflatoxin.

economic impacts by making food unfit to eat or trade, robbing humans of health, and stunting and killing farm animals. Biocontrol technologies for aflatoxin exist that make use of natural competitors rather than industrial chemicals, and have been safely and effectively adopted on increasingly large areas of farmland over the past decade. Aflasafe® is product made in Africa for Africa that greatly reduces aflatoxin levels in food, and is inexpensive and cost-effective to purchase and use. For additional information on this technology, contact Dr. Charity Mutegi of IITA by email at c.mutegi@cgiar.org.

Aflasafe® product with its blue dye on a sorghum carrier.

Technical Description. Aflatoxins are extremely carcinogenic and pose a serious health threat in Africa, but one that can be met with an exciting new technology. Aflatoxins are poisons that are produced by fungi that grow in soil and plants, and that can proliferate in improperly stored foods, including maize. Contaminated maize then enters the general food supply and when used as feeds can also pass into animal products such as eggs and milk. Exposure to aflatoxin is associated with stunting in children, liver damage, cancer and other disorders. Biocontrol technologies for aflatoxin, such as Aflasafe®, use harmless types of the fungus *Aspergillus flavus* which do not and cannot produce the toxin. These "atoxic" types occupy the soil and crop where they out-compete their poisonous relatives, preventing dangerous ones from gaining a foothold into food supplies. Aflasafe® products are sophisticated in that they combine four different strains of *Aspergillus*, thus having multiple actors with different strengths to fight together. The particular strains in Aflasafe® are native to African countries and very common in the environment, meaning the balance of microbial ecosystems is not disturbed. The atoxic fungi are coated onto ordinary sorghum grain for transferring these innovative biocontrol agents to farmers' fields where these are broadcast before the start of the reproductive stage of crops. Aflasafe® stops contamination of food up to the point where it reaches consumers since it is carried along with grains during harvest, transport, and storage. Biological control technologies against aflatoxin work best in combination with other post-harvest practices such as proper drying and storage, but also perform under poor conditions such as damp storage within smallholder granaries.

Uses. Preventing food contamination by aflatoxin through the introduction of natural competitors of poisonous fungi is suitable for all types of agricultural production areas in Sub-Saharan Africa. Since the approach of Aflasafe®, and other biological products for aflatoxin management, is based on the use of atoxic fungal strains that naturally occur in agro-ecologies, the technology is well adapted to local conditions, including heat and drought. Aflasafe® products have a special mixture of fungal strains that is collected and tested over several years in various countries, and only strains that heavily suppress toxic fungi are included. Applying biological control products on farmer fields is sensitive to weather conditions, but even if drought strikes, the spores of atoxic fungi remain viable and take effect later once growth conditions become more favorable.

Composition. The active ingredients of Aflasafe® are strains of the fungus *Aspergillus flavus* which do not produce aflatoxin. Combinations of four strains are carefully tailored for each country by screening thousands of candidates obtained from local environments. Each strain is subjected to extensive field testing to ascertain they are physically incapable of producing aflatoxin. For Aflasafe® sorghum grains are used as carriers of the spores of these biological control agents after the grains are killed by roasting in a heat tunnel. This heat treatment ensures that the sorghum carrier cannot germinate in farmers' fields and grow as an unwanted crop. A small amount of maize starch is mixed with the spores to ensure they adhere onto the surface of the carrier grain in adequate numbers. The sorghum grain acts as an initial substrate (food source) for the atoxic fungi once they are applied

to the field and become activated. A blue dye is also added to distinguish Aflasafe® product from other sorghum for food or feed use. Carrier materials that are cheaper than sorghum grain, such as cassava peel waste, are being tested as alternative carriers as well.

Application. Aflasafe® products must be spread within crop stands 2-3 weeks before the onset of the flowering stage, which can be performed by broadcasting handfuls onto the surface of the soil, or by using tractor-mounted spinners or side-dressers. Farmers need to apply Aflasafe® to their crops early so that native poisonous fungi cannot get a competitive advantage. Farmers must be able to anticipate flowering for Aflasafe® to be used most effectively so it is important that farmers carefully monitor crop growth. Applying the biological control products should coincide with rainfall and moist soil conditions to become well established. Using Aflasafe® is highly effective in conjunction with grain banking schemes where farmers set up their own marketing associations to inspect, bulk, store and trade maize or groundnut. This strategy allows them to sell produce for top prices to larger-scale buyers, such as millers, but also gain greater control over their quality of their local food supply and to sell small quantities of safe foods for reasonable prices during grain shortages.

Commercialization and Start-up Requirements. Aflasafe® products are currently being produced and marketed in Burkina Faso, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, Tanzania, The Gambia, Uganda and Zambia. Other countries are in the process of identifying and registering the biocontrol agents, and constructing production facilities. The following steps need to be taken for scaling aflatoxin management strategies among farmers: 1) Registering biocontrol agents with national authorities and supporting them through the process of health assessment, 2) Developing plans for rolling out the control strategy based on specific local conditions and expert advice, 3) Drawing up legal technology transfer agreements with partners that enter into Aflasafe® production, 4) Providing support for start-up of manufacturing, distribution, and marketing by companies and organizations, and 5) Training in quality assurance and establishment of safety checks. Clearly, public sector support is required to initiate his process, but it can then become run by private sector biotechnology companies.

Production Cost. The machinery needed to produce Aflasafe®, such as the cleaner and roaster for the sorghum carrier, the seed treater, and the packaging equipment, is available off-the-shelf throughout Africa. For large-scale production a starter dry inoculum for the atoxic fungi can be used that is convenient in storage and handling, which avoids the need of a sterile laboratory to multiply the agents and substantially saves on costs. Producing these spores can become a separate enterprise. Purchase and installation of equipment and construction of a plant for production of Aflasafe® in Kenya with a capacity of 10 ton per day cost US $1.2 million to construct. Investments for manufacturing and distribution are typically made by both the public and private sectors. The task of applying Aflasafe® on farmer fields is quick and easy with an area of one hectare taking one hour to treat by four people. At the required dosage of 10 kg/ha the Aflasafe® product costs between US $12 and $20, which should be applied by farmers once each growing season. The advantages of protection against aflatoxin are best supported through higher prices for safer commodities.

Treatment of maize field to prevent aflatoxin contamination.

Customer Segmentation and Potential Profitability. Biological control technologies for aflatoxin are intended for use by small-scale and commercial maize farmers. The strategy is highly cost-effective since the product is relatively cheap and generates large returns on investment. A survey of smallholder maize farmers in Nigeria who used Aflasafe® found that an extra US $318 per year was earned on average, which increased net income by 16%. Preventing the contamination of food through biological aflatoxin control makes it possible for African harvests to be sold on high-value international markets as well, and improves local production for livestock and poultry farmers through the assurance of safer feeds. Market studies demonstrated that poultry producers are willing to pay a premium of 4 to 20% more for Aflasafe®-treated feed since it is good for their business. Further benefits from aflatoxin management include reduced incidence of preventable chronic sickness and cancer that strain health systems, and makes households loose income.

Equipment needed to produce Aflasafe® at commercial scale.

Licensing Requirements. Manufacturers of biological control technologies for aflatoxin must gain approval to use certified strains of atoxic fungi, and then comply with national regulations around production and distribution of microbial agents. Farmers do not require permits to apply Aflasafe® to their fields. The atoxic strains of *Aspergillus flavus* used in biocontrol are never copyrighted in any way, but remain the genetic resources and property of the nations where they are discovered so they may be used for maximum good. The International Institute of Tropical Agriculture Business Incubation Platform is responsible for the development and dissemination of Aflasafe® across Sub-Saharan Africa.

TAAT as your technology broker of choice

TAAT offers its services toward the advancement of modernized agriculture. It brokers a wide range of needed technologies as represented in this catalogue and bundles them through a process of co-design into winning solutions. It recognizes that modernized agriculture is destined to serve as the main engine for economic growth in Africa's maize production areas. Change is intended to achieve not only food and nutritional security but also to meet increased trade and improved environmental quality, allowing collaborative efforts to better combine global, national and community-level interests. TAAT operates from a unique perspective to mobilize innovative solutions through better partnering that includes honest technology brokerage and effective, scalable skills development through five key mechanisms.

- ☑ **Unique understanding:** Expertise is offered in the areas of site characterization and problem identification.
- ☑ **Innovative solutions:** Leadership is provided in technology brokerage and solution bundling based upon a dynamic portfolio of candidate technologies.
- ☑ **Better partnering:** Assistance is offered in the better co-design and management of projects prompting agricultural transformation.
- ☑ **Replicable approaches**: Assistance is available to advance skill sets in technology brokerage and project management through customized Training of Trainers.
- ☑ **Honest brokerage:** An independent capacity for impact assessment and constructive learning is achieved through standardized monitoring and evaluation.

These partnership mechanisms are applied to the technologies featured in this catalogue as follows:

1. **Improved varieties of maize.** The latest improved varieties of maize in terms of drought tolerance, combating parasitic striga and nutritive biofortification are provided by TAAT to national authorities for testing and approval, and upon release assistance is provided in the design of seed systems that accelerate seed production and distribution to farmers. Alternatively, the emergency release of imported seed directly to farmers can be arranged to combat project food shortages. *These services are arranged by TAAT and IITA with its partner The African Agricultural Technology Foundation (AATF).*

2. **Accelerated commercial licensing of improved varieties and hybrids.** TAAT's Maize Compact partner, AATF operates a mechanism that accelerates and supports the licensing of improved maize varieties and hybrids to commercial seed producers. The TEGO® and TELA® mechanisms is not only extremely useful to those intending to license and produce these improved maize varieties, but it serves as a model to others who seek to distribute improved varieties of other crops, particularly those offering environmental resilience to climate variation. *These services are arranged by TAAT through its partner AATF.*

3. **Improving maize-based cropping systems.** While this catalogue features several key technologies related to maize farming, it is not intended as a grower's manual. At the same time, it recognizes that modern farmers are interested not only in the production of single commodities such as maize, but rather in the establishment of high yielding and profitable cropping systems. For this reason, this catalogue includes reach to mechanization services, fertilizer strategies, integrated cereal-legume production and weed and insect pest management. All of these technologies are intended to cut across individual crop enterprises and assist African farmers to modernize their systems as a whole. Allow *TAAT and its partnering expertise in soil and water management from the International Water Management Institute*

and the International Fertilizer Development Center to assist in the design of more robust cropping systems better able to overcome climate variation related to combinations of heat, drought, flooding and more rapidly evolving pests and pathogens.

4. **Food systems perspective.** Agriculture, food, nutrition and public health are becoming unified into the common perspective of food systems after having been fragmented into individual disciplines for many years. TAAT offers technologies related to nutritionally-enriched foods, requiring that biofortified crops be introduced in a multidisciplinary manner before they can achieve their intended impacts. Allow TAAT to assist in developing a more advanced food systems perspective and to provide the biofortified crops and accompanying management technologies required to achieve healthier crops, animals and people. *Indeed, TAAT and all of its partners hold expertise in food systems and are committed to transforming agriculture from the food, nutrition and health perspective.*

Be assured that TAAT is prepared to partner with development investors, national projects and the private sector in a demand-driven manner; always in the spirit of participation toward the co-design and collaborative implementation of solutions that advance the modernization of African agriculture.

Conclusions

This catalogue provides a wide variety of options for modernizing maize production in Africa. It identifies high yielding varieties that resist drought and pernicious pests, and means to improve nutritional value of this important grain staple. It provides better options for large-scale production of improved maize seed through existing mechanisms for commercial licensing, and access to mechanized agricultural equipment through platforms for contracting between owners, brokers and farmers. The catalogue advances fertilizer and soil nutrient management in maize cultivation by featuring balanced pre-plant and top-dress mineral inputs along with mixed cropping with legumes to increase belowground N stocks in cropland soils. The catalogue advances weed management by signalling the advantages of specialty herbicides for application during the early stages of the maize production cycle. It also provides insights about the techno-economic implementation of Fall Armyworm control strategies by seed-coating and spraying of chemical agents. It also features a biotechnology that prevent aflatoxin contaminants from entering food systems. Maize grain is an important human food, but it can also be processed into high quality flour and possibly starches from which a wide variety of products can be manufactured. In addition, maize stover is widely used as fodder for livestock, and important for practices like mulching and soil carbon maintenance. Technologies featured in this toolkit offer the means for maize growing communities in Africa to access the high-end of the value chain and global market place, which can boost incomes of small-scale farmers and commercial agribusinesses alike.

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 maize around its toolkit of modernizing technologies. Members of the private sector, including seed producers, 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

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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 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 photos: Seed maize for multiplication of TEGO® under commercial license (left), and women applying Aflasafe® to prevent contamination of maize crops (right). Photographic credits: African Agricultural Technology Foundation (AATF) and International Institute of Tropical Agriculture (IITA).

Maize Technology Toolkit Catalogue

In collaboration with

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PROSPERITY THROUGH TECHNOLOGY

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