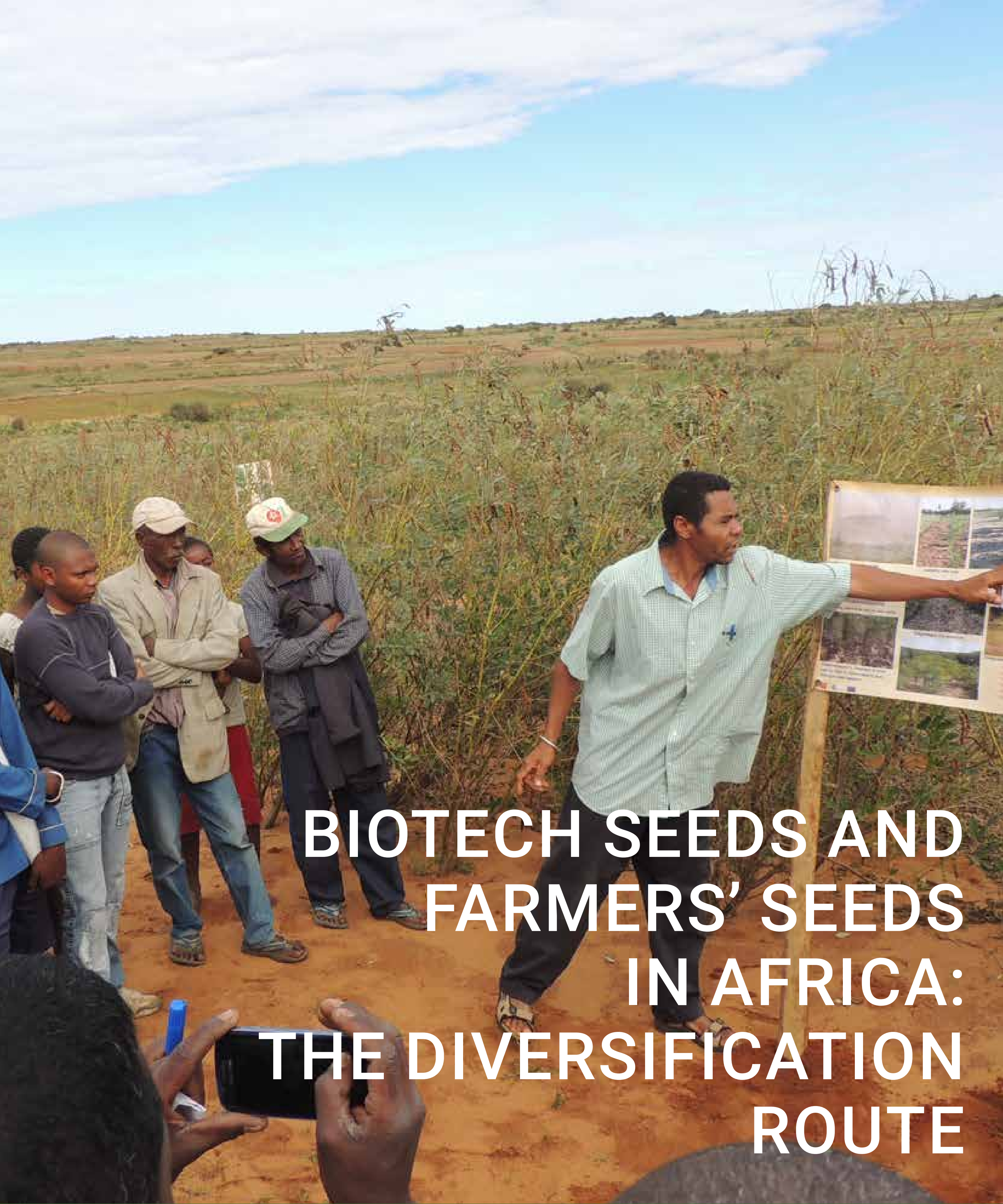

BIOTECH SEEDS AND FARMERS' SEEDS IN AFRICA: THE DIVERSIFICATION ROUTE

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Monthly reports

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In December 2019, Kenya decided to authorise the commercialisation of transgenic cotton within the country. "*This should help farmers increase revenue thanks to increased levels of production"*, explained Head of State Uhuru Kenyatta. The decision has largely gone unnoticed. However, it represents a turning point. The country, which passed a bio-security law in 2009, had banned all imports of transgenic products, including food products and seeds for food production. GM (genetically modified) plantations were banned. Only strictly-controlled research projects were able to take place. On one side, the *African Agricultural Technological Foundation* (AATF), a pro-GMO organisation based in Nairobi, was lobbying the government to repeal the ban. On the other, Greenpeace was calling for the ban to be maintained **to prevent *"big business from taking over the food production system"*.**

In the end, Kenya decided to adopt a three-phase approach to setting up GM farms, known as 3 F: Fiber-Feed-Food. The first phase involves adopting Bt cotton[1], followed by fodder crops. Only then will the production of GM food products for human consumption be considered. In this way, the authorities plan to give themselves time to assess the risks involved in this decision. Bt cotton field tests carried out in the country over the past few years have shown that the transgenic crop produces yields 30% greater than conventional cotton. There is, therefore, an agronomic argument to be made. The other argument is industrial, with the country's ambition to impose itself as the regional leader in textile production. As East Africa's biggest economy, Kenya's position may influence its neighbours, which share the same agricultural and industrial challenges.

Since the 1980s, new technologies used by plant breeders have emerged, inspired by genetic engineering and genomics, leading to the development of GM plants. Since then, biotech research has expanded considerably. With African populations still suffering from food insecurity, the use of these resources, in particular transgenic seeds, is presented by supporters as a means of overcoming most of the constraints which are hindering the development of agriculture. However, African decision-makers, scientists and farmers remain divided over the advantages and potential risks of transgenic crops.[2]

How is the argument framed, and what are the options for using biotech seeds to overcome agricultural and food production issues in Africa? This question underpins the continent's food and nutritional security. It is all the more pressing in the context of emerging from the COVID-19 pandemic crisis, which will have disturbed agricultural and food production systems while opening the way to new options.

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[1]"Bt" refers to a toxin produced by strains of the bacterium *Bacillus thuringiensis*. It is a GM variety created by the American firm Monsanto (absorbed by Beyer in 2018).

[2] The African Seed Access Index (TASAI) monitors essential indicators (number of varieties, accessibility, quality, price, yield, extension services) crucial to the development of the seed sector for fourteen African countries.

GMOs - precedents in South Africa and Sudan

In 2018, there were almost 192 million hectares of GM crops, or 12% of crops worldwide, in 26 countries (ISAAA, 2018). Four GM crops dominate - soybeans for livestock fodder, maize, rape, and cotton - achieving almost complete market saturation in the United States, with 93.3% of the market (average for soybeans and maize), Brazil (93%), Argentina (almost 100%), Canada (92.5 %) and India (95 %). Biotech crops have expanded with alfalfa, sugar beets, papaya, squash, aubergine, potatoes and apples, which are all already on the market. Indonesia has planted the first drought-resistant sugar cane. Research into biotech crops by public sector institutions includes rice, bananas, cassava, yam, cocoa beans, coffee bushes, potatoes, sweet potatoes, wheat, chickpeas, pigeon peas (*Cajanus cajan*) and mustard. This research focuses on various aspects of nutritional quality and economic advantages for producers and consumers of food products in developing countries.

In Europe, maize MON810, which produces an insecticide to protect the plant from corn borers, is the only GM crop approved for use in Europe. France has put in place a moratorium on planting GM crops. However, 70 GMOs are authorised for consumption in Europe, most of them for livestock. In this way, Europe imports transgenic soybeans to feed cattle, thus consuming them indirectly.

Transgenic cottons are now produced by most of the major cotton-growing countries: China, the United States, Australia and India, on very large farms. Brazil authorised GM cotton in 2006. Two African countries have been part of this group for several years: South Africa and Sudan.

South Africa was one of the first ten countries in the world to plant 2.7 million hectares of biotech crops. From 1997, over two million hectares of transgenic, lepidopteran-resistant cotton and maize were planted for commercial purposes. The country then approved GM soybeans. Adoption has been progressive. Today, 80% of maize, 85% of soybeans, and almost 100% of cotton in South Africa is genetically modified, for a total of around three million hectares.

For its part, Sudan has grown 245,000 hectares of Bt cotton with a 98% adoption rate among farmers. 90,000 of these farmers operate small farms, averaging 2.1 hectares. Some of the genes were introgressed with local varieties, to stimulate the expansion of this biotechnology with varying degrees of success. For small-scale farmers, farming by hand, the additional cost of transgenic licences is rarely covered by increases in yield, which remain low. However, for farms 50 hectares or more in size, there is a clear economic advantage which, nevertheless, varies depending on the level of infestation in fields and weather conditions.

GMOs, the newcomers

With over 3 million hectares of GM crops in 2018, Africa contains less than 2% of GM crops in the world. Apart from South Africa and Sudan, ten countries – Cameroon, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Nigeria, Uganda, Eswatini (formerly Swaziland) and Tanzania – are carrying out research and tests into biotech crops, with fourteen indicators covering twelve crops currently in development[3].

The Kingdom of Eswatini has started to grow IR (Bt) cotton commercially, with an initial launch of 250 hectares, making it the third African country to plant biotech crops.

Uganda is currently carrying out a series of GMO trials in *National Agricultural Research Organization* (NARO) centres. These GM plants are designed to be resistant to two cassava diseases whose spread cannot be contained by pesticides: brown streak virus disease, which destroys the edible roots, and mosaic virus disease, which can impede the growth of plants or even kill them. Ongoing trials are also examining a vitamin-A fortified banana and drought-resistant maize designed for the semi-arid Karamoja region, in the north-east of Uganda.

In Nigeria, the authorities approved the introduction of GM cotton in 2017. The country was also the first in the world to approve biotech cowpea farming, adding another crop to the worldwide GMO basket. This development was important because cowpea constitutes one of the main sources of protein for people with low incomes in rural and urban areas. The advantage of this variety is that it requires fewer pesticides (two sprays instead of eight) to protect it from, in particular, the *Maruca vitrata* pod borer, one of the most destructive insect pests for cowpeas, which can cause losses in yield of up to 80%. The PBR cowpea variety has increased crop yields by 15 to 20% during moderate *Maruca* infestations and by more than 100% in the event of severe infestations, given standard farming practices. This new variety represents one million of the 3.8 million hectares of cowpea currently being grown. The *Nigeria Agricultural Quarantine Service* (NAQS) has also supported initial herbicide-tolerant soybean trials. The *Virus Resistant Cassava for Africa* (VIRCA Plus) project is in trial phase. As there are a great many varieties,

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[3] Source: I*nternational Service for the Acquisition of Agri-biotech Applications.*

applying the technology is complex, and approval is needed for each one. Furthermore, crops such as bio-fortified sorghum are at different trial stages.

Rice has become a priority crop with strategic importance for food security in most African countries, where consumption continues to increase at a rate of 6 to 12%, which is higher than the rate of increase in production (3.4%), leading to a rice deficit of over 12 million tons a year. Biotic and abiotic constraints are the main factors contributing to low productivity. Most of these pressures are connected to the depletion and imbalance of soil nutrients (salinity, nutrient deficiencies and toxins) and availability of water (drought and excess water) given levels of rainfall in Africa. Furthermore, salinity in the rice production system in Africa is seriously exacerbated by the use of large quantities of irrigation water in lowland rice due to poor farming practices on the part of farmers, involving the use of brackish groundwater. In Ghana, scientists are carrying out trials of NEWEST (*nitrogen-use and water-use efficient and salt tolerant*) rice, designed to limit the use of nitrogen fertilisers and to grow in salty soils, while offering a good yield. Field tests in confined conditions showed that yields for NEWEST rice were 14 to 25% greater than traditional varieties.

GMOs - a disappointing experience in Burkina Faso

In West Africa, at the end of the 1990s, the cotton sector (white gold), was confronted with a devastating pest which was destroying harvests - the whitefly. Faced with this scourge, the government of Burkina Faso, one of the largest African producers of cotton (which represents 65% of monetary income for rural households), authorised tests for Bt cotton farming, carried out in partnership by Monsanto and the Institute for the Environment and Agricultural Research (Inera). Two local varieties were therefore introgressed at the Inera using Monsanto's Bt gene. The insect-resistant transgenic seeds were then made available to farmers in 2008. These locally-produced seeds were aimed at eliminating the cotton pest. In 2014, Burkina Faso counted the greatest number of transgenic cotton producers in Africa: over 140,000 smallholder farmers were then growing Bt cotton or 75% of them. Studies had shown that transgenic cotton would increase yields by 50% on average, despite the high cost of the seeds. The number of insecticide sprays could be reduced from six to two, significantly reducing the exposure of farmers to dangerous chemicals and saving them precious time.

However, five years after the operation was launched, it became clear the Bt cotton was not delivering on its initial promise. Inera-Monsanto varieties saw a drop in the quality of fibres, which is measured in length, leading to cotton from Burkina Faso being downgraded on the international market. Several explanations were suggested for the reduction in the length of fibres, without any one of them ever gaining traction over the others: poor understanding of necessary technical processes on the part of farmers, zones where cotton was not the main crop, exceptional increase in attacks from pests. Another factor was suggested by producers: the poor quality of Inera seeds and fertilisers distributed by cotton companies. The failure can therefore be attributed to a range of factors.

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Finally, even if yields appeared to be better in the fields, the cotton harvested had fewer fibres. For farmers who enjoyed a guaranteed price from cotton companies, this drop in fibre quality was not a deterrent in the short term. But for the three companies which dominate the cotton sector in Burkina Faso — Sofitex, Société Cotonnière du Gourma (Socoma) and Faso Coton — the situation was catastrophic. In 2016, seven years after adopting Monsanto's Bt cotton, they therefore decided to give up this variety of seed. In the space of a year, the Bt cotton variety therefore went from 70% to zero.

The fall in production which followed was terrible, with the worst results for twenty-two years. In 2018-2019, the harvest collapsed by 30% compared with the previous year. While producers were banking on a harvest of 800,000 tons of seed cotton, only 436,000 tons were produced, according to data from the Regional Program for Integrated Cotton Plant Protection in Africa (PR-PICA). Burkina Faso, which was the leading producer in Africa, dropped to fourth place, behind Benin, Mali and Côte d'Ivoire.

Reeling from the previous season's revenue losses and heavily indebted, a number of farmers from the traditional cotton-growing regions in the West (Boucle du Mouhoun and Kénédougou regions), decided in 2019 to divest from cotton and diversify their production. The 2018 drought did not improve matters, and security issues in the East of the country drove other farmers to abandon their harvest. Over 200,000 hectares went unplanted.

The example of Burkina Faso demonstrates the complexity of debates surrounding the advantages of transgenic crops for low-income farmers. In this specific case, the technology seems to have achieved its targets: making crops resistant to pests, reducing the use of pesticides, increasing yield, making working conditions less arduous. Others contend that many farmers appreciated these services, even though some doubted its capacity to resist predators in the long term and complained about abnormal deaths of animals which had eaten cotton residue. But the unexplained negative impact on the length of Bt cotton fibres resulted in companies abandoning this biotech option.

The real potentials of biotech

For three decades, controversies have impeded the use of genetic engineering technologies as a means of overcoming food security issues, as championed by their supporters. In fact, the players in these sometimes confused debates are often using different points of reference: politicians, researchers or technologists, farmers, seed companies, agro-food businesses, whistleblowers, the media.

In the face of serious challenges relating to rural development and food security, biotech agriculture is presented by its supporters as one of the solutions, with a clear, twofold objective: increasing the resilience of crops affected by droughts and attacked by pests, and stimulating yields thanks to properties which seeds would not have been able to acquire, or only at a later point, with traditional selection (ISAAA, 2018). How? We must go back to the question: what is a GM plant?

Plant biotechnologies are technologies which cover all *in vitro* modification of the organs, tissues, cells or DNA of plants, either to control or accelerate their production, or to improve their characteristics at the service of agriculture. GMOs are the product of these biotechnologies, but not all biotech seeds are GMOs. GMOs have, in their genome, one or two additional genes from a different species (most of the time a bacterium). These have been inserted in a laboratory and lend them new properties. The main plants grown (soybeans, maize, cotton, rape, alfalfa, beets) are genetically modified versions, with enhanced positive properties: resistance to parasites, fortified in nutrients, reduced need for fertilisers.

In this way, production is made more efficient for farmers, with many direct benefits: reduced use of insecticides or herbicides, time savings, simplified management of crops. There are significant advantages for consumers too: improved storage (delayed ripening tomatoes), improved nutrition (vitamin A-fortified rice, reduced nitrate levels in lettuce).

A new stage in the transgenic revolution is anticipated with, for example, the sale of drought-resistant varieties of maize, or other seeds which use nitrogen more efficiently, thus reducing greenhouse gas emissions. Additional qualities, such as protein content, may yet be found. The research also focuses on production related to typically African issues, such as developing transgenic cowpea seeds which are resistant to corn borers (insect pests which can destroy up to 80% of a harvest), or cassava seeds genetically modified to be fortified in iron, zinc, proteins and vitamin A, to overcome the main nutritional deficiencies for malnourished populations (25% of children in Africa). Sorghum is also a very important crop in Africa. It is a cereal which is well-adapted to semi-arid tropical regions, thanks to its hardiness and moderate consumption of water. But its yields are threatened by the parasitic plant Striga, which affects 40% of arable savannah land. Researchers combined the use of molecular genetics, biochemistry and agronomy to identify genes which would provide resistance to Striga. These were multiplied in locally-adapted and more modern varieties of sorghum, creating Striga-resistant hybrids adapted to Africa's different agricultural systems and ecological zones. These new types of sorghum are now grown from Sudan to Zimbabwe.

Because of this potential, the use of transgenic seeds is highly encouraged by international initiatives, such as the New Alliance for Food Security and Nutrition (NAFSN), launched in 2012 by the G8, which predicts a move towards the distribution, adoption and consumption of biofortified crop varieties. Foundations (such as the Bill and Melinda Gates Foundation) or charities which are part-funded by them (Africa Harvest, Africa Bio, Agricultural Technology Foundation, International Service for the Acquisition of Agri-biotech Applications) are lobbying States and funders intensely.

The most frequent objections

Will biotech plants (and animals) be part of the solution to future food security, or do they represent an agri-food industry being led astray by science and technology, as environmentalists and some scientists fear?

A recent ISAAA study (2018) carried out in six African countries - South Africa, Kenya, Egypt, Tunisia, Ghana and Nigeria - showed that an overwhelming majority of stakeholders emphasise the importance of proper assessment and management of the risks associated with biotechs. Because of limited capacity in Africa, a lack of scientific expertise and worries on the part of local populations, a centralised risk assessment system, similar to the European Food Safety Authority, is to be recommended.

While some varieties are already being grown and distributed in Africa, many voices are calling for caution with a long period of testing in a controlled environment to study all potential agricultural applications and all possible interactions with already fragile ecosystems.

The main reservations relate to GMOs. These reservations are of different types. There are two levels of risk to the agricultural ecosystem.

First of all, genes can travel to neighbouring plants and contaminate traditional seed or "organic" seed crops (when they exist). In practice, it is impossible to avoid pollinating insects or wind spreading pollen from genetically modified plants. Transgenes are present and active in pollen. If this "transgenic" pollen encounters sexually compatible non-transgenic plants, it could fertilise them, leading to part-transgenic progeny. Contamination risks also affect wild plants. There are therefore concerns of a "chemical escalation" which could damage farmers who want to grow non-GM crops.

The main GMOs are designed to make crops resistant to insect pests. Yet there are sometimes invasions of other varieties of insect than the ones against which the plant has been immunised. New, resistant predators appear (known as "secondary" pests). After a few years, farmers facing this situation are forced to increase the quantities of insecticides used. In the same way, the emergence of weeds (such as amaranth) sometimes requires new herbicides. When situations such as these emerge, it is easy to understand how the advantages of transgenic farming are cancelled out.

There is also the issue of health, which is articulated around the question: can the emergence of toxic or allergenic substances in food produced using GMOs be harmful to health? After dozens of years of transgenic plants such as maize, soybeans, potatoes or apples being consumed, epidemiologists have not flagged any causal relationship with the development of chronic diseases such as cancers, obesity or diabetes. However, caution should be exercised as "*the difficulty lies in detecting subtle or long-term effects on health or the environment*" (Kuntz, 2018).

Finally, the question must be put into context. Sometimes, genetic engineering is considered to overstep the bounds of what is socially acceptable. Most approaches to biosecurity focus on the health and environmental consequences of modern biotechnology. However, much of the resistance against the introduction of biotechnology is rooted in another reality - that of social traditions.

The question at the heart of the debates is not just whether the agricultural yields can be increased. It also concerns the preservation of the environment, health, social acceptance and the vulnerability of the populations in question.

Science has a vital part to play in these debates, as long as it does not position itself in opposition to traditional knowledge but rather aims to further it. Local knowledge may draw on biological resources in a way that is adapted to their environment. This knowledge can be articulated with the technical expertise of research teams building on other experiences in different regions with comparable ecosystems.

The need for seed diversity

Africa has a less diverse pool of seed varieties than other continents, in particular when it comes to subsistence crops. The majority of seeds used in Africa are, incidentally, produced by farmers themselves, except for industrial farming and market gardens. They come from three sources: 1. varieties improving on conventional plants from public plant breeders which, for the most part, "evolved" in farmers' fields and may have diverged from the original varieties; 2/ recent varieties from public and private plant breeders, mainly purchased by farmers. 3/ traditional varieties selected and preserved within a collective (family, cooperative).

Traditional or farmer varieties are not protected by intellectual property rights and are exchanged between farmers, respecting the collective rights (often oral) of communities which have selected and preserved them. These varieties represent an intersection of biological entity and farmer knowledge connected to it. They are often managed on a cooperative basis (community seed bank). They are adapted to regional environments and modes of production, and they present qualitative characteristics which appeal to local food product businesses and consumers.

The improvement of plants in Africa for subsistence crops traditionally involves a range of players: public research, responsible for creating the variety and basic seeds; the national seed service, responsible for organising the production of certified seeds either as a public administrator (although this is rarely the case any longer) or through networks of seed-producing farmers; the state service responsible for overseeing the certification and quality of seeds; extension services (which tend to be disappearing); and, finally, farmers, who buy the certified seeds which have been produced.

These farmer and traditional varieties do not have a legal status most of the time. Their characteristics have not been recorded, so as to be included in an Official Catalogue. However, original varieties are increasingly listed in regional catalogues (CEDEAO since 2015 and COMESSA more recently). To be recorded in these catalogues, varieties must present a minimum level of homogeneity. Without a catalogue, there is no trade, or almost none (AFSA and GRAIN, 2018).

The number of public plant breeders is in decline. The private sector, for its part, is almost exclusively focused on breeding plants in profitable sectors such as floriculture or market gardens, some industrial crops, and crops such as maize, in particular hybrid varieties. It is hardly present at all in the area of important traditional subsistence crops such as millet (Grain and AFSA, 2018).

The preservation but also the renewal of an increasingly less diverse seed pool in Africa are vital questions in the face of climate change. In certain countries, the average age of certain varieties of seed on the market is more than fifteen years. This is the case in Kenya (sorghum and cowpeas), Madagascar (maize and peanuts), Malawi (peanuts), Senegal (all crops) and Tanzania (beans). (Source TASIA, 2018). Without policies to renew the seed pool, there will be no resilience.

Lifting patenting constraints?

The agricultural biotechnologies sector is structured around two major developments: huge leaps forward in biotechnology (as discussed above) and the enhancement of legal protection for innovations. Plant biotech research is expensive (around 40 million euros to bring to market a genetic modification such as the aforementioned Bt in Europe). As for conventional selection, it takes around ten years to develop new varieties and, as is the case of for all applied research, doing so is a high-risk activity. Plant breeders must be able to exploit their products commercially. Intellectual property law exists to guarantee their return on investment. Successive conventions of the International Union for the Protection of New Varieties of Plants (UPOV) have put in place legal instruments for protecting innovations.

For a long time, aside from Kenya, South Africa, Morocco and Tunisia, African countries had no intellectual property system and public or private plant breeders did not receive remuneration, even when their varieties were widely used. As a result, public research budgets have shrunk as funders have moved out of the agricultural sector. The number of new varieties available to farmers, which was already low, has diminished further still.

In Europe, Plant Breeders' Rights (PBR) as assigned by the International Union for the Protection of New Varieties of Plants (UPOV) is considered to be the only effective *sui generis* system to protect plant variety. The UPOV system has three advantages compared with patents for varieties (which are forbidden in all African countries) beyond the essential shared advantage, which is to reward selection. The first is the option of using it freely for the selection of other varieties, protected varieties, without the agreement of the owner of the variety and without the need to pay them anything. The second is that farmers can use and reproduce these varieties for family uses, that is to say for what is known as subsistence farming. The third is the possibility for "commercial" farmers to reproduce the seeds of these varieties while paying the plant breeder less than what is required for certified seeds.

However, even though the Plant Breeders' Rights (PBR) system is less restrictive and rigid than patents, there are other options, drawing inspiration from India in particular. India, which is not a member of the UPOV, has adopted an original *sui generis* system with the 2001 *Protection of Plant Variety and Farmers Right Act*. Thanks to this law, farmers enjoy unlimited use of all varieties of plant, including transgenic varieties. They can trade and sell farm seeds as long as sales are not made under the name of the variety.

What are the hopes for change? The Plant Breeders' Rights (PBR) system is less limiting and rigid than patents. Putting in place generics may be an interesting development when it comes to patented genetic characteristics or events. The first GMO patents, which had twenty-year terms, are now in the public domain. That means that royalties need no longer be paid to patent owners. Biotechnological applications will therefore be less expensive and their use by farmers less restricted if new players (particularly from the public sector) decide to use these innovations to produce varieties of seeds which integrate them.

Other paths are open, drawing inspiration from the Indian example in particular. India, which is not a member of the UPOV, has adopted an original *sui generis* system with the 2001 *Protection of Plant Variety and Farmers Right Act*. Thanks to this law, farmers enjoy unlimited use of all plant varieties, including transgenic varieties. They can trade and sell farm seeds as long as sales are not made under the name of the variety.

Public research programmes using royalty-free biotech seeds and participative selection programmes both represent viable ways forward. "Licenses for humanitarian use" could also be an option. These would give farmers the right to use patented technologies for themselves or their close communities. A much-quoted example of this type of license is golden rice. Golden rice, created in 1999, is a transgenic variety fortified in iron and vitamin A, through the introduction of a ferritin gene. Vitamin A deficiency is a major cause of childhood blindness. Golden rice thus improved the lot of hundreds of thousands of children in the Philippines. Seventy patents were involved in the technologies used in this type of rice. The licenses were granted to the *Golden Rice Humanitarian Board* by around thirty companies and universities for free, without the need for small farmers to pay royalties. The episode remains controversial, but it does represent a precedent.

Research capacities exist in Africa with, in particular, four centres attached to the *Consultative Group on International Agricultural Research* (GCIAR) network: ILRI (livestock farming) in Nairobi, *World Forestry Center* also in Nairobi, ITA (tropical agriculture) in Ibadan and *AfricaRice* in Cotonou. Research has focused on creating new varieties better adapted to the environment in which they are farmed, but also on connected issues such as the occupation of land, enabling harmonious integration and synergy between different activities and improving environmental services such as water purification, flood and climate regulation, access to spaces where biodiversity is developed and valued, etc.

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To finish this overview, we will end on two certainties.

The first is that African farmers need quality seeds, and time is running out to put in place the solutions to agricultural and food security challenges in a context which will be marked, in the long term, by demographic growth, the dangers of climate change, and various upheavals which will surely follow the great COVID-19 pandemic of 2020. The continent is vulnerable, of course, but its capacity for resilience in the face of risks is also great.

The second certainty is that the potential of combining genetic engineering with environmental engineering, in association with the ingenuity of farmers, will be important to creating a sustainable agriculture and responding to the challenges of food production, which will need to double by 2050 in Africa. Biotech plants, including GM plants, are not a panacea and do not represent the main solution for the future of agriculture in Africa. They can, however, offer welcome technical responses within an overall approach to diversifying agricultural practices and uses, alongside agro-ecology, conventional agriculture and organic farming. Diversity guarantees sustainability.