THE EXCITING ROLE OF PUBLIC AGRICULTURAL RESEARCH IN AFRICA'S GREEN REVOLUTION

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ABSTRACT

While the potential for public agricultural research institutions in Africa to play a role in an African Green Revolution has been frequently noted, the input these institutions have had on food supply and farmer productivity has often fallen short of its promise. Recently, however, through a series of innovative, new partnerships formed with the private sector, agricultural universities and national agricultural research institutes have begun to emerge from the shadows to play a more critical role in creating positive change for farmers.

In fact, Africa's universities and agriculture research institutes have long been aware of their own capabilities, but perhaps remained too protective of their results in the interest of preserving the sanctity of 'public goods'. Research publications in international journals, improved technologies for crop management and improved crop varieties all figure in the litany of achievements by researchers working with public universities and institutes. What has frequently been lacking from the equation is an effective means for sharing such technologies on a sustainable basis with large numbers of farmers in a way which would allow for meaningful feedback on needed improvements (an effective feedback loop). Farmers on the other hand, have often been deprived of access to these technologies, and indeed most remain unaware that such research is being carried out on their behalf. A number of aborted attempts by universities and public research institutes at commercializing their own results have only served to reveal the inappropriateness of these institutions at surviving long-term in an increasingly competitive commercial environment.

Recently, however, a growing number of public universities and research institutes in Africa have overcome previous misgivings about the role of the private sector in agriculture development and have formed genuine partnerships with private companies. These partnerships have been facilitated, in part by policy reforms which allow them. In part, they are also the result an emerging (and increasingly professional) generation of private, agricultural enterprises. Through such agreements, public goods remain public in ownership but are transformed into commercial, privately- managed products through their use by private enterprises. At a recent field day conducted at the Kenya Agricultural Research Institute, a series of new, high yielding maize varieties was on display, with the name of the hybrid and the name of the private seed company which entered into a licensing agreement to commercialize that hybrid prominently displayed. Several new soybean varieties developed at a university in Uganda have likewise begun to reach small-scale farmers in large quantities through licensing agreements with seed companies.

In the view of the author, this can only bode well for the public institutions involved the private, risk-taking agricultural enterprises, and farmers , who for too long have remained in the shadows of Africa's liberalised economies. Several of the KARI hybrids have already been multiplied in the hundreds of metric tons and sold to farmers, whose yields have increased as a result. The case of soybean in Uganda is a similar,

emerging, success story. It is high time Africa's public research institutions and agricultural universities shed their remaining misgivings about 'going commercial'.

1.0 INTRODUCTION

Agriculture continues to be Sub-Saharan Africa's largest area of economic activity, accounting for 40% of GDP and 60-80% of employment and yet it is the one region of the world where the food supply situation continues to worsen as the population grows. In the rest of the world food supply has been increasing faster than population for a decade or more. In Africa the food supply situation can only be described as urgent:

(i) In the past 15 years, the number of hungry people has risen by 20% to over 203 million (IFPRI, 2005).

(ii) In the past five years alone, the number of underweight children has risen by approximately 12% (IFPRI, 2005).

(iii) 16 of the 18 most undernourished countries in the world (>35% of population undernourished) are in Africa (FAO, 2005).

As it has been throughout the world, increasing the level of farmer productivity is a prerequisite for economic growth and development in most African countries. The production growth needed will have to come from improved farm policies, technologies (high quality seeds of improved crop varieties of local staples, improved fertilizer use and integrated soil fertility management technologies) and techniques, including those that address climate change. However, for such productivity gains to be achieved, strong public agricultural research institutions are needed to generate key technologies needed to improve crop production in farmers' fields and effective linkages of these public institutions to the private sector that can scale up and disseminate these technologies to the farmers. All these require well trained human capacities.

Increasing agricultural research capacity is seen as an important factor in building food security and economic stability in Africa. New and better-targeted technologies are essential to this process, and a well-developed and well-supported agricultural research system is a prerequisite not only for the design of these technologies but also for their dissemination and adoption (Beintema, 2004). Growth in agricultural research and development (R&D) investments in SSA has however, remained stagnant over the past two decades while funding has become increasingly scarce, irregular, and donor-dependent. Institutional reforms and sound S&T policies are needed to improve the efficiency and effectiveness of agricultural research in Africa. Several research success stories are worth noting in Africa. These include; Nerica rice varieties, better adapted to harsh environmental conditions, can smother weeds and are more productive, enabling farmers to achieve improved livelihoods. These varieties have spread through most of the continent. Another case to note is the improved cassava varieties that are resistant to

African Cassava Mosaic Virus and resulted in a yield increase of 49 % over the average yields. The last case of a non exhaustive list to note are the biological control methods developed through research that have significantly reduced the losses caused by the cassava mealy bug and green spider mite. These successes and many others indicate the immense potential available in public and international research scientists and institutions to solve problems of small holder farmers in Africa.

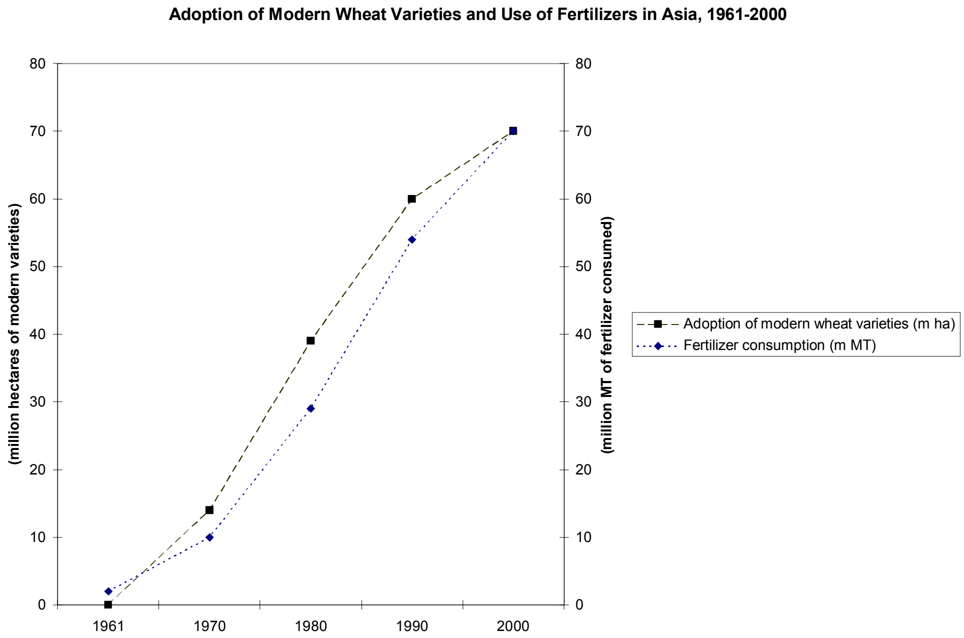
African farmers are concerned by the weak engagement of farmers and farmer organisations with research institutions in terms of setting the research for development agenda, weakness of the extension/agricultural advisory services, leading to failure of research findings reaching the farmers and failure of research to address current and emerging challenges in agricultural support and advocacy among others (GCARD Farmer Multi-stakeholder Platform, 2009).

The traditional public agricultural research institution in most African countries was to generate technologies with or without farmers inputs and hope the extension system would pick the results and disseminate them to the farmers. In most African countries the extension systems have completely collapsed and this role has in some cases been picked up by non-governmental organizations and in others by no one resulting in a lot of technologies sitting on shelves in public research institutions. The researchers have published papers and in some cases received accolades for their research but the results of the research have not reached the farmers. This paper reports the need for public research and private sector partnerships in bulking up and disseminating results of research and reports some success examples from both public universities and national agricultural research institutions.

1.1 Green Revolution

Asian farmers transformed their agriculture from being dependent upon old unimproved varieties grown with little fertilizer and constantly threatened by shortages of basic food staples into a commercial agricultural system based on modern, high-yielding varieties and fertilizer that is growing more rapidly than population through the Asian Green Revolution in the 1960's and 70's. In this green revolution, average maize yields nearly doubled between 1961 and 2000 in India, rising from 0.9 MT/ha to 1.8 MT ha; rice yields also just about doubled from 1.5 MT/ha to 2.9 MT/ha. Meanwhile wheat yields more than tripled, rising from approximately 0.8 MT/ha to 2.8 MT/ha (FAOSTAT). Initiated in wheat and rice, later development of high yielding varieties of sorghum, millet and maize likewise played an important role in raising the productivity of dryland farming areas of Asia, especially India (Streeter, 1969, Evenson and Gollin, 2003).

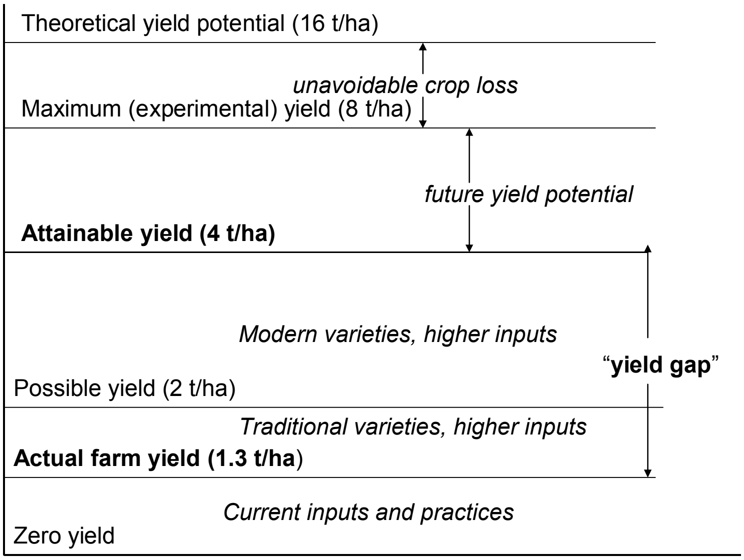
The Asian Green Revolution took from the 1960s until 2000 for suitable modern varieties to be created to cover 80% of Asia's crop land (Evenson and Golli, 2003). In the first decade a handful of wheat and rice varieties spread to over 30 % of the area, creating "breathing room" for the breeders to create varieties with greater degrees of pest resistance



in the second decade and greater local adaptability in the third decade. As in Asia, in Africa, seeds can be the point of the arrow that drives through the barrier of stagnation. The new varieties yielded more when grown with fertilizers, and use of the two inputs took off together, as illustrated (adapted from Borlaug, 2003). The Green Revolution allowed farmers to take full advantage of investments in irrigation and roads, and the creation of agricultural universities and research institutes generated indigenously educated plant agriculturalists to make the process self-sustaining (Streeter, 1969).

1.2 Africa Faces a Yield Gap and a Variety Gap

All across Africa actual yields of farmers are far below attainable yields because they grow low-yield potential varieties with poor agronomic practices, limited inputs, and because abiotic and biotic production constraints reduce the yields of those varieties. Applying higher inputs or using better farming approaches with current varieties would increase yields somewhat, as illustrated, but by a relatively small amount. Suitable modern varieties, because they are resistant to abiotic and biotic challenges and are responsive to inputs, when grown with higher inputs give a much higher yield than is attainable under farmers' conditions. Maximum yields as achieved on experiment stations or in advanced countries are still higher, and demonstrate the potential for still further gains, but under current farming condition in Africa are not attainable at this time.



Average and Attainable Maize Yields in Africa

Generating suitable varieties to overcome these yield gaps presents a greater challenge in Africa than it did in Asia because African agriculture is much more diverse and current capacity is much more limited. Africa has many different important food crops, different production conditions and great diversity of climate and soil. It has many small countries with different policies and institutions, most of which have limited government budgets for agriculture. Any new variety is adapted to a relatively small region, whereas in Asia, some Green Revolution-style rice or wheat varieties targeted to irrigated farmland were adopted on hundreds of thousands of hectares in many countries. Developing suitable technologies for Africa will be challenged by six major factors discussed below using the plant breeding and seed systems sector examples.

Many Staple Food Crops

Africa's food base is made up of at least eight staple crops, each of which is the leading contributors of caloric intake in one or more countries, whereas Asia has only two - wheat and rice. In the Sahel countries, sorghum and/or millet are the key contributors. In coastal zones of West Africa, cassava, yam, and banana form the food base. In Southern Africa, maize is the predominant crop, except in the semi-arid zones where sorghum and millet again play critical roles. In East Africa, maize is the leading contributor of dietary calories, except in the highland zones of Uganda, Rwanda, and Burundi, where highland, starchy bananas predominate. In the Horn of Africa, teff and sorghum are the two main crops. Maize is the leading crop in terms of per capita production in six countries. Cassava is the leader in 16 countries. Rice is the leader in two. Sorghum is the leader in five.

Diverse Production Environments
The diversity of African cropping systems makes it very difficult to characterize broad cropping patterns in large sub-regions of the continent. Africa also has very limited irrigation (only 5.2 million hectares in 2002, whereas Asia had 87 million hectares in 1961), and it's upland ecologies are highly varied, which results in significant differences with regard to local pests, diseases, rainfall patterns, and soil properties.

Diversity of Required Traits
Greater environmental diversity translates directly into a need for greater crop genetic diversity and management systems. The very low level of use of fertilizers, irrigation, and other purchased inputs means that African crops are subjected to high levels of stress and that more must be accomplished through genetics. Breeding successful varieties in Africa often requires setting up screening facilities which reveal and isolate key stress-resistance genes and then testing candidate varieties under local farming conditions, where farmers themselves can assist with selections. Finally, crop traits that are important to the way the harvest is processed, stored, and eaten in African villages must be included as well.

Limited Human Capacity
The absence of well-trained African scientists meant that most of the breeding had to be performed by expatriate scientists, often working from a limited number of distant locations. Breeding operations have been relatively limited in geographic extent and cannot address many of the important production zones in Africa. For example, CIMMYT data for maize shows 210 public and 290 full-time maize scientists at work in Latin America, 150 private and 505 public maize scientists at work in all of Asia, and only 45 private and 109 maize scientists in Africa. In density, Africa has about one third the maize scientists per million hectares of maize and between one third and one ninth the density of improved maize varieties as Latin America and Asia (CIMMYT,).

Constrained Breeding Facilities
The breeders in place in African national agricultural research programs have exceedingly limited support. Like most public sector workers their salaries are very low and they have essentially no operating funds to purchase fertilizer or pay laborers. In addition, agricultural experiment stations are usually outside urban areas and are frequently without water and electricity service for many hours every week, telephone service is erratic, and virtually none have internet access. The few that have operating vehicles find them expensive to maintain and when vehicles are operating the shortage of operating funds mean that they can purchase very little fuel making it impossible to operate participatory breeding programs with farmers.

Capacity to Leverage Varietal Improvements
The depressed state of African transportation infrastructure development, energy and water infrastructure, governance and institutions, and financial systems is a significant barrier to agricultural development. Ensuring adoption of improved varieties will require complementary investments in farmer training, seed enterprise development, strengthened input and output markets, improved market information systems, and knowledge and technologies to improve soil fertility and manage water catchments and water use.

The great diversity and current limits on capacity imply that a greatly increased plant improvement effort is necessary if Africa is to get the new varieties it needs to mount a Green Revolution.

2.0 CURRENT CROP IMPROVEMENT EFFORTS ARE CENTERED IN NATIONAL INSTITUTES AND THE CGIAR

Most of Africa's plant breeding capacity is in public sector national agricultural research institutes. While plant breeding in the industrialized regions of the world (and South Africa) has largely shifted from the public to the private sector, in the rest of Africa virtually all plant breeding is still conducted within the public sector, for a number of reasons: (1) seed markets, like most other markets, are poorly developed, have limited information flow, undeveloped grades and standards, and are part of a business environment in which contracts are hard to enforce; (2) the many different African food crops and constraints mean the market for any single variety is too small to repay the research investment a private company would have to make to develop well-adapted varieties; (3) intellectual property protection is limited so companies are reluctant to make investments in self-reproducing plants; (4) emerging, small seed companies lack the financial resources to hire their own breeders and support their operations during the long R&D phase.

Most national agricultural research institutes are overseen by the Ministry of Agriculture. Even small African countries have their own national agricultural research institute, although in some countries these institutes primarily test varieties produced elsewhere and carry out little or no independent plant breeding. Because these public institutes are spread throughout the continent and have the mandate of their governments to carry out plant breeding, they are a great resource for addressing the continent's agro-ecological complexity. However, as indicated earlier, they are vastly under-financed and in most countries are expected to generate varieties of all the staple crops grown in each country. Clearly these institutes are struggling. About 20 African universities teach plant breeding but few of them have much research capacity or funding.

The international agricultural research centers that fall under the ambit of the Consultative Group on International Agricultural Research (CGIAR) are another significant plant breeding resource for Africa. Each of the CGIAR research institutes are independent and separately managed although they are funded by the donor members of the CGIAR, a loose organisation of more than 40 donor agencies and foundations with a Secretariat administered by the World Bank. Seven have significant plant breeding activities in Africa (Table 2). The International Institute of Tropical Agriculture (IITA) and the West African Rice Development Association (WARDA) are headquartered in Africa; the International Maize and Wheat Improvement Center (CIMMYT), the Center of Tropical Agriculture (CIAT) and the International Center for Research in the Semi-Arid Tropics (ICRISAT) has permanent offices and breeding programs in Africa. Two other CGIAR centers, the International Rice Research Institute (IRRI), the International Two other CGIAR centers, the International Rice Research Institute (IRRI), the International Potato Center (CIP) have limited crop genetic improvement activity in Africa.

The CGIAR institutes represent a great resource for improving Africa's crops, as they house extensive collections of germplasm, both from Africa and other regions. They are relatively well-funded and are mandated by their supporters to carry out germplasm improvement activities and provide breeding lines to national programs. They also carry out "pre-breeding" activities that address some of the more challenging constraints. However, they are constrained by the Science Council which advises the donors of the CGIAR to produce only "international public goods" and hence are not supposed to produce finished varieties; their primary aim is the development of source germplasm and research techniques. Without strong national programs, the work of the CGIAR centers has limited impact; conversely, without the CGIAR or some similar place from which to obtain "source germplasm" small national programs have limited impact.

Table 1: CGIAR centrer in Africa and their focus crops

Centre	*Focus Crops*	*Locations*
CIAT	Beans, cassava, rice, forages	Kampala, Lilongwe
CIMMYT	Maize, wheat	Harare, Nairobi, Addis Ababa
CIP	Sweet potato, potato	Nairobi, Maputo
ICRISAT	Sorghum, millet, pigeon pea, peanut, chick pea	Bamako, Bulawayo, Nairobi, Niamey
IITA	Cassava, cowpea, maize, yam, banana, plantain	Cotonue, Ibadan (HQ), Douala, Kampala, Lilongwe, Nairobi
IRRI	Rice	Cotonue
WARDA	Rice	Cotonue (HQ), Dar es Salam

Table 2: Barriers to the adoption of new agricultural products and practices by poor farmers

Barriers to Adoption: Context	*Barriers to Adoption: Technical*
Price collapse at harvest and lack of markets.	Technologists do not understand system complexity and farmer choice.
Lack of demand drivers for increased outputs.	Relative price of the new technology.
Social, political, or gender barriers to access.	Comparative advantage of new technology.
Physical distance from markets and other adopters.	Local biophysical suitability.
Declining soil fertility.	Compatibility with existing systems and practices
Lack of extension training.	Technology complexity and ease-of-use.
Lack of labor.	Trial-ability – are results visible and obvious
Access to credit and finance. Lack of or cost of complementary inputs.	Ignorance or misconceptions of technology and its benefits.
	Lack of physical availability or appropriate timing.

Source: IFPRI literature survey

3.0 THE ROLE OF THE PRIVATE SECTOR IN PUBLIC AGRICULTURAL RESEARCH IN AFRICA

The private sector can play a critical role of bulking up and disseminating technologies that the farmers can use a function that public agricultural research systems cannot accomplish as they lack capital and the ability to take risks. Innovative systems of disseminating research results are needed. Innovation is the application of knowledge to bring about technological, organisational, institutional and political change. The key elements of a good innovation systems research are research priority setting, involving other actors in the decision making process, developing and implementing demand-led research programs, and bringing relevant issues to the attention of policy makers. Researchers working in isolation of other actors have been a major cause of disappointments (Jones, 2009). Examples of successful public research scientists' partnerships with private seed companies' research are described briefly below.

The researchers discussed below have worked with farmers and other stakeholders to ensure uptake and further utilization of generated technologies.

3.1 Makerere University

Dr Phinehas Tukamuhabwa, a plant breeder and lecturer at Makerere University has a big soybean breeding program supported by AGRA entitled "**Deployment of Maksoy 1N and Namosy 4M soybean varieties and development of rust resistant soybean genotypes for improved household food security and income in Uganda".** The objectives of this project were to advance seed multiplication and dissemination of Maksoy 1N and Namsoy 4M soybean varieties and to develop superior soybean varieties that are resistant to soybean rust. Soybean research activities have been conducted in all major soybean growing regions in Uganda. Dr Tukamuhabwa has several soybean lines in intermediate trials and others in national performance trials. He has also released a variety called Maksoy 2N which is high yielding, rust resistant and has good quality seed (large round cream coloured seed). Breeder seed production (4tons of each) of the Namsoy 4M, Maksoy 1N and Maksoy 2N has been produced and distributed to NASECO a private seed company in Uganda and Leldet Seed a seed company in Kenya for bulking up and sale to smallholder farmers . Dr Tukamubwa in collaboration with the millennium villages is promoting soybean through farmer field schools

3.2 University of Nairobi

Professor Paul Kimani is a lecturer at the University of Nairobi and a bean breeder. He and a few other scientists from the College of Agriculture have developed several hybrids of climbing beans and bush beans with partners that include CIAT and Kenya Agricultural Research Institute. The climbing beans have taken up rapidly in Rwanda. The College of Agriculture of the University of Nairobi has also been able to link up with a private seed company in Kenya for bulking up and marketing of these varieties all over Kenya and within the region.

3.3 Kenya Agricultural Research Institute (KARI)

Dr Jane Ininda was a plant breeder with the KARI for about 24 years and was able to release 33 varieties in 10 years from grants from Rockefeller Foundation and other sources. These hybrids were bred for resistance to maize streak disease, turcicum leaf blight, high yield, flint grain and early maturity and are adapted to the mid altitude areas of Kenya.

She managed to get non-exclusive licenses to about 2 private seed companies for her varieties resulting in these varieties available in most parts of Kenya.

3.4 Institut d'Economie Rurale (IER), Mali

Dr Aboubacar Toure is a sorghum breeder who worked for IER for about 27 years. He has released over 20 varieties that have been disseminated and popularized through the National Seed Systems as Mali until recently did not have many private seed companies. The new seed companies in Mali are also bulking some of these hybrids for sale. He was the breeder of the most prolific variety to date in Mali called Sewa.

3.5 Research and Specialist Services (R&SS), Chiredzi, Zimbabwe

Dr Isaiah Mharapara an agronomist with R &SS in Zimbabwe and some partners from other government ministries and non-governmental organizations developed technologies for sustainably cultivating wetlands with a range of crops including rice, maize, beans, vegetables and fodder that impacted thousands of farmers in the Lowveld areas of Zimbabwe that was always vulnerable to droughts and food shortages. The researchers developed the technologies with farmers on farm and on-station together with extension personnel. The regional Initiative for the Development of Equity in African Agriculture (IDEAA) then popularized these technologies to reach more farmers. IDEAAs core business was to transform agriculture service delivery mechanisms of institutions to be more responsive to the needs of smallholder farmers.

4.0 FORMATION OF PARTNERSHIPS OF ACTORS, TO IMPROVE SMALLHOLDER FARMER PRODUCTIVITY

An example of this is Agri-ProFocus which focuses on farmer entrepreneurship. Agri-ProFocus is a partnership of Dutch donor agencies, credit institutions, companies, training and knowledge institutions, with the goal to promote farmer entrepreneurship in developing countries. The Partnership has 26 members and collaborates closely with the Directorate General for Development Cooperation (DGIS) of the Ministry of Foreign Affairs and with the Ministry of Agriculture, Nature and Food Quality (LNV).

Agri-ProFocus believes that Agricultural producer organizations in developing countries are key to economic development and poverty reduction. Promoting farmer entrepreneurship through cooperation, exchange and learning is the goal of its partnership. The focus is on seven African countries, farmer entrepreneurship, demand-driven trajectories worldwide and four themes: value chains, financial services and sustainable food production, with gender as a cross-cutting theme. Its mission is to provide coherent and demand-driven support to enhance the capacity of producer organizations in developing farmer entrepreneurship within the context of poverty reduction. The focus is on promoting farmer entrepreneurship, action-oriented country programs, learning and innovation at the level of members and producer organizations, intensification of member commitment and stronger private sector involvement.

4.1 Agricultural Research Trust Farm Case

The Agricultural Research Trust Farm was started by the Commercial Farmers Union in Zimbabwe to tap into both public and private sector research results. It showcased good public and private sector research results and the farmers would visit it on several field days a season and learn the technologies they could adopt from scientists and then adopt them. It was used to show for example the performance of new varieties from the government research and that of imported varieties by seed companies. Agro-chemical companies would also do demonstration plots to show the efficacy of some of their products. Although this is for a commercial farmer sector the lesson from here is that the farmers sought a way to learn the research results as soon as possible and the public and private sector researchers got a way to create a demand for the technologies they generated and give the farmers the choice of technology packages they can use. Smallholder farmer organisations can be facilitated to form such organisations where they demand research results and thereby increase their productivity.

In conclusion, the key to effective production of research results and their utilisation by the farmers and agro-industries is to involve the farmers in the inception and at various other stages of the research and the private sector and other players to scale-up and disseminate key technologies to the end-users. The Centre for Tropical Agriculture (CTA) African Caribbean and Pacific Islands (ACP) Science and Technology Advisory Council has just this past week come up with 5 key technological challenges ACP agriculture will face over the next 5-10 years and these are listed below:

(i) Coping with the effects of climate change.
(ii) Developing and utilising biotechnology and nanotechnology.
(iii) Establishing information and Communication systems for agricultural research and development.
(iv) Developing green agricultural innovations and to resolve issues of competing land use, and,
(v) Trading in regional and global markets.

They also selected the five disciplines below as those that were most important for the transformation of ACP agriculture.

(i) Biotechnology and Plant breeding
(ii) ICT's
(iii) Natural resource management (including Bioversity)
(iv) Post-harvest technologies
(v) Soil Sciences