1 The Importance of Generating and Documenting Varietal Change in Sub-Saharan Africa

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When a farmer in sub-Saharan Africa plants a food crop, the odds are increasing that the variety sown will be an improved variety touched by science. But more likely the farmer plants a local variety that is more or less the same as that cultivated by his or her parents, grandparents and great-grandparents. For some farmers, such as groundnut growers in West Africa and sweetpotato producers in East Africa, it is likely that the variety cultivated is a product of agricultural research but that the improved variety was bred more than 40 years ago.

A lack of dynamism in varietal change in food crop production represents a wasted opportunity that is potentially high, exacting a heavy toll on poor producers and consumers alike. Crop production consumed in the household and sold in the market may represent more than 50% of the income of poor farmers. Expenditures on staple and secondary food crops may eat up more than 60–70% of the budget of poor consumers. Because crop variety improvement can increase production that in turn can lead to declining and more stable prices, it is a cost-effective intervention with a broad scope to leverage positive outcomes and impacts for hundreds of millions of poor rural and urban households in sub-Saharan Africa.

Modern varietal change is an important tool with large potential contributions to agricultural development. Unlike some other types of agricultural technology, modern varietal change is not limited by agroecology and population density, nor does it require major capital investments by potential adopters. Uptake of improved varieties can lead directly to positive consequences for food security. Modern varietal change in and of itself may not lift large numbers of people out of poverty but greater dynamism in this area can go a long way to moving poor people closer to the poverty line. Moreover, modern varietal change can set the stage for the adoption of more intensive crop production practices, such as row planting, and is a precursor to the judicious use of purchased inputs that spark multiplier effects for economic growth.

Agricultural Research: The Engine for Generating Varietal Change

Since the independence of most African nations in the 1960s and 1970s, a foundation for modern varietal change in food crops was laid down by public-sector national research programmes

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 Crop Improvement, Adoption and Impact of Improved Varieties in Food Crops in Sub-Saharan Africa (eds T.S. Walker and J. Alwang)

(NARS) in the countries of sub-Saharan Africa. Beginning in 1968, the International Agricultural Research Centers (IARCs) have been a partner in that effort. That seems like a long time ago but it is a recent undertaking compared to the genetic improvement in export crops, such as cocoa, cotton and rubber, that occurred much earlier in the 20th century.

In spite of its youth, crop genetic improvement in food crops is not as vigorous or widespread as it should be in sub-Saharan Africa. Its effectiveness is compromised for multiple reasons. Agroecological conditions are extremely heterogeneous in many African countries, especially compared to those in South Asia where widespread diffusion of modern varieties sparked the Green Revolution, which contributed to remarkable productivity growth and poverty reduction beginning in the mid-1960s. Limited infrastructure and weak support systems in sub-Saharan Africa have constrained the uptake of improved varieties. Lack of funding for operating budgets is an important limitation that is shared by both NARS and IARCs. Largely because of declining global food prices, real resources had steadily become scarcer for crop improvement research by IARCs and NARS, especially from the early 1990s to the early 2000s (Beintema and Stads, 2006). Expansion of the mandates of the IARCs into areas such as natural resource management also contributed to the erosion of resources for genetic improvement.

Since the abrupt rise in global food prices after 2008, funding for agricultural research has improved. Donors, in general, and the Bill & Melinda Gates Foundation (BMGF), in particular, have invested heavily in food-crop genetic improvement in sub-Saharan Africa. Once again, a strong partnership between NARS and IARCS is a hallmark of that investment.

Documenting Varietal Change: The Need and Past Achievements

Without the adoption of agricultural technologies, there is no impact (Adato and Meinzen-Dick, 2007). Indeed, the area planted to a new technology is the most important determinant in the size of economic benefits (Walker and Crissman, 1996; Morris *et al.*, 2003). Cost savings per unit of output of the new technology also determine impact by influencing diffusion and creating economic benefit for each area unit of spread.

Impact analysis of varietal change has largely relied on the economic surplus approach to estimate standard rates of return to the research. These studies suggest that, although returns to research have been positive in sub-Saharan Africa, they have been lower than in other regions. In addition to monitoring for a high return on investment, however, donors want to be better informed about the impact of research on the development goals of poverty reduction, food security and environmental sustainability. In spite of increasingly numerous reviews, impact assessment of agricultural research in sub-Saharan Africa is still best described as sparse (Maredia and Raitzer, 2006).

Highly specific information on adoption and benefits from variety use provides research managers with needed ammunition for deciding on the relative resource allocation for commodities and specific lines of research. To be successful, research needs to be sensitive to users' demands. For crop genetic research, the demand for traits is of paramount importance. The opportunity costs for research funds are high, and research on adoption levels and impacts can establish which traits are in demand and where acceptable trade-offs can be made.

Globally, credible databases on the diffusion and impact of well-identified improved varieties are rare. Maize, other cereals and oilseeds are a notable example of where sales information on hybrid seed can provide solid data on varietal uptake. Vegetatively propagated crops, such as potatoes, that are legislatively required to be planted with clonal-specific certified seed represent another case. Aside from these exceptions varietal-specific information is seldom widely available for important food crops even in developed countries. For example, the United States Department of Agriculture (USDA) stopped collecting data on the adoption of improved wheat varieties in the mid-1980s. But in developed-country agriculture, improved varieties are replaced by farmers every 2–5 years; varietal change is no longer an issue that impinges on economic and social development. In contrast, not knowing about the pace and dynamics of varietal change is a luxury that developing countries in sub-Saharan Africa can ill afford because both the level of modern cultivar adoption and the velocity of improved varietal turnover are low.

Since the release of maize hybrids in Kenya in the 1960s, episodic research on adoption of modern cultivars has been conducted in sub-Saharan Africa (Gerhart, 1974). Dana Dalrymple was the first agricultural scientist to make a systematic effort to document the diffusion of improved varieties in food crops. In 1978, Dana Dalrymple completed the sixth review of the spread of the high-yielding varieties (HYVs) of wheat and rice in developing countries (Dalrymple, 1978). These semi-dwarf, short-duration varieties had entered Africa as early as the late 1960s. Dalrymple estimated that the diffusion of modern rice varieties had reached 4% by 1978. He included 15 rice-growing countries in his assessment that was based mainly on direct communication with in-country scientists working on rice genetic improvement in Africa.

By the 1970s, sub-Saharan African farmers began to benefit from recently bred varieties in several primary and secondary food crops. A firm baseline for evaluating the effectiveness of food-crop genetic improvement, however, only began to emerge in the mid- to late-1990s. A global monitoring and evaluation research agenda (referred to here as the 1998 Initiative) retrospectively assessed varietal output, adoption and production impacts in food-crop genetic improvement in developing country agriculture (Evenson and Gollin, 2003). That initiative resulted in several surprises including the realization that dynamic varietal change was not confined to the so-called Green Revolution period between the mid-1960s and the early 1980s, but that it continued deep into the 1990s. But estimated adoption levels in Africa, averaging 22%, were especially low.

The estimates reported in Evenson and Gollin (2003) were based on partial results with limited data available for a number of crops and countries. As a result, the picture of modern varietal adoption in sub-Saharan Africa was somewhat fuzzy and fragmented even at that time and, in the past decade, no comprehensive study had updated or clarified those estimates.

The DIIVA Project

Here, the baseline established by Evenson and Gollin (2003) has been updated, widened and deepened. We report on the results of a CGIAR project – Diffusion and Impact of Improved Varieties in Africa (DIIVA Project) – the first major study to focus on the diffusion and impacts of improved crop varieties in SSA. Supported by BMGF, seven CGIAR Centers (CG Centers) and their national and other partners carried out adoption research and impact assessments as part of DIIVA. The DIIVA Project, which was directed and coordinated by CGIAR's Standing Panel on Impact Assessment (SPIA) and administrated through Bioversity International, began on 1 December 2009 and ended on 30 June 2013.

A budget of slightly under US$3 million was allocated to three objectives designed to:

- Attain a wider understanding of the performance of food-crop genetic improvement in priority crop-by-country combinations in sub-Saharan Africa;
- Verify and gain a deeper understanding of the adoption and diffusion of new varieties in selected priority countries and food crops in sub-Saharan Africa;
- Acquire more comprehensive insight in to the impact of crop improvement on poverty, nutrition and food security.

The DIIVA Project is viewed as a major building block in the construction of a routine system for monitoring varietal adoption and impact in sub-Saharan Africa for the CGIAR research programmes. This work has been driven by three complementary activities that respond to three project objectives: (i) documenting the key performance indicators of crop genetic improvement; (ii) collecting nationally representative survey data on varietal adoption; and (iii) assessing the impact of varietal change.

The novelty and value of the research reported in this book stems from its wide scope in terms of crops and countries with intensive data collection via standardized protocols. This standardization permits comparisons across countries, over time and among crops in a given country. The study is also unique for its emphasis on validation and on the use of sound integrated methods for impact assessment. In particular, household- and field-level data are used to estimate productivity gains, per-unit reductions in cost of production and other household-level outcomes. These methods represent an improvement over standard surplus estimation techniques, which usually rely on data from experimental trials. Trial data do not reflect regional variability in agroecology and yield potential or idiosyncratic differences in household management of production processes.

The adoption of improved varieties of 20 food crops in 30 countries covering about 85% of food crop production in sub-Saharan Africa was assessed in the DIIVA Project. More than 200 individuals, the majority of whom were scientists from national agricultural research systems, contributed to this effort. The DIIVA database contains information on more than 3500 formally and informally released varieties and more than 1150 improved varieties that were adopted by farmers in 2010 (http://www.asti.cgiar.org/diiva).

This volume represents the full rendering of DIIVA-related research by the participant scientists who assembled the information and collected the data. Earlier publications with a narrower focus include Alene *et al.* (2011) and Walker *et al.* (2014).

Fields crops in sub-Saharan Africa are almost entirely grown in dryland agriculture. The BMGF also invested in a smaller comparative project called TRIVSA (Tracking Improved Varieties in South Asia) that supplied information on varietal generation and adoption in food crops cultivated in the rainy season in South Asia. Research from the TRIVSA Project is represented by two chapters in this book and findings from South Asia serve as a point of reference for the results from sub-Saharan Africa that are highlighted in the synthesis chapters described below.

Organization

This volume is divided into four sections. Part 1 sets the stage by first reviewing investments in food-crop improvement in sub-Saharan Africa (Chapter 2). Chapter 2 shows that, starting from a low base in the 1960s, investments in crop improvement in the region grew robustly before slowing in the 1980s. Following a long period of stagnation beginning in the 1980s, robust growth in funding returned in 2001. The chapter shows that funding increases have also been accompanied by a generalized improvement in human capacity in national systems, but that aggregate figures of investments and growth can be misleading. Growth in funding and capacity is concentrated in the larger national research systems, whereas some smaller systems have shrunk substantially. Studies of rates of return to agricultural research is sub-Saharan Africa are summarized and these show varied results but, before the mid-1990s, estimated rates of return to crop improvement were lower than those in other regions of the world.

Chapter 3 defines concepts and hypotheses that have guided the DIIVA research on inputs, outputs, outcomes and impacts. The study documents two key inputs into crop improvement by year and country: scientific capacity and research intensity. Measured outputs in the study are variety releases, and outcomes are adoption and rate of variety turnover. The impact measures employed vary by study; these include yield, productivity, household income and poverty reduction. Chapter 4 goes on to describe data, methods and crop by country coverage. The DIIVA data can be divided into three domains: assembled data on scientific capacity and varietal release/availability; elicited estimates of varietal adoption; and household survey data. The variety-specific data contain about 150 crop-by-country observations selected to cover the most important food crops in the main producing countries. Crop-by-country data were assembled to provide a broad perspective of the important food crops in the region and to allow the study to be comparable to the 1998 Initiative.

Chapter 5 provides the historical context for genetic improvement for the 11 crops in the 1998 Initiative and an exploratory analysis of the variation in inputs, outputs and outcomes across commodities and countries. Country- and crop-specific comparisons show striking differences in scientific staff capacity and research intensity, but comparisons to the rest of the developing world show that sub-Saharan African indicators of these inputs are in line with other continental regions. The 1998 estimates of variety release display high variability over time for most crops in many countries. The most salient finding is that varietal output from crop improvement programmes accelerated dramatically in the 1990s. This acceleration sets the stage for a renewed look at impacts, as a variety's uptake lags behind its release, often by many years.

Impacts are likely to have become more pronounced and visible after 1998.

Varietal generation, output, adoption and turnover in food crops are addressed in nine studies in Part 2. Chapters 6–12 focus on sub-Saharan Africa. They are organized around and are synonymous with the mandated-crops of these CG Centers: International Institute for Tropical Agriculture (cassava, cowpea, maize and yams); International Center for Research in the Semi-arid Tropics (groundnut, pearl millet, pigeonpea and sorghum); International Center for Tropical Agriculture (beans); International Potato Center (potato and sweetpotato); International Center for Maize and Wheat Improvement; International Center for Agricultural Research in Dryland Areas (barley, chickpea and faba bean); and AfricaRice. This work is complemented by two comparative studies from South Asia where the commodity emphasis is on rainfed rice in multiple countries and states in India (Chapter 13) and on sorghum, pearl millet, groundnut, pigeonpea and chickpea in peninsular India (Chapter 14).

The impact of the adoption of modern varieties is assessed in case studies on maize in Ethiopia (Chapter 15) and beans in Rwanda and Uganda (Chapter 16). These studies show that impacts of adoption on productivity and cost savings are relatively large at the field level. They show that poor farmers have not been excluded from adoption; these varietal improvements seem to be accessible to all farmers. Benefits are broad-based, but vary by characteristics of adopting farmers and their agroecologies and, because areas planted are relatively small, impacts of adoption on household income and poverty are modest.

Estimates of total factor productivity with the updated DIIVA adoption data in sub-Saharan Africa are found in Chapter 17, the final chapter in Part 3. Chapter 17 shows that adoption of improved food crop varieties raised productivity of adopting areas in sub-Saharan Africa by an average of 47% and accounted for about 15% of the growth in food crop production between 1980 and 2010. By 2010, the higher productivity of improved food crop varieties had added US$6.2 billion to the annual value of agricultural production in the sub-continent.

Both substance and process are featured in Part 4, which begins with two syntheses that draw on the data and findings in Chapters 6–14. Varietal generation and output are the subjects of Chapter 18. Adoption, turnover and impact are themes for Chapter 19. What we learned about estimating varietal adoption and assessing varietal impact is discussed and summarized in Chapters 20 and 21.

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