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An Exploration of a Green Revolution in Sub-Saharan Africa

guest editors
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Introduction

While population still continues to grow rapidly in Sub-Sahara Africa, the expansion of cultivation area has slowed down considerably due to the increasing scarcity of uncultivated land. Since the yield of food grain per unit of land has remained largely unchanged in this region, food production per capita has declined and if the current trend continues, food shortages are likely to arise in near future. Food production per capita also tended to decline in tropical Asia in the 1950s and early 1960s. The pessimistic prospect for future food-population balance in Asia then was not too different from the current situation in Sub-Sahara Africa, even though social infrastructures, including irrigation facilities and roads, were better developed in the former than in the latter.

Subsequently, rice and wheat yields in Asia began to grow dramatically due to the development and adoption of fertilizer-responsive, high-yielding modern rice and wheat varieties, which is heralded as the Green Revolution. Owing to sustained improvements of grain yields in subsequent decades, the grain production in tropical Asia more than doubled and the per capita food production significantly increased over the last few decades. This Asia-Africa comparison raises an important question: Whether it is possible to transfer the Green Revolution (GR) that lifted Asia out of massive food shortages to Africa? Answer to this question is vital because recently, the executive director of the World Food Program, James Morris, made a statement to the UN Security Council on April 8, 2003 that 40 million Africans, most of them women and children were in danger of starvation.

Our proposition is that one possible strategy to restore and improve food security in Sub-Sahara Africa is to transfer the ”basic principles” underlying the process of Asian Green Revolution to Sub-Sahara Africa. Needless to say, we do not recommend direct transfer of the “existing technology” in Asia to Africa without taking into account Africa-specific production environment. Instead, we propose to transfer the basic principles underlying the process of technological breakthrough realized in Asia, which have led to the remarkable success of sustained yield growth.

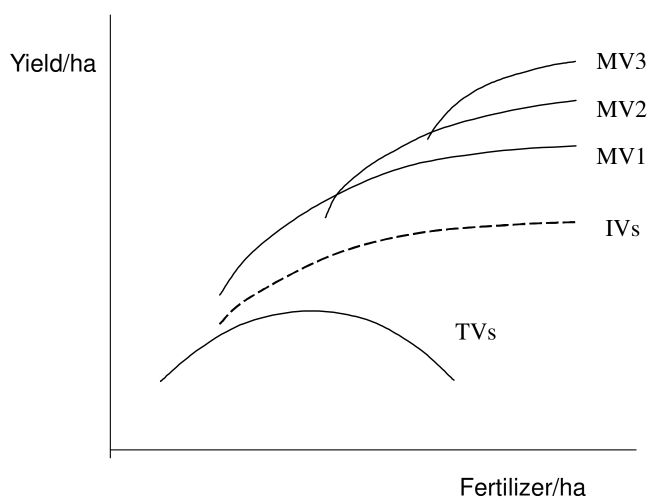
In order to examine the transferability of the experience of the Asian Green Revolution to Africa, we must have proper understanding of the mechanisms underlying the Asian Green Revolution. In addition, we must have sufficient knowledge on the current farming conditions in Sub-Sahara Africa. Despite the critical importance of these issues, relevant social science research has seldom been attempted in recent years. With the aim to fill up this gap in the literature, the objective of this special issue is to explore the possibility of transferring the Green Revolution technology to Sub-Saharan agriculture.

The structure of our arguments is as follows. An Asian model of Green Revolution is discussed in the following section. The status of existing agricultural technological performance of coarse cereals, which play a vital role in feeding the Sub-Saharan population, is summarized based on the case studies included in this special issue in the next section. A final section offers policy recommendations to strengthen the transfer of the Green Revolution to Africa.

1. An Asian model of Green Revolution

There is remarkable consensus on the evolutionary process of the Green Revolution in Asia in the literature, which is illustrated in Figure 1 (Barker and Herdt, 1985; David and Otsuka, 1994; Hayami and Kikuchi, 1982; Pingali *et al*., 1997). As is well known, traditional varieties (TVs) do not respond well to increased fertilizer application, which is depicted by an inverted U-shaped fertilizer response function or yield function of TVs. A major breakthrough was achieved by the advent of “first-generation MVs” (MV1), such as IR8, which is characterized by its fertilizer-responsive, high-yield potential. This is illustrated by the yield curve of MV1 in Figure 1, which is located far above that of TVs and characterized by high fertilizer responsiveness.

Figure 1. An Asian model of Green Revolution



MV1 was originally developed by international agricultural research centers (IARCs), i.e., IRRI for rice and CIMMYT for wheat and maize. MV1 is a regional public good, in the sense that it is widely diffused not only in the country in which it was developed but also in other countries in tropical Asia, thereby accruing benefits to wide areas. Furthermore, the research knowledge leading to the development of MV1 was widely shared across country borders. If agricultural research were carried out only by individual countries for the purpose of generating "local" public goods for their own benefits, the Green Revolution would not have been possible. This must be the first major lesson to be learned from the Asian process of technological breakthrough.

Although MV1 is potentially high-yielding, it is susceptible to pests and diseases. Moreover, its yield potential is realized only in favorable production environments, such as irrigated and shallow rainfed areas. Thus, in reality, the aggregate yield effects of MV1 may not be as dramatic as its yield curve in Figure 1 may indicate. MV1, however, increased the productivity of subsequent breeding research by providing high-yielding genes to the "second-generation MVs" (MV2), which are resistant to pests and diseases. The leadership of developing MV2 was again taken by IARCs. Gradually, however, national agricultural research systems (NARS) undertook breeding research using both MV1 and MV2 as parental materials. In this sense, too, MVs should be considered as regional public goods. As a result, the yield function shifted further upwards. According to the Philippine study, the rate of upward shift of the aggregate yield function from MV1 to MV2 was larger than the shift from TVs to MV1 (Estudillo and Otsuka, 2004).

Finally, MV3 was developed primarily by NARS, which is characterized by higher-grain quality and wider geographical adaptability because of the development of a large number of location-specific varieties. Thus, the adoption areas of MVs reached almost three-fourths of the rice growing areas and the average rice yield more than doubled in Asia. It is important to emphasize that because of its location specificity, MV3 is typically a "local" public good, whose provision should be undertaken by NARS. It is also clear that the productivity of NARS research was enhanced by prior research by IARCs.

It is worth noting here that the above mentioned evolutionary process has been supported by cheap prices of chemical fertilizer relative to rice and other cereal prices (Hayami and Ruttan, 1985). Partly because of such favorable relative prices and partly because of the significant shifts of the yield functions, the profitability of MVs has been significantly larger than that of TVs in Asia, particularly at the high level of fertilizer application.

Thus, we can identify the following 'guiding principles' on how to transfer Asia's technological breakthrough successfully to Africa: (i) The IARCs should take a leading role in developing inproved varieties such as the MV1 or MV2 type in Asia effectively; (ii) the NARS should play an active role in developing location-specific and fertilizer- responsive varieties similar to the MV3 in Asia; and (iii) given the macroeconomic fiscal conditions faced by several African countries that constrain fertilizer subsidies, NARS should do research and disseminate the use of other soil nutrients to compensate for the low usage of chemical fertilizers at the farm level due to its high cost.
Now, it becomes necessary to examine the status of the existing agricultural technology at the farm level in Sub-Sahara Africa.

2. Performance of Sub-Saharan African agriculture

The papers included in this special issue demonstrate the dynamic nature of the new agricultural technology for upland crops, particularly in relation to the changing demands placed upon agricultural research. It brings out the range of actual field performances of the high yielding varieties evolved through decentralized research, in comparison with those of the local varieties in areas with and without major socio-economic and environmental constraints on performance. In order to critically examine the determinants of farm-level performances of major crops in major producing countries in

Sub-Sahara Africa in the context of rural development and poverty alleviation, this volume considers three groups of countries in terms of their agricultural performances – successful (maize in the highlands of Kenya by Otsuka and Yamano), successful earlier, but stagnant now (maize in Kenya by De Groote *et al*., and in Zimbabwe by Alumira and Rusike) and never successful (maize in Uganda by Sserunkuuma and sorghum and millet in West Africa by Ndjeunga and Bantilan). In order to prove that the Green Revolution took place not only in rice and wheat sectors but also in maize, sorghum, and millet sectors in Asia, the case of coarse cereals production in India is also included in this issue (Aldas *et al.*). These papers argue that the dynamism achieved in Asian agriculture is also possible in African agriculture through sustained improvement and efficient use of technologies, institutional changes to facilitate technological innovations, and public investment in rural infrastructure.

First, we would like to discuss briefly the cases of the successful performances. The high productive regions in India, which experienced GR as early as the 1970s, have registered high yields with a marginally declining trend through the subsequent period. The medium and low yield regions also picked up with increased adoption rates of MVs after the 1980s, and their yields are becoming closer to those of high yield regions over the period. The total factor productivity (TFP) growth contributed substantially to the output growth of coarse cereals over the past three decades. The TFP growth was not necessarily higher in those states where coverage of irrigation was relatively high. For instance, TFP grew at an average of 1.4 percent per annum throughout the GR period for sorghum in the sate of Maharashtra where about half of the India's sorghum area is concentrated mostly under rainfed conditions. The implication is that the Green Revolution for coarse grains is possible in unfavorable agricultural areas.

The successful performance in the Sub-Sahara Africa concerns the performance of maize in the highlands of Kenya (by Otsuka and Yamano). The new farming system, which may be dubbed an "Organic Green Revolution (OGR)," is based on the use of manure produced by improved dairy cows (i.e., cross breeds of European and local cattle). A typical farmer who employs this farming system cultivates feed crops and grows fodder trees with the capacity to fix nitrogen (i.e., agroforestry trees) on his farm, feed them to improved cattle in stalls, obtain manure from the stalls, and apply the manure or compost on crops such as maize or banana. If combined with improved maize varieties, this has potential of nearly doubling maize yield. Another advantage of using manures on crops is that it facilitates retaining moisture on soil longer, which to a certain extent is an appropriate technology for the areas with less rainfall and irrigation facilities.

With respect to the cases of successful performances coming to a standstill, the papers by De Groote et al., and Alumira and Rusike re-examine the maize green revolution that increased maize yields in Kenya and Zimbabwe, respectively, through the use of improved varieties and fertilizer in the 1970s and early 1980s. The question is why it has stalled in recent times in these two countries. These two papers examine how input and output markets have been affected by the policies in the maize sector. Analysis of farm level surveys from 1992 and 2002 in Kenya indicates slight increases in the adoption of improved maize varieties and fertilizer, but a substantial decrease in the intensity of fertilizer use. The econometric analysis suggests that the intensity of fertilizer use has a major effect on maize yield. The use of improved maize varieties, however, did not affect yield significantly, suggesting that there are local varieties for some areas that do as well as improved varieties. Inference can be made from these results that the modern varieties of maize in Kenya are not sufficiently responsive to fertilizers. Because, the successful performance in the highlands of Kenya (by Otsuka and Yamano) indicates that farmers applied large amount of fertilizers when they found that the modern varieties are responsive to fertilizers (organic or inorganic). Both Kenya and Zimbabwe papers insist that research is needed to develop improved varieties responsive to fertilizers and for areas where there are no modern varieties. They also point out the need for the development of alternative affordable soil fertility management methods such as the application of cattle manures.

With respect to the cases of stagnant agricultural performances, another paper analyzed the adoption and impact of improved maize varieties and land management practices on maize yield and factor payments in Uganda, where the yield for many crops has stagnated or declined throughout much of the 1990s. The results have shown that, although the number of households using improved seeds is fairly high and increasing, and that there are some marginal gains ensuing from switching from the production of traditional to improved maize varieties, there is a much bigger gap between yields reported in the survey data and on-farm trials yields, with the former being only one fifth of the latter. This yield gap is attributed to several factors including the recycling of hybrid seeds by farmers and limited use of yield-enhancing inputs such as fertilizer and appropriate land management practices.

The sorghum and pearl millet production in West Africa has never been successful. Ndjeunga and Bantilan argue that during the last three decades, donors and governments have invested heavily in the development and dissemination of new technologies in the semi-arid tropics of West Africa, including Burkina Faso, Mali, and Niger. A wide range of improved technologies has been developed, but their uptake by farmers is still low. Adoption of improved technologies remains low without a significant impact on crop productivity, rural income and poverty. Agricultural transformation as occurred in East Asia has not yet occurred in the semi-arid tropics of West Africa. Limited productivity gain arising from the adoption of improved varieties is found to be a major constraint on the uptake of new technologies.

To sum up, in terms of Figure 1, the yield function shifted upwards by the introduction of improved varieties (IVs) in some parts of Sub-Sahara Africa, such as Kenya and Zimbabwe, but not in others, such as Uganda and West Africa. The shift in production function, however, is not sustainable in many parts of Kenya and Zimbabwe because of the unsustainable soil management practices except in the highlands of Kenya, where the organic Green Revolution is taking place.

Thus, the status of the existing agricultural technology in Sub-Sahara Africa indicates that the "guiding principles" identified as important for the transfer of the GR technology to Africa are not completely missing. In other words, there has been collaboration between IARCs and NARS, even though they are not as effective as they should be. Further, given the Africa-specific production environment in terms of low irrigation and high fertilizer prices, other types of soil nutrients such as vegetation and cattle manure are being applied at the farm level at least in some areas, such as the highlands of Kenya. These situations provide a positive sign for technology transfer from Asia to Africa. What is needed urgently now is to find ways to improve the existing agricultural technological situation in Africa, which are attempted in the following section.

3. Possible policy suggestions for the transfer of a Green Revolution to Africa

No doubt, it is imperative to improve crop yields in Sub-Sahara Africa in order to reduce rural poverty and improve food security. The purpose of this special issue is to explore the possibility of a Green Revolution in this region, which has been successfully realized in Asia. The most important lesson Sub-Saharan African countries can learn from Asia's Green Revolution is that the increased application of fertilizer and the development of fertilizer responsive MVs are essential strategies for increasing crop yields. Needless to say, we duly recognize that considering the major climatic, political, and cultural differences between Asia and Africa, the direct transfer of the Green Revolution technology from the former to the latter is not appropriate. However, it is also true that the Green Revolution in Sub-Sahara Africa will remain as a mere dream, if the basic principles underlying the successful experience of Asia's Green Revolution is ignored.

In our view, it is essential to apply a large amount of soil nutrients to crop fields planted with fertilizer-responsive varieties, if the objective is to increase crop yield per unit of cultivated land substantially. However, given the existing chemical fertilizer prices, which are prohibitively high in Sub-Sahara Africa, African farmers seldom apply it. Thus, there is obviously a need for a slightly different approach to motivate the farmers to increase fertilizer application in Sub-Sahara Africa. Towards this objective, one possibility is to use manure from cattle and leaves from agroforesty trees with nitrogen fixation capacity. Results from the study by Otsuka and Yamano indicate that a new farming system based on the use of manure produced by improved dairy cows is promising because the data suggest a potential to nearly double maize yields under the new system. This case vividly illustrates the importance of increasing the application of organic fertilizer in order to achieve significant yield gains.

Simultaneously, IARCs abd NARS need to promote not only the region- and location-specific research in breeding (Evenson and Gollin, 2003), but also research in farming systems with due consideration of interactions among seeds, livestock, and agroforestry trees. Also, governments must invest in physical infrastructure, which have significant impact on the effective use of technology and more widespread use of chemical fertilizer at the farm level. These factors are complementary to each other in the sense that they enhance the effect of each other.

To strengthen our arguments, we would like to point out that in Asia, the Green Revolution was technology-driven, where MVs developed by IRRI led to subsequent changes in the national research, extension, marketing, and irrigation policies of the government and international donor communities to facilitate and strengthen the overall impact (Hayami and Kikuchi, 1982). In other words, the development and use of MVs was a real breakthrough, which, in turn, induced a series of institutional innovations conducive to the realization of the Green Revolution. This suggests that there is a large role to be played by crop-breeding research to develop higher-yielding varieties appropriate for Sub-Sahara Africa.

In our view, while the Asian Green Revolution can be termed "seed-chemical fertilizer" revolution, the African Green Revolution must be based upon new farming systems consisting of "seed-livestock-agroforestry" interactions. Overall, there is a clear potential to realize a Green Revolution in Sub-Sahara Africa, if sufficient research on the improvement of crop varieties is made together with the implementation of appropriate measures to increase the application of sufficient nutrients to hitherto degraded African soils.

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