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Towards Genetically Engineered Crops in Ghanaian Agriculture: Confined Field Trials and the 'Next-door Neighbor Effect' Theory

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Genetically engineered (GE) crops have a role to play in increasing agricultural productivity. However, efforts to promote genetic engineering agriculture in Africa have been met with some amount of resistance. Here, we report recent efforts to promote GE agriculture in Ghana, a West African nation considered one of Africa's model democracies and growing economies. Ghana is currently running confined field trials of some selected GE crops, but analysis of ongoing genetically modified organism (GMO) debates and published opinions shows a considerable amount of opposition to GE agriculture and GMOs in Ghana. This notwithstanding, we suggest that Bt cotton cultivation in Burkina Faso—Ghana's immediate neighbor to the north—may play a role in eventually putting Ghana on the map of GE agriculture countries, a phenomenon reported elsewhere which we have described in this article as the 'next-door neighbor effect.' The biosafety implications of the 'next-door neighbor effect' are also discussed here. We conclude that the 'next-door neighbor effect'—in addition to corporate and political interests—will explain the entry of GE crops into some new markets.

Key words: Ghana, GMO adoption debates, GE agriculture, next-door neighbor effect, confined field trials.

Introduction

Agriculture is confronted with many significant challenges globally. These challenges include farmers' reliance on nutrient-depleted soils, lack of water resulting in dependence on rain-fed agriculture in parts of the world, biotic stresses such as insect-pest and pathogen challenges to crop plants, and competing demands for arable lands from urbanization and new human settlements. These problems have even been made more daunting by a changing climate that paints a gloomy picture of the future of world agriculture. To deal with these challenges in a sustainable manner, strategies need to consider the capacity of the receiving environments such that these strategies will be contained and managed in ways that avoid large perturbations in the ecosystems. To this end, although strategies for agricultural improvement may differ from one agricultural system to the other, crop genetic improvement is fundamental and essential for all agricultural systems if crop productivity were to be raised (Huang, Pray, & Rozelle, 2002).

A crop genetic improvement technology that holds promise for combating some of the challenges that confront agriculture but remains controversial is genetic engineering. In 1996, the first-generation genetically engineered (GE) crops became commercialized, and it has been two decades since. However, the never-ending debates about GE crops—which have focused, primarily, on their environmental and health impacts—have largely affected the adoption rates of these crops in commercial agriculture across the world. Adoption rates have been greatest in North America, where the United States and Canada have planted GE crops to large fields. In Europe, societal resistance, stemming from negative public perception of GE crops (Gaskell, 2000; Gaskell et al., 2000), has effectively ensured that GE crop cultivation has not seen much increase. While GE crop cultivation in Africa is limited to a few countries—namely, South Africa, Burkina Faso, Egypt, and Sudan (Ademola, 2011; James, 2012)—there has been a recent wave of genetically modified organism (GMO) debates across a number of African countries due, in part, to the moves by these nations to institute regulatory regimes that will see to the implementation of crop biotechnology programs. In particular, we refer to the Ghana debates, which have seen civil society groups as well as prominent politicians leading the efforts to block any attempts by government to promote crop biotechnology programs in its agriculture modernization efforts. The decision to adopt GE agriculture by some African countries has come on the back of calls for a green revolution in Africa, a continent which, it is argued, stood by and watched the benefits of the first green revolution accrue only to those nations that participated actively in it. While it has been suggested that Africa needs no such green revolution (Holt-Gimenez, Altieri, & Rosset, 2006)—because this form of agriculture is particularly inappropriate for agricultural systems in developing countries—arguments have been advanced in favor of GE agriculture in Africa (Kathage & Qaim, 2012; Wambugu, 1999), with suggestions that GE agriculture is an essential tool for dealing with food security problems.

In this article, we highlight the GMO debates emanating from Ghana's efforts towards the adoption of GE crops in Ghanaian agriculture and theorize that a phenomenon we describe as the 'next-door neighbor effect' may ultimately influence Ghana's decision to adopt GE agriculture. Furthermore, we hold the view that the 'next-door neighbor effect' may partly explain the choice of GE crops for Ghana's ongoing confined field trials.

Agriculture in Ghana: Overview

Agriculture in Ghana is predominantly manual and reflects the general situation in African agriculture, where nearly 70% of the population is engaged in farming (Cooke & Downie, 2010; Djaney Djagbletey & Adu-Bredu, 2007). The agricultural sector is the mainstay of Ghana's economy, and until recently when it was displaced to second position by the services sector, was the biggest contributor to the nation's gross domestic product. This situation was not wholly unexpected, as agriculture is, in most cases, rain-fed, and crop failures resulting from inadequate and/or erratic rainfall are not uncommon. Besides, Ghanaian agriculture is largely subsistent in nature and is dominated by smallholder agriculture; commercial farms are almost always limited to cash-crop farming. Other bottlenecks in Ghana's agricultural system include the lack of adequate storage facilities to minimize post-harvest losses. It is this observation that informs the suggestion by some that the problems confronting Ghanaian agriculture can be dealt with effectively without resorting to agricultural improvement technologies such as genetic engineering. However, others have argued that if—despite a large labor force being employed in Ghanaian agriculture—the desired impact is not being made, then a clear case for a rethinking of agriculture is established. It has, thus, been suggested that alternative ways of doing agriculture, including genetic engineering technologies, be employed to improve agriculture in a developing country like Ghana.

Towards GE Agriculture in Ghana

The general view that agricultural systems in developing countries have not delivered the desired results has made some African countries (including Ghana) move towards the adoption of GE technologies in their agriculture modernization efforts. In Ghana, one of the early signals of this intent was the establishment of the National Biosafety Committee, which would oversee the formulation and adoption of a national biosafety law. Ghana's Biosafety Act of 2011 (Act 831) has since been promulgated. This Act provides for the establishment of a National Biosafety Authority, which would take over the functions of the National Biosafety Committee to regulate all activities pertaining to biotechnology in Ghana. A National Biosafety Authority has since been established. While a 2011 study has revealed that many Ghanaians are opposed to genetically modified foods (Buah, 2011), an earlier study (Quaye, Yawson, Yawson, & Entsi Williams, 2009) showed that the confidence of the Ghanaian public in the ability of government's regulatory systems to handle issues related to biotechnology (or GE technology) is low, and that the public would want to see the establishment of a special body to regulate biotechnology research and activities in Ghana.

A recent attempt to pass a plant breeders bill into law "to provide for the grant and protection of plant breeder rights and for related matters" has provoked a national debate on GMOs. In the process, some have called for the repeal of the Biosafety Act of 2011. Repealing the Biosafety Act would mean that there would be no room for a National Biosafety Authority, as the establishment of this authority is grounded in this Act. However, despite the debates, confined field trials of some GE crops (Bt cotton, Bt cowpea, GE rice, and GE sweet potato) are currently underway (Table 1).

GE Agriculture Adoption around the World: The 'Next-door Neighbor Effect'

Evidence shows that despite the arguments against GE agriculture, in some countries where GE agriculture has never been practiced, farmers on their own go out to look for GE crops to plant when they learn of benefits accruing to their counterparts in neigboring countries where GE agriculture has taken root, either completely disregarding or unaware of the arguments against GE crops. We call this phenomenon the 'next-door neighbor effect.' In our view, the 'next-door neighbor effect' may occur when the following conditions are satisfied:

- Farmers in a non-GE crop-producing country have their livelihoods tied to a single or few economic crops and these crops have some peculiar production challenges.

Table 1. GE crops undergoing confined field trials in Ghana.

GE crop	Goal	Other African countries where cultivated	Reference
Bt cotton	Resistance against insect pests	Burkina Faso, South Africa, Egypt, Malawi[a]	James (2012); Arthur (2012)
Bt cowpea	Resistance against insect pests	Nigeria[b], Burkina Faso[b]	African Agricultural Technology Foundation (AATF, n.d.)
GE rice	Tolerance to drought and salinity; nitrogen use efficiency		Arthur (2012)
GE sweet potato*	Enhanced nutritional content (increased essential amino acid content)		Arthur (2012)

** GE sweet potato: Approved for confined field trials in Ghana, but trial could not start as scheduled.*
[a] Malawi: Bt cotton cultivation is on experimental scale.
[b] Nigeria and Burkina Faso: Bt cowpea cultivation is on experimental scale.

- There is a GE variety of the economic crop next door (in a neighboring country) which, in the estimation of the farmers in the non-GE crop-producing country, appears to be coping with the production challenges.
- The climate in the non-GE crop-producing country is the same as, or is similar to, that in (part of) the GE crop-producing country.

The 'next-door neighbor effect' theory puts into perspective some of the emerging theories on adoption of GE crops in developing countries. The "bio-hegemony theory" by Schnurr (2013), for example, cites corporate actors, development agencies, policy officials, and research scientists as being mainly responsible for pushing GE crops into new markets, often for political and commercial reasons. Theories such as this one often do not account for the evidence available in the literature and the fact that farmers could also have a positive view of GE crops and could be actively involved in turning a non-GE crop-producing country into a GE crop-producing country. It is this evidence that motivated our formulation of the 'next-door neighbor effect' theory.

A key example of the 'next-door neighbor effect' is the reported smuggling of GE soya into Brazil from neigboring Argentina by farmers in the south of Brazil (Branford, 2004) or the purchasing of GE seeds from Argentina and planting those seeds in Brazil by Brazilian farmers while GM crop cultivation was not yet legal in Brazil (Huang et al., 2002). It is important to note that Argentina started GE crop cultivation long before Brazil began, and that the illegal planting of GE soya by Brazilian farmers was one of the factors that influenced the adoption of GE technology in Brazil (Branford, 2004). In Pakistan, too, cotton farmers reportedly smuggled Bt cotton planting material from neighboring India (Ali & Abdulai, 2010) and according to the Pakistan Central Cotton Committee, as cited in Ali and Abdulai (2010), more than 60% of Pakistani cotton farmers planted these unapproved materials. The extent to which the 'next-door neighbor effect' influences adoption of GE crops around the world is not clear. What is clear from the above examples, however, is that farmer perception of the contribution of GE agriculture to increasing agricultural productivity can be positive, and this may lead non-GE crop-producing countries along the path of GE agriculture.

Possible Influence of the 'Next-door Neighbor Effect' on GE Crop Selection for Confined Field Trials in Ghana

The ongoing GMO debates in Ghana have been triggered, in part, by confined field trials of GE crops underway in Ghana. Below, we discuss how the selection of some of these crops for the field trials may have been influenced by developments in Ghana's next-door neighbor Burkina Faso, as well as by developments in the sub-region.

Bt Cotton

Burkina Faso—Ghana's immediate neighbor to the north—is one of Africa's leading GE agriculture countries. Burkina Faso is well known for its Bt cotton. Ghana's three northern regions, which are the cotton-producing zones, are located close to Burkina Faso (Figure 1). Cotton-producing areas in both countries belong to the savannah agro-ecological zone. It is known that one of the peculiar challenges of cotton production is insect pest attack; one way to address this challenge is to use pesticides, a practice that imposes additional costs on the farmers, as well as health and environmental implications. Indeed, a 1997 estimate suggests cotton

Figure 1. Cotton-producing regions of Ghana in close proximity to Burkina Faso where Bt cotton production takes place.

production contributes to 25% of all pesticides used, despite cotton production being limited to less than 2.5% of the global cultivated acreage (Krattiger, 1997). Thus, the use of Bt cotton has been advocated as an alternative to the use of chemical sprays.

It has been argued previously that, considering the proximity of Ghana's cotton-growing regions to Burkina Faso, if the benefits associated with the use of Bt cotton in Burkina Faso were to become apparent to Ghanaian cotton farmers, these farmers may be tempted to plant Bt cotton without the established biosafety regime being in place in Ghana (Agorsor, Yafetto, Otwe, & Galyuon, 2014). This would be consistent with what has happened in other developing countries that share boundaries with countries where GE agriculture is practiced: farmers in the non-GE crop-producing countries "smuggled" into their countries GE crops from the neighboring GE crop-producing countries.

Indeed, there is indirect evidence that the possibility of the 'next-door neighbor effect' occurring in Ghana influenced the decision of Ghana's Council for Scientific and Industrial Research, the coordinator of Ghana's confined GE crop field trials, to include Bt cotton in the trials. Ghanaian cotton farmers have called for Bt cotton adoption based on what they have described as successful Bt cotton farming in Burkina Faso, suggesting that their cotton farms are not doing as well as those of their Burkinabe counterparts (*Seed Today*, 2013). Analyses of results of Burkina Faso's own Bt cotton field trials—from 2003 to 2005—showed yield increases of nearly 20%, as well as environmental benefits from an almost two-thirds decrease in insecticide sprays (Vitale, Glick, Greenplate, Abdennadher, & Traore, 2008; Vitale, Glick, Greenplate, & Traore, 2008). It has been shown that in India, too, farm-scale evaluation of Bt cotton revealed a reduction in pest damage, as well as a yield increase and a 50% gain in profit from cotton sales by smallholder farmers (Kathage & Qaim, 2012; Qaim & Zilberman, 2003). These benefits associated with Bt cotton cultivation may make Bt cotton attractive to Ghanaian cotton farmers as well.

Bt Cowpea and Other Crops

Bt cowpea, GE rice, and GE sweet potato are the other crops undergoing (or selected for) confined field trials in Ghana. Cowpea (*Vigna unguiculata* [L.] Walp) is an economically important legume in Africa, with West and Central Africa being the main centers of cowpea trade (Langyintuo, 2003). As with cotton production, one of the biggest cowpea production constraints is insect pest attack; the most important pests are *Maruca testulalis*, *Maruca vitrata*, *Megalurothrips sjostedti*, and a host of other pod-sucking bugs (Huesing et al., 2011; Murdock et al., 1997). Generally, natural sources of genetic resistance to the pests for breeding programs have been lacking. For example, germplasm screens for resistance to *M. vitrata* have returned very low levels of resistance to the pest (Singh, Jackai, Dos Santos, & Adalla, 1990). Although cowpea's wild relative *V. vexillata* shows strong resistance to *M. vitrata*, it has not been possible to transfer this trait to cowpea cultivars due to hybridization barriers (Barone & Ng, 1990). These have constrained conventional breeding programs that aim to develop cowpea varieties with resistance to these pests. Genetically engineering a gene from *Bacillus thuringiensis* (Bt) into cowpea to confer resistance to these major pests has therefore been considered. Efforts are presently underway in Nigeria and Burkina Faso to adopt Bt cowpea (Ezezike & Daar, 2012; Langyintuo & Lowenberg-DeBoer, 2006).

While we cannot claim the 'next-door neighbor effect' as a reason for Ghana's inclusion of Bt cowpea in her confined field trials—because commercial cultivation is yet to begin in either Nigeria or Burkina Faso—a 2006 analysis (Langyintuo & Lowenberg-DeBoer, 2006) showed that Bt cowpea adoption will lead to improved cowpea production, resulting in prices of this commodity falling in West and Central Africa. Langyintuo and Lowenberg-DeBoer (2006) further argued that cowpea producers in non-Bt cowpea-producing countries will be negatively affected by this development, and that if Bt-cowpea were to be adopted, it must be adopted by all countries in West and Central Africa where cowpea production occurs in order to ensure the benefits of Bt cowpea adoption accrue to all countries.

Meanwhile, GE rice with improved nitrogen-use efficiency, water-use efficiency, and salt tolerance (i.e., NEWEST rice) is a multi-stakeholder project taking place in only two other African countries—Uganda and Nigeria. The overall goal is to increase these nations' self-sufficiency in rice production.

Ghana's GE sweet potato 'project' for enhanced nutritional content is, to the best of our knowledge, the first example of a GE sweet potato program for improved nutritional content in Africa. Apparently, the only other GE sweet potato project in Africa has been a project aimed at genetically engineering sweet potato for virus resistance in Kenya (Wambugu, 2003).

The 'Next-door Neighbor Effect' and Implications for Regional/Sub-regional Biosafety Policy Framework

Clearly, the 'next-door neighbor effect' has some implications for biosafety and biosafety policy framework formulation for the nations concerned. Since non-GE crop-producing countries may be taken completely unawares by their farmers' adoption of GE crops from neighboring countries, development of biosafety policy framework and legislation across nations and regions/sub-regions needs to be given careful consideration. Moreover, since the non-GE crop-producing countries may not have a functioning biosafety regime in place prior to the "forced adoption" of the GE crops by their farmers, these countries may have to start from scratch in order to institute biosafety frameworks so as to be able to appropriately govern their GE agriculture. To begin this process, these countries may have to draw lessons from existing biosafety policy documents in their sub-region and, more importantly, that of the neighboring GE crop-producing country. Indeed, the possibility of the GE crop-producing countries exporting their surplus produce to neighboring non-GE crop-producing countries also presents a case for regional efforts towards biosafety policy adoption and harmonization.

Concluding Thoughts

The 'next-door neighbor effect' theory recognizes that positive views/perceptions of farmers in a non-GE crop-producing country about GE agriculture in a neigboring country can result in the non-GE crop-producing country adopting GE agriculture. Although this trend has been shown for only a few countries—where previously non-GE crop-producing countries were compelled to become GE crop-producing countries because of their farmers' preference for these crops—we may see more of this effect going forward. An example is Ghana's move to experiment GE agriculture; that crop selection for confined field trials may have been influenced by developments in the sub-region demonstrates this concept. The 'next-door neighbor effect' theory thus puts emerging theories about the adoption of GE crops in developing countries into perspective and recognizes that other factors apart from corporate and political interests may be driving the entry of GE crops into new markets and that farmers can be actively involved in turning a non-GE agriculture country into a GE agriculture country.

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