TAILORING BIOTECHNOLOGIES
Vol. 2, Issue 1, Spring-Summer 2006, pp: 79-94

Genetically Modified Crops for a Hungry World: How Useful are they Really?

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Introduction

In this analysis I take very seriously the oft-repeated claim that genetic engineering of crop seeds could be an important way to attack hunger in the nations of the South, submitting it to a rigorous critical analysis. Industry and mainstream research and policy institutions often suggest that transgenic crop varieties can raise the productivity of poor third world farmers, feed the hungry, and reduce poverty (see, for example, www.whybiotech.com; McGloughlin, 1999a, 1999b; Pinstrup-Andersen, 1999). In order to address these propositions critically, we must examine the assumptions and claims that lie behind them. In order to do so, I first briefly review the notion that hunger is due to a scarcity of food, and thus that it could be remedied by producing more. I then look into the situation faced by poor farmers in the Third World, including the issue of their productivity. I close by examining some of the special risks that genetic engineering for agriculture it may pose for peasant farmers.

Food Availability and Hunger

Global data shows that there is no relationship between the prevalence of hunger and our ability to produce enough food. In fact, per capita food production increases over the past four decades have far outstripped human population growth. The world today produces more food per inhabitant than ever before. Enough is available to provide 4.3 pounds every person everyday, including 2.5 pounds of grain, beans and nuts, about a pound of meat, milk and eggs and another of fruits and vegetables, more than enough for a healthy, active life. The real causes of hunger are poverty, inequality and lack of access by people who are cash-poor, to readily available food-but food which can only be obtained with money. Too many people are too poor to buy the food that is available (but often poorly distributed) or lack the land and resources to grow it themselves (Lappé et al., 1998). In fact, farmers around the world, both North and South, believe that overproduction - and consequent low crop prices-is one of the most persistent problems generating poverty (and thus hunger) in rural areas (McMichael, 2004).

At this level of macro analysis, then, it should be clear that we most definitely do not need more food in order to end hunger. Thus, at a global scale, improved crop production technology of any kind is unlikely to help.

However, this may not be true in all cases of individual countries, or regions within countries, where per capita food production figures and food availability may lag behind global averages. Thus we must take seriously the notion that in some cases (i.e. parts of Sub-Saharan Africa) we may have to address the productivity of poor farmers who grow foodstuffs for consumption in regional and national markets, in order to effectively combat hunger (de Grassi and Rosset, forthcoming).

When we speak of these national markets, we find that small and peasant farmers, despite their disadvantaged position in society, are the primary producers of staple foods, accounting for very high percentages of national production in most Third World countries. This sector, which is so important for food production, is itself characterized by poverty and hunger, and in some cases, lagging agricultural productivity. If these problems are to be addressed by a proposed solution - transgenic crop varieties in this case - we must begin with a clear understanding of their causes. If the causes lie in inadequate technology, then a technological solution is at least a theoretical possibility. Thus let me begin by examining the conditions faced by peasant producers of staple foods in most of the third world.

Historical Background

The history of the Third World since the beginning of colonialism has been a history of un-sustainable development. Colonial land grabs pushed rural food producing societies off the best lands most suitable for farming, the relatively flat alluvial or volcanic soils with ample, but not excessive, rainfall (or water for irrigation). These lands were converted to production for export in the new global economy dominated by the colonial powers. Instead of producing staple foods for local populations, they became extensive cattle ranches or

plantations of indigo, cocoa, copra, rubber, sugar, cotton and other highly valued products. Where traditional food producers had utilized agricultural and pastoral practices developed over thousands of years to be in tune with local soil and environmental conditions, colonial plantations took a decidedly short-term view toward extracting the maximum benefit at minimal costs, often using slave labor and production practices that neglected the long term sustainability of production (for further development of the arguments put forth in this sections, see Lappé et al., 1998, and Ross, 1998).

Meanwhile local food producers were either enslaved as plantation labor or displaced into habitats which are marginal for production. Pre-colonial societies had used arid areas and desert margins only for low intensity nomadic pastoralism, had used steep slopes only for low population density, long fallow shifting cultivation (or sophisticated terracing in some cases), and had used rain forests primarily for hunting and gathering (with some agroforestry) all practices that are ecologically sustainable over the long term. But colonialism drove farming peoples-accustomed to the continuous production of annual crops on fertile, well drained soils with good access to water - *en masse* into these marginal areas. Whereas pre-colonial cultures had never considered these regions to be suitable for high population densities or intensive annual cropping, in many cases they were henceforth to be subject to both. As a result forests were felled and many fragile habitats were subject to un-sustainable production practices, in this case by poor, newly destitute and displaced farmers, just as the favored lands were being degraded by continuous export cropping at the hands of Europeans.

National liberation from colonialism did little to alleviate the environmental and social problems generated by this dynamic, as the situation in fact worsened in much of the third world. Post-colonial national elites came to power with strong linkages to the global export-oriented economy, often, indeed, connected to former colonial powers. The period of national liberation, extending over more than a century, corresponded with the rise of capitalist market and production relations on a global scale, and in particular, with their penetration of third world economies and rural areas. New exports came to the fore, including coffee, bananas, ground nuts, soy beans, oil palm, and others, together with new, more capitalistic (as opposed to feudal or mercantile) agroexport elites. This was the era of modernization, whose dominant ideology was that bigger is better. In rural areas that meant the consolidation of farm land into large holdings that could be mechanized, and the notion that the "backwards and inefficient" peasantry should abandon farming and migrate to the cities where they would provide the labor force for industrialization. This ushered in a new era of land concentration in the hands of the wealthy, and drove the growing problem of landlessness in rural areas. The landless rapidly became the poorest of the poor, subsisting as part-time seasonal agricultural or day laborers, share croppers or migrating to the agricultural frontier to fell forests for homesteads. Also among the poor were the "land poor:" sharecroppers, renters of small plots, squatters, or legal owners of parcels too small or too infertile to adequately support their families.

Thus rural areas in the Third World are today characterized by extreme inequalities in access to land, in security of land tenure and in the quality of the land farmed. These inequalities underlie equally extreme inequities in wealth, income and living standards. The poor majority are marginalized from national economic life, as their meager incomes make their purchasing power insignificant.

This creates a vicious circle. The marginalization of the majority leads to narrow and shallow domestic markets, so landowning elites orient their production to export markets where consumers do have purchasing power. By doing so, elites have ever less interest in the well-being or purchasing power of the poor at home, as the poor are not a market for them, but rather a cost in terms of wages to be kept as low as possible. By keeping wages and living standards low, elites guarantee that healthy domestic markets will never emerge, reinforcing export orientation. The result is a downward spiral into deeper poverty and marginalization, even as national exports become more "competitive" in the global economy. One irony of our world, then, is that food and other farm products flow *from* areas of hunger and need to areas where money is concentrated, in Northern countries.

The same dynamic drives environmental degradation. On the one hand, rural populations have historically been relocated from areas suitable for farming to those less suitable, leading to deforestation, desertification and soil erosion in fragile habitats. This process continues today, as the newly landless continuously migrate to the agricultural frontier.

On the other hand, the situation is no better in the more favorable lands. Here the better soils of most nations have been concentrated into large holdings used for mechanized, pesticide and chemical fertilizer-intensive, mono-

cultural production for export. Many of our planet's best soils - which had earlier been managed sustainably for millennia by pre - colonial traditional agriculturalists - are today being rapidly degraded, and in some cases abandoned completely, in the short term pursuit of export profits and competitiveness. The productive capacity of these soils is dropping rapidly due to soil compaction, erosion, waterlogging, and fertility loss, together with growing resistance of pests to pesticides and the loss of in-soil and above-ground functional biodiversity. The growing problem of "yield decline" in these areas has recently been recognized as a looming threat to global food production by a number of international agencies (see also Pingali et al., 1997).

Structural Adjustment and Other Macro Policies

As if that were not enough, the past three decades of world history have seen a series of changes in national and global governance mechanisms, which have in their sum, eroded the ability of governments in southern nations to manage national development trajectories with a view to the broad-based human security of their citizens. Their ability has been critically weakened to ensure the social welfare of poor and vulnerable people, achieve social justice, guarantee human rights, and protect and sustainably manage their natural resources. These changes in governance mechanisms have been made within a paradigm, that sees international trade as the key resource for promoting economic growth in national economies, and sees, that growth as the solution to all ills (Lappé et al., 1998).

In order to make way for increased import/export activity and export-promoting foreign investment, structural adjustment programs (SAPs), regional and bilateral trade agreements, and GATT and World Trade Organization (WTO) negotiations, have all shifted the balance of governance over national economies away from governments and toward market mechanisms and global regulatory bodies like the WTO. Southern governments have progressively lost the majority of the management tools in their macroeconomic policy toolboxes. They have been forced to drastically cut government investment through deficit slashing requirements, to unify exchange rates, devalue and then float currencies, to virtually eliminate tariff and non-tariff import barriers, to privatize state banks and other enterprises, and to slash or eliminate subsidies of all kinds, including social services and price supports for small farmers. In most cases, either in preparation for entering trade agreements, or with international financial institution (IFI) funding and/or guidance, governance over land tenure arrangements has followed suit, with privatization, land markets and market mechanisms coming to the fore, in search of greater investment in agricultural sectors (ibid.; Rosset, 2004; Bello et al., 1999)

While such changes have in some cases created new opportunities for poor people to exploit new niche markets in the global economy (organic coffee, for example), they have for the most part undercut both government provided social safety nets and guarantees, and traditional community management of resources and cooperation in the face of crises. The majority of the poor still live in rural areas, and these changes have driven many of them to new depths of crisis in their ability to sustain their livelihoods. Increasingly they have been plunged into an environment dominated by global economic forces, where the terms of participation have been set to meet the interests of the most powerful. Small farmers find the prices of the staple foods they produce dropping below the cost of production, in the face of cheap imports freed from tariffs and quotas. They are increasingly without the subsidized credit, marketing and prices which once helped support their production, and with communal land tenure arrangements under attack from legal reforms and private sector investors. The result is the declining productivity of small farmers who produce food for domestic consumption, especially in regions like Sub-Saharan Africa (Lappé et al., 1998; de Grassi and Rosset, forthcoming).

Lagging Productivity

Third World food producers demonstrate lagging productivity not because they lack 'miracle' seeds that contain their own insecticide or tolerate massive doses of herbicide, but because they have been displaced onto marginal, rainfed lands, and face structures and macroeconomic policies that are increasingly inimical to food production by small farmers. When development banks are privatized by SAP’s, credit is withdrawn from small farmers. When SAPs cancel subsidies for inputs, small farmers stop using them. When price supports end, and domestic markets are opened to surplus food dumped by Northern countries, prices drop and local food production becomes unprofitable. When state marketing agencies for staple foods are replaced by private traders, who prefer cheap imports or buying from large wealthy farmers, small farmers find there are no longer any buyers for what they produce. These then, are the true causes of low productivity. In fact, in many parts of the Third World, especially in Africa, *farmers today produce far less than they could with presently available know-how and technology*, because there is no incentive for them to

do so-there are only low prices and few buyers. No new seed, good or bad, can change that, and thus it is extremely unlikely that, in the absence of urgently needed structural changes in access to land and in agricultural and trade policies, genetic engineering could make any dent in food production by the world's poorer farmers (Lappé et al., 1998; de Grassi and Rosset, forthcoming).

When seen in this light, it should be clear that genetic engineering is tangential at best to the conditions and needs of the farmers we are told it will help - it in no way addresses the principal constraints they face. But tangential is a far cry from 'bad.' Now I turn to the question of whether genetically engineered crops are simply irrelevant to the poor, or if they might actually pose a threat to them. First we must ask about the actual circumstances of peasant farming.

A Complex, Diverse and Risk-Prone Agriculture

Because peasant farmers have historically been displaced, as described above, into marginal zones characterized by broken terrain, slopes, irregular rainfall, little irrigation, and/or low soil fertility; and because they are poor and are victimized by pervasive anti-poor and anti-small farmer biases in national and global economic policies, their agriculture is best characterized as complex, diverse and risk prone (Chambers, 1990, 1993).

In order to survive under such circumstances, and to improve their standard of living, they must be able to tailor agricultural technologies to their variable but unique circumstances, in terms of local climate, topography, soils, biodiversity, cropping systems, market insertion, resources, etc. For this reason such farmers have over millennia evolved complex farming and livelihood systems which balance risks -- of drought, of market failure, of pests, etc. -- with factors such as labor needs versus availability, investment needed, nutritional needs, seasonal variability, etc. Typically their cropping systems involve multiple annual and perennial crops, animals, fodder, even fish, and a variety of foraged wild products (Chambers, 1990, 1993; de Grassi and Rosset, 2003, and forthcoming).

Repeating the Errors of Top Down Research

Such farmers have rarely benefited from 'top down' formal institution research and 'green revolution' technologies. Any new strategy to truly address productivity and poverty concerns will have to meet their needs for multiple suitable varieties. Peasant farmers typically plant several different varieties on their land, tailoring their choice to the characteristics of each patch, whether it has good drainage or bad, is more or less fertile than the rest, etc. However, such varieties cannot be easily developed with current research and extension structures and methods - the same structures that biotech proponents use for genetically engineered varieties (the arguments in this section are developed in Chambers, 1990, 1993; de Grassi and Rosset, 2003, and forthcoming).

Formal research methods are not able to handle the vast complexity of physical and socio-economic conditions in most Third World agriculture. This stems from the discrepancy between hierarchical research and extension systems, which value monocultural 'yield' above all else, and complex rural realities. The result of the mismatch is that numerous variables important to farmers have to be reduced in order to produce new technologies. Measured in a few variables, new seeds are perceived by researchers to be better than old ones, who are puzzled when farmers fail to adopt them widely.

In reality seeds have multiple characteristics that cannot be captured by a single yield measure, as important as this measure may be, and farmers have multiple site-specific requirements for their seeds, not just controlled condition high-yields. These interconnections stand in direct contrast to formal breeding procedures where varieties are selected individually for discrete traits, then crossed to combine these individual traits. According to Jiggins and co-authors (1996), high-yielding variety trials in Sub-Saharan Africa show "larger variations, for both 'traditional' and 'improved,' *among* farmers and *between* years, than the mean differences between 'traditional' and 'improved' yields in a single year. There is indeed overwhelming evidence throughout SSA that the yield response to fertilizer and improved varieties, soil management and other practices is highly site-, soil-, season, and farmer-specific."

Given such conditions the inescapable conclusion is that a different approach is essential- participatory breeding by organized farmers themselves-which takes into account the multiple characteristics of both seed varieties and farmers. Miracle seeds will not just be developed in laboratories and on research stations and then effortlessly distributed to farmers. Sadly, genetic engineering is the very antithesis of participatory, farmer-led research. Proponents of genetically engineered varieties are repeating the very 'top down' errors which led first generation green revolution crop varieties to have low adoption rates among poorer farmers.

Yet many would argue that possibility of delivering enhanced nutrition to the poor should outweigh such concerns, for example in the case of the famous 'golden rice' which has been engineered to contain additional beta-carotene, the precursor of vitamin A.

Enhanced Nutrition?

The suggestion that genetically altered rice is the proper way to address the condition of 2 million children at risk of Vitamin A deficiency-induced blindness reveals a tremendous naiveté about the reality and causes of vitamin and micro-nutrient malnutrition. If one reflects upon patterns of development and nutrition one must quickly realize that Vitamin A deficiency is not best characterized as a problem, but rather as a *symptom*, a warning sign if you will. It warns us of broader dietary inadequacies associated with both poverty, and with agricultural change from diverse cropping systems toward rice monoculture. People do not present Vitamin A deficiency because rice contains too little Vitamin A, or beta-carotene, but rather because their diet has been reduced to rice and almost nothing else, and they suffer many other dietary illnesses that cannot be addressed by beta-carotene, but which *could* be addressed, together with Vitamin A deficiency, by a more varied diet. A magic-bullet solution which places beta-carotene into rice-with potential health and ecological hazards-while leaving poverty, poor diets and extensive monoculture intact, is unlikely to make any durable contribution to well-being. In fact, there are many readily available solutions to Vitamin A deficiency-induced blindness, including many ubiquitous leafy plants which when introduced (or re-introduced) into the diet provide both needed beta-carotene and other missing vitamins *and* micro-nutrients (Altieri and Rosset, 1999a, 1999b; ActionAid, 1999; Ho, 2000).

Yet it is clear that the genetic engineering juggernaut is moving ahead a full speed. What then are the risks associated with 'forcing' transgenic (genetically engineered) varieties into complex, diverse and risk-prone circumstances?

Risks for Poor Farmers

When transgenic varieties are used in such cropping systems, the risks are much greater than in green revolution, large, wealthy farmer systems, or farming systems in Northern countries. The widespread crop failures reported for transgenics due to stem splitting, boll drop, etc., (see for example, Eckardt at al., 1998; Gertz et al., 1999; Hagadorn, 1997) pose economic risks which can affect poor farmers much more severely than wealthy farmers. If consumers reject their products, the economic risks are higher the poorer one is. Also, the high costs of transgenics introduce an additional anti-poor bias into the system (Altieri and Rosset, 1999a, 1999b).

The most common transgenic varieties available today are those that tolerate proprietary brands of herbicides, and those than contain insecticide genes. Herbicide tolerant crops make little sense to peasant farmers who plant diverse mixtures of crop and fodder species, as such chemicals would destroy key components of their cropping systems (Altieri and Rosset, 1999a, 1999b).

Transgenic plants which produce their own insecticides - usually using the 'Bt' gene, closely follow the pesticide paradigm, which is itself rapidly failing due to pest resistance to insecticides. Instead of the failed "one pest-one chemical" model, genetic engineering emphasizes a "one pest-one gene" approach, shown over and over again in laboratory trials to fail, as pest species rapidly adapt and develop resistance to the insecticide present in the plant. Bt crops violate the basic and widely accepted principle of "integrated pest management" (IPM), which is that reliance on any single pest management technology tends to trigger shifts in pest species or the evolution of resistance through one or more mechanisms. In general the greater the selection pressure across time and space, the quicker and more profound the pests' evolutionary response. Thus IPM approaches employ multiple pest control mechanisms, and use pesticides minimally, only in cases of last resort. An obvious reason for adopting this principle is that it reduces pest exposure to pesticides, retarding the evolution of resistance. But when the product is engineered into the plant itself, pest exposure leaps from minimal and occasional to massive and continuous, dramatically accelerating resistance. Most entomologists agree that Bt will rapidly become useless, both as a feature of the new seeds and as an old standby natural insecticide sprayed when needed by farmers that want out of the pesticide treadmill. In the United States, the Environmental Protection Agency has mandated that farmers set aside a certain proportion of their area as a 'refuge,' where non-Bt varieties are to be planted, in order to slow down the rate of evolution by insects of resistance. Yet it is vanishingly unlikely that poor, small farmers in the third will plant such refuges, meaning that resistance to Bt could occur much more rapidly under such circumstances (Altieri and Rosset, 1999a, 1999b).

At the same time, the use of Bt crops affects non-target organisms and ecological processes. Recent evidence shows that the Bt toxin can affect beneficial insect predators that feed on insect pests present on Bt crops, and that windblown pollen from Bt crops found on natural vegetation surrounding transgenic fields can kill non-target insects. Small farmers rely for insect pest control on the rich complex of predators and parasites associated with their mixed cropping systems. But the effect on natural enemies raises serious concerns about the potential of the disruption of natural pest control, as polyphagous predators that move within and between mixed crop cultivars will encounter Bt-containing non-target prey throughout the crop season. Disrupted biocontrol mechanisms may result in increased crop losses due to pests or to the increased use of pesticides by farmers, with consequent health and environmental hazards (Altieri and Rosset, 1999a, 1999b; Hillbeck et al., 1998; Dutton et al., 2002).

The fact that Bt retains its insecticidal properties after crop residues have been plowed into the soil, and is protected against microbial degradation by being bound to soil particles, persisting in various soils for at least 234 days, is of serious concern for poor farmers who cannot purchase expensive chemical fertilizers, and who instead rely on local residues, organic matter and soil microorganisms (key invertebrate, fungal or bacterial species) for soil fertility, which can be negatively affected by the soil bound toxin (Zwahlen et al., 2003; Donnegan et al., 1995; Altieri and Rosset, 1999a, 1999b).

When the Bt genes fail, what would poor farmers be left with? It is entirely possible that they would face the serious rebound of pest populations freed of natural control by the impact Bt had on predators and parasites, and reduced soil fertility because of the impacts of Bt crop residues plowed into the ground. These are farmers who are already risk-prone, and Bt crops would likely increase that risk.

In the Third World there will typically be more sexually compatible wild relatives of crops present, making pollen transfer to weed populations of insecticidal properties, virus resistance, and other genetically engineered traits more likely, with possible food chain and super-weed consequences. With massive releases of transgenic crops, these impacts are expected to scale-up in those developing countries which constitute centers of genetic diversity. In such biodiverse agricultural environments, the transfer of coding traits from transgenic crops to wild or weedy populations of these taxa and their close relatives is expected to be higher. Genetic exchange between crops and their wild relatives is common in traditional agroecosystems and transgenic crops are bound to frequently encounter sexually compatible plant relatives, therefore the potential for "genetic pollution" in such settings is inevitable (Altieri and Rosset, 1999a).

Perhaps of greater concern to peasant farmers is the possibility that their locally adapted crop varieties will be contaminated with transgenes via cross-pollination from transgenic varieties planted by other farmers. This concern was recently highlighted by the contamination with transgenes of local maize varieties in Mexico. It is in Mexico that, maize, was domesticated by indigenous peoples, and the region remains the present-day center of genetic diversity for this staple food crop so critical to global food security. The thousands of local varieties still cultivated by peasant farmers contain untold genetic diversity upon which crop breeders and farmers worldwide depend as a source of novel traits for their breeding programs. Recognizing that this constitutes a critical biological heritage for all of humanity, the Mexican Environment Ministry in 1996 prohibited the import of transgenic maize seed, for fear of contaminating this resource. Unfortunately transgenic maize grain was still imported for human consumption, and is sometimes planted by the poor in lieu of maize sold specifically as seed. Thus in 2001 scientists discovered alarmingly high rates of contamination of local maize races, presumably via wind-borne pollination from such plants (Quist and Chapela, 2001). Because of molecular promoters of gene expression incorporated into transgenic varieties, contamination poses a threat to the genetic integrity of local landraces, as these promoters can potentially scramble the genomes of contaminated varieties (Ho et al., 2003; Wilson et al., 2004). Thus peasant farmers could lose the locally adapted varieties that they depend upon, and the world could lose germplasm that is critical to future food security.

There is also potential for vector recombination to generate new virulent strains of viruses, especially in transgenic plants engineered for viral resistance with viral genes. In plants containing coat protein genes, there is a possibility that such genes will be taken up by unrelated viruses infecting the plant. In such situations, the foreign gene changes the coat structure of the viruses and may confer properties such as changed method of transmission between plants. The second potential risk is that recombination between RNA virus and a viral RNA inside the transgenic crop could produce a new pathogen leading to more severe disease problems. Some researchers have shown that recombination occurs in transgenic plants and that under certain conditions it produces a new viral strain with altered host range (Steinbrecher, 1996). Crop losses caused by new viral pathogens could have a more significant impact on the livelihoods of poor farmers than they would for wealthier farmers who have ample resources to survive poor harvests.

In sum, these and other risks seem to outweigh the potential benefits for peasant farmers, especially when we consider the factors that currently limit their ability to improve their livelihoods, which are largely structural in nature-and thus political-rather than technological. Furthermore, to the extent that 'better' technologies are needed to improve farmer livelihoods and/or productivity, there are a wealth of proven agroecological, participatory and empowering alternatives available to them (see Altieri et al., 1998, Ho et al., 2003; and Pretty et al., 2003, for an introduction to these alternatives).

Conclusions

In this paper I have argued that the causes of rural poverty and hunger in the Third World, and of lagging productivity among peasant farmers, are first, structural in origin, due to colonial and post-colonial patterns of large-scale export cropping on favorable lands and the displacement of food producers to marginal habitats; and second, exacerbated by recent policy trends. Policies that enforce exclusion and depress productivity include the cutting of public sector budgets for agriculture, and the privatization of marketing and credit, under structural adjustment. They also include trade liberalization, which has led to the inundation of local markets with cheap foodstuffs, often at prices below the cost of production. Faced with little or no credit for production, few or no buyers for their products, and prices often at or below the cost of production, peasant farmers have scaled back their production and produce less than they could with present technology, land and know-how. This is because they lack basic economic incentives to produce more. Under such conditions, I argue, innovations based on crop genetics, including genetic engineering of seed varieties, are unlikely to have any positive impact, as they are tangential at best to the real constraints to production. Furthermore, I argue, the nature of both genetic engineering technology, and the complex, diverse and risk-prone nature of peasant farming, makes genetically engineered crops a particularly risky and inappropriate technology for such farmers. This is especially the case given the existence of more appropriate, agroecological alternatives, although the real challenge is to change the structural and policy conditions that impede the productive activities of small-scale farmers.

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