The Social Impact of Biotechnology on Farming and Food Production

Introduction

The family farm is disappearing. The family farm is quite enduring. New technology is the cause of social change. New technology is the consequence of social change. Biotechnology is revolutionary. Biotechnology is really more of the same. The world needs more food production. The world already produces enough food to meet its needs. Biotechnology will radically alter living nature. Biotechnology will merely reveal the potential inherent in nature.

These and other antinomies are commonplace in discussions of the impact of biotechnology on farming and food production. They tend to polarize the participants in the debate, though not all participants can be found on the same side of each antinomy. In fact, each of us can be found on both sides of the debate at different points in time. This position is representative of recent developments in the social studies of science. See, for example, Latour (1988) and Busch, Lacy, Burkhardt, and Lacy (1990). Rather than attempting to place myself on one or the other sides in these antimonies, or, alternatively, trying to arrive at some sort of compromise between the two, I wish to begin instead by asking the question: What is it about technical change that gives it this dual appearance? Why does technology appear on the one hand to be the result of deliberate human endeavor and on the other hand the revealing of nature's grand design? Why does it appear on one hand to be the result of heated debate and on the other the irresistible working out of a grand Hegelian plan?

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Let us begin by considering the work of plant breeders. Plant breeders, according to textbook definitions, would appear to be engaged in the process of modifying the genetic makeup of plants within the constraints of Mendelian genetics. But that is only part of the work of breeders. In addition, they perform another kind of equally important work—work that is essential if their discipline is to succeed. What breeders also do is to change the behavior of farmers, processors, wholesalers, retailers, and consumers. In short, plant breeders are responsible for changing human behavior.

Now at first this may appear absurd. After all, we have been brought up to think that it is sociologists, psychologists, or perhaps advertising agents who change people's behavior. However, consider what it means to be a *good* plant breeder. First, a good plant breeder amasses a wide range of promising materials from all over the world. A good breeder knows the material with which he or she works very well. This kind of knowledge is essential since only someone who knows the material well can pick out the anomalies, the mutations, the extraordinary from the mass of materials that have been collected. Then, the breeder selects only those materials that contain the character(s) of interest which are crossed with other plants to produce a new cultivar. Once the cultivar is produced, we are told that it is simply the best that nature could offer. All the work, all the effort made over several years, is incorporated into the new seed, but it is no longer visible. The new seed looks to all much like the older seeds that have been around for some time. Yet, it contains within it new characters that were never put together in that sequence before.

This does not mean that the work of the breeder is complete. Far from it. If so, we would be very proud of the breeder who collected hundreds of jars filled with samples of new cultivars that never went beyond his or her office. No, the good breeder must also get people to use the new varieties. The diffusion models of technical change (e.g., Rogers, 1983) suggest that breeders develop their new varieties without much regard (at least initially) to the needs and interests of farmers, processors, consumers or anyone else outside the scientific community. Yet, if this were the case, it would be the rare, accidental innovation indeed that actually met the wants or needs of some individual or group. To the contrary, *the good* breeder will be in touch regularly with farmer groups, processor organizations, transporters, and others to find out just what they will find advantageous to them. Therefore, as soon as he or she has a new cultivar to release, there will already be a market for it. Hightower (1973), in his much acclaimed and much attacked book of nearly twenty years ago, *Hard Tomatoes, Hard Times,* took the diffusion model seriously. Since all the good ideas were to emerge from the heads of clever scientists and be packaged as technologies that would be available to all, he was scandalized by what he saw as the overly close linkages between certain farmers and agribusiness corporations and public sector scientists.

But let us return to our plant breeders. The good plant breeder must necessarily be in touch with a wide range of (potential) constituent groups in order to know just which two or three of the myriad characters for which one could possibly breed should be the object of breeding work. This will involve negotiation, persuasion, and even coercion on the part of the breeder and the constituent groups (Busch, 1980). However, in the final analysis, our good breeder will choose those characters that are of interest to his or her audience: those involved in the production, processing, and consumption of a particular agricultural commodity. In some cases, breeders take into account some clients but not others, leading to disastrous consequences. See, for example, Flora (1986). Other clients are often ignored by virtue of their powerlessness (Friedland, *et al.,* 1981). In so doing, the good breeder will assure that what has been created by breeding will be rapidly and widely adopted as the new industry standard. In short, the good breeder will and must be just as interested in changing the behavior of people as in changing the genetics of plants.

However, the agricultural sector is different from other sectors of the economy in at least two very important ways and these differences make technical change in agriculture very different than technical change in other economic sectors. First, in agriculture research and development are separated from the production of agricultural products. General Electric and AT&T produce nearly all of their technical innovations within their respective companies. Only a handful of farm businesses (e.g., poultry) do their own research and development work. Instead, public sector institutions such as Land-Grant universities and the United States Department of Agriculture (USDA), and increasingly private companies of various sorts, provide nearly all of the desired research and development. When a scientist at General Electric begins to work on a technical change which appears to have no relevance to the firm's products or processes, his or her work is quickly brought under corporate scrutiny (Reich, 1985). Its potential is discussed and analyzed. Market testing might even be performed. In the agricultural sector, input suppliers and public sector scientists perform the research and development for farmers. Private sector firms can and do engage in product testing on farms. And public sector scientists often test new varieties in on-farm trials. However, farmers and other potential users are usually brought into the process much further down the line and they virtually never have the same interests as the producers of the innovation.

A second difference between the agricultural sector and the rest of the economy is the inelastic character of the demand for most agricultural products. If the cost of production of automobiles or television sets is forced downwards through technical change, there is a compensatory increase in the number of television sets sold. Certain firms may lose out as a result of this technical change, but the total value added within the commodity subsector will actually rise. Within very wide limits this is true for nearly all industrial products. In contrast, with a reduction in the cost of production of agricultural products, there is virtually no change in the quantity demanded. As a result there is a (temporary) glut on the market until some farmers are forced out of business, the remaining farmers increase their market share, and the remaining value added in agriculture is distributed elsewhere—usually off the farm. Thus, public sector agricultural scientists are faced with a very complex ethical decision: Do they not work for any organization directly involved in the production of an agricultural commodity? Their goal is to further the public good, so their loyalty must be divided among all the constituents of a given commodity subsector. Yet, it is almost inevitable that the result of technical change will be the redistribution of wealth and income within that subsector. Boysie Day (1978) has argued that agronomists should be revolutionaries, pushing aside all who would block the technical changes they propose; doubtless, other agricultural scientists would disagree. Ruttan (1982) has argued at length that scientists should not be asked to shoulder too much responsibility for their actions. Nevertheless, even he notes that "When credit is claimed for the productivity growth generated by advances in agricultural technology, responsibility cannot be evaded for the impact on environmental amenities or on the health of workers and consumers" (1982, pp. 13-21). With this rather lengthy but necessary background, let me now turn to agricultural biotechnology. As I noted in my introduction, there are two competing views that may be taken of the new biotechnologies. On the one hand, it may be argued that biotechnology is much like other technical change. Its consequences will be little different from what has already been experienced. On the other hand, it may be argued that biotechnology represents a qualitative shift in the process of technical change in agriculture. I shall not argue for one or the other position here. Instead, I wish to argue that both positions are in some sense right.

Biotechnology Is Like Other Technical Change

Biotechnology will probably have less impact on the total number of farms than previous mechanical and chemical technologies adopted by farmers during the last 50 years (Buttel, 1989). This is the case simply because the overwhelming majority of farms that once existed in the United States are now no longer in existence. The largest 13 percent of farms now produce over 75 percent of the value of total production. The *rate* of increase is bound to slow as we approach 100 percent. With only two percent of the population on farms, the cost of replacing more people with capital will be far greater than it was in the past. In addition, the vast majority of small farms are now buffered from the effects of technical change by the fact that farm income is no longer the primary source of income for their owners. Thus, irrespective of the changes wrought through biotechnology, small farms are likely to continue to exist. In short, biotechnology will not exacerbate the decline in the number of farms, though it will certainly continue present trends.

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Biotechnology will certainly continue to produce labor saving farm level technologies. This has little to do with the total amount of labor available. It has to do with the fact that labor control on the farm has always been and will continue to be a source of difficulty for farmers (Friedland, *et al.*, 1981). Farmworkers, on the other hand, have rarely enjoyed access to research laboratories and, in any case, are not the purchasers of the new technologies. However, this is only a continuation of a long, well-established (though not necessarily morally justified, end substituting technology for labor in farming (and in most other industries as well)). Social scientists and others in Land-Grant Universities have been concerned for some time about the inattention paid to the problems of farm labor. See, for example, Cargill and Rossmiller (1969), Friedland (1984), and Coye (1984). On the other hand, biotechnology will probably also create some new high technology jobs in the farm input and food processing sectors. The factory setting in these industries makes labor control much easier. Again, the same could, and has been said, about older mechanical and chemical technologies.

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Biotechnology will also continue to reduce production costs. This, as with any new technology is an essential component—though certainly not the only one—in its adoption. Thus, we can expect biotechnology to cut further both on-farm and off-farm agricultural production costs. However, the impact on consumers is likely to be greatest for off-farm cost reductions as the on-farm component is now a negligible percentage of the total cost of food and fiber.

Biotechnology will increase the value-added off-farm at the expense of value-added on-farm. Here again, this is an old pattern of technical change, due in large part to the inelastic demand for farm products as noted above. However, since most value is now added off-farm, new biotechnologies will likely have less effect than the older mechanical and chemical technologies. In short, as Goodman, *et al.*, (1987) have argued, the new biotechnologies will further both appropriation and substitution. On the one hand, they will further appropriation by continuing to remove certain processes from the farm and inserting them into indus- trial production (e.g., the removal of butter processing from the farm to the factory). On the other hand, they will further substitution by creating whole new processes (e.g., the substitution of margarine for butter). In these senses, the new biotechnologies do not represent a significant change; they are merely more of the same.

Biotechnology Is Unlike Other Forms of Technical Change.

Yet, at the same time, we may argue that biotechnology is quite unlike other forms of technical change that have affected the agricultural sector. First, biotechnology will bypass the Extension Services. Previous forms of biological research have been marketed through the Extension Service. New seeds may often have been produced by private seed companies, but the Cooperative Extension Service has played the role of telling farmers what seeds would do best in given climates and soils. The creation of seed-chemical packages puts together decisions previously made serially. Extension has been skillful in recommending specific incremental changes in products and practices, but it has never been able to distinguish between various combinations of inputs and practices. This has always been left to the farmer. Hanway (1978, p. 5) has noted that "Up to the present time we have not really developed comprehensive, integrated, multidisciplinary research programs that deal with improvement of crop production systems as systems.... In the United States most individual compo-

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nents are studied independently of others. Recommendations and educational efforts are carried out by specialists each traveling his own way and telling his own story. The farmer is confronted with making a system out of all the diverse information that comes his way. I'm sure experiment stations have not often assembled all the components of the systems they recommend to see how they function together." In fact, in many states Extension no longer has the expertise (when compared to farmers) even to carry out its old mission; evaluation of packages is a task for which Extension is totally unprepared. Moreover, since the new packages will not emerge from Land-Grant research, public sector scientists will have little knowledge with which to support Extension programs. In short, the evaluation of the various packages will require skills that surpass those in the Extension Service. Given the current funding shortfalls in Extension, it is unlikely that this problem will be remedied. More likely, Extension will (not so) gradually be reduced to playing a secondary role in farm change.

Biotechnology will also accelerate the trend toward contract integration. Already, commodities such as poultry and most processing vegetables are produced on contract. Such contracts specify the seeds, chemicals, planting and harvesting times, and other aspects of farm production. Some have argued that farmers who produce on contract are best viewed as employees of the contracting company as their role in decision making has been so reduced as to eliminate their autonomy (e.g., Heffernan, 1984). Through the development of functional attribute crops, biotechnology will speed the push toward contract production into other commodities (Moshy, 1986). It will also increase the importance of precision in planting, growing, and harvesting crops in order to fit certain markets. This will further reduce the autonomy of farmers and will most certainly reduce their contacts with and needs for Cooperative Extension.

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A third change that is on the horizon as a result of the new biotechnologies is an increase in the number of market niches in farming. Functional attribute crops, already noted above, will make it possible to produce special grains for starch production, crops designed for the production of plastics (e.g., Pool, 1989), and other yet to be invented specialty crops. This differentiation within farming will actually reverse the long trend toward dedifferentiation within agriculture. However, it will not merely involve the return to some earlier time. Consider a crop like wheat. One hundred years ago wheats varied enormously in quality, yield, color, texture, etc. Over the last century, largely as a result of breeding combined with product standards, there are not only fewer wheat cultivars, but also far less variation in the quality of wheat products. This homogenization of wheat has been advantageous to some in that it made it possible to trade internationally in wheat without seeing the product before delivery. It also virtually eliminated poor quality bread from the market. On the other hand, it is unlikely that consumers ever wanted white pan bread with the startling uniformity it had for more than half a century in the United States (Giedion, 1975). This said, the new biotechnologies offer the possibility of specialized wheats designed for use in the manufacture of specific food products as well as for industrial uses (e.g., Austin, 1986). These new market niches will involve the proliferation of standards rather than a return to the situation of 100 years ago when standards did not exist.

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The new biotechnologies will also restructure the relations between farmers and researchers. Until very recently, farmers were seen as the primary clientele for public sector research. However, the entry of molecular biology into agricultural research has been accompanied by the insertion of the agribusiness sector between farmers and researchers. The Rockefeller Foundation report (1982) and the National Research Initiative have supported a move to what is commonly called basic research. Agriculture, and particularly the plant sciences, have suffered from a lack of attention to fundamental questions. However, the National Association of State Universities and Land-Grant Colleges has noted a considerable decline in the numbers of plant and animal breeders employed at Land-Grant Universities (NASULGC, 1989). It is apparent that most of these positions have been filled with molecular biologists. Breeders have traditionally seen their prime clientele in the farm population. Farmers often visit breeders to make specific requests of them. In contrast, much of the work of molecular biologists only benefits farmers (to the extent that it benefits them at all) by contributing to the product development work in the private sector. As a result it is quite possible—indeed, likely—that certain problems not of interest to the agribusiness sector will not be the subject of public research either.

The new biotechnologies also have within them the potential to change the very nature of food itself. In the past, the ability of scientists to alter food has been limited by three factors: First, nearly all genetic change in crop plants has been limited to that which could be achieved through sexual reproduction. Thus, the categories of food plants and animals were grounded in certain natural obstacles that could not be overcome. Now it is possible to move genetic material virtually at will among plants, and between plants, animals, and microorganisms. Second, while it has been possible to mix ingredients from various sources to produce food products for millennia, it was very difficult (and in many cases impossible) to break down food products into their essential components. Now it is possible to consider the production of fabricated foods (e.g., Stanley, 1986) in which basic foods are broken down into their component parts (e.g., starch, fat, sugar) and recombined to make wholly new types of foods. Finally, while human beings were required to raise entire plants and animals in order to obtain the parts that were edible or useful, we are now on the verge of being able to produce just those plant or animal parts we desire *in vitro* (Rogoff and Rawlins, 1987). Already, Imperial Chemical Industries (ICI) has managed to synthesize vanilla *in vitro* (Bock and Marsh, 1988). That product will be cheaper than vanilla from vanilla beans but more expensive than the artificial vanilla currently available. Its use now hinges on whether or when the Food and Drug Administration (FDA) will grant ICI the right the call the new product "natural vanilla." I shall refrain here from speculating as to the short- or long-term consequences of such a restructuring and industrializing of the food supply (but see Busch, 1990). Suffice it to say that such new forms of food will make it far more difficult for the consumer to obtain a balanced diet than at present. It will also make food production more and more like the production of other manufactured goods.

Last, the new biotechnologies will increase the possibility of what Charles Perrow (1984) has called normal accidents through tight coupling. Until very recently, foods have been adulterated only by virtue of deliberate human decisions. In some cases, adulteration was the result of adding things to food (e.g., watering down milk), while in other cases it was the result of neglecting to take necessary precautions in processing. Our pure food and drug laws were passed with those notions in mind. However, the new biotechnologies raise yet another possibility: that the increasing complexification of food production, the creation of more and more complex systems in which food passes near potentially harmful substances, raises the possibility of accidental contamination that is not due to any human decision but to the complexity of the systems themselves.

Conclusions: Research For What and For Whom?

In short, the very fact that the new biotechnologies have to date had very little effect on farming or food production makes it possible to argue both sides of the case. Consider the case of the gasoline-powered farm tractor. When initially introduced it was the subject of raging debate among farmers and scientists alike. Would it replace the horse and ox? Would it transform world agriculture? Now, with the advantage of 20/20 hindsight we can argue that the triumph of the gasoline powered tractor was certain. It had the necessary flexibility, it did not require feeding all through the winter like a horse, and it was lighter than steam tractors and therefore not as likely to get bogged down in the mud. In other words, the gasoline tractor was an inevitable step on the path to progress.

However, to do that is to forget the powerful interests that lined up behind the tractor and those that eventually abandoned the horse and the steam tractor. These interests that built repair shops and gasoline distributorships, that permitted and even encouraged bank loans to farmers who wanted to buy tractors, and restructured rural society so as make it more amenable to tractor production helped to create the "inevitability" that the tractor had. And, at the same time, the tractor itself was changed considerably (Sahal, 1981). The iron wheels were replaced first with hard rubber and then with balloon tires permitting greater buoyancy in the field and less soil compaction. The power takeoff was added, permitting the tractor to engage in a wide variety of work far beyond what a horse could do by dragging a plow.

The situation for the new biotechnologies today is much the same as it was for the tractor at its inception. Strong claims on all sides are the order of the day. Yet, the outcome is quite unclear. It is conceivable that certain biotechnologies will go unused because certain groups see them as too dangerous, as a violation of deeply held values, or less desirable than other existing alternatives. It is equally conceivable that the new biotechnologies will push aside existing technology and social relations and transform society once again. Only in half a century will the "inevitability" of the process become apparent.

In the meantime we who are in the public sector, who are paid by the public purse, need to ask the tough questions that proponents of these and other technologies will not and need not ask: What will be the benefits of the new technologies? Which of them do we need and want? What limits do we want to put on their development and use? Who will benefit from these new technologies? Will the benefits and costs be equally distributed, or will some benefit while others bear the costs? How much power do we want to have over the natural world? Do we have the wisdom to know what to do with that power once we have it?

Technology is a human creation. It is not a matter of whether its development shall be controlled, but who shall control it? Shall it be developed to serve narrow vested interests or broad public goods? Shall it serve to reinforce widely held values or to shatter them? As I noted above, scientists always do double work: They at once modify nature and human behavior and institutions. If that is the case, then scientists have a special obligation to take these questions very seriously, and not to let funding sources, enthusiasm with the power of the new technology (Idhe, 1979), or personal gain or glory permit the avoidance of these difficult questions.

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