Much food, many problems

A new agriculture, combining genetic modification technology with sustainable farming, is our best hope for the future.

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Whatever the reasons for the current furore in the United Kingdom over genetic manipulation of plants, an abundance of food is certainly one of them. We are inundated with new foods, and supermarkets respond to every consumer whim. People in the West eat a much healthier diet now than at the turn of the century, thanks to cheap, plentiful food provided by modern intensive agriculture. But wealth brings its own problems, not least acceleration in technological change. With an abundance of food and long life has come the demand for a risk-free world. Under these circumstances, the public is little interested in new ways of producing the same food, especially if there is even a minute health risk.

Attempts to introduce genetically modified (GM) foods have stimulated, not a reasoned debate, but a potent negative campaign by people with other agendas who demonize the technology. These opponents ignore common farming practice and well-investigated facts about plants, or inaccurately present general problems as being unique to GM plants. Almost without exception, opponents of GM foods are not plant biologists.

As a plant biologist myself, I have little time for big, insensitive agribusiness. The 'green revolution' of the 1970s, which developed crops of direct value to many people, particularly those in the developing countries, was publicly funded. A decade ago, most plant biologists supposed that genetic manipulation would be used to the same end, for example to produce crops resistant to yield-destroying diseases such as rust or rice blast, or pests such as locusts. Herbicide-resistant plants would have been near the bottom of my list of priorities, especially using the effective and innocuous herbicide glyphosate.

Superweeds

The British Medical Association[1] and green (environmental) activists have objected to GM rape containing resistance to glyphosate, claiming that it will generate superweeds by gene flow of the one specific transgene into three or four weedy relatives. Yet weeds (and crops) resistant to one or another specific herbicide have been known for 50 years, and ecological studies of the spread of resistance investigated this in detail 20 years ago[2]; such weeds can be eliminated by using another herbicide. (Perhaps Synchrony beans, bred from soybean individuals naturally resistant to sulphonyl urea herbicides, should be relabelled 'superbean' to make this point.)

Introduced plants are the real superweeds. Three thousand alien species in the United Kingdom alone, mainly introduced by gardeners, now outnumber the 1,500 or so indigenous species and cause serious environmental damage (for example, *Rhododendron ponticum*) and/or are resistant to virtually all herbicides (for example, Japanese knotweed, *Fallopia japonica*). At least 60 aliens have hybridized with indigenous species, producing additional environmental contamination from the unpredictable consequences of mixing thousands of new genes in a continuing process of illegitimate gene flow. Yet, although environmental activists label gene flow as unacceptable genetic pollution[3], there is no trampling of flowers or demonstrations at the international flower shows that are potent sources of new foreign pollen, nor demands for barriers miles thick at such shows to prevent cross-pollination by bees. Nor have there been requests for strict laws to prevent people introducing new foreign seeds into their gardens on the grounds that this would cause serious environmental damage by new hybridization and subsequent gene flow.

Another common argument is that, once a transgenic plant is released, it can never be withdrawn. But all domesticated crop plants lack the genetic variability and weedy characteristics of wild plants and quickly disappear from fallow fields.

Just what do anti-GM-food environmentalists really care about? Rachel Carson in her 1962 classic book *Silent Spring* documented the urgent need to reduce pesticide applications to crops. She argued that mankind's best chance for long-term survival depends on minimal impact on planetary ecosystems, and that the biodiversity on which we are ultimately interdependent must be maintained.

On average, conventional farming uses five or more broad-spectrum pesticide applications on crops each year. The technology is ultimately self-limiting because pest resistance rapidly emerges, much as overprescription of antibiotics by the medical profession is hastening the end of useful drugs. The *Bacillus thurigiensis* (*Bt*) insecticidal proteins (a family of 130 proteins) selectively kill some beetles and caterpillars[4] and target insects that eat crops. Expression of *Bt* protein into cotton and corn has reduced the application of specific, highly toxic pesticides by more than 80%, allowing a substantive return of wildlife to crop fields (refs 4, 5, and www.econ.ag.gov./whatsnew/issues/biotech).

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Even though the technique is not perfect, it is surely better than killing virtually all field insects with pesticides. Yet opponents of GM technology not only have not welcomed this giant stride towards Carson's goal, but have completely rejected it. A laboratory study on the effects of GM crops on the monarch butterfly[6] was exaggerated out of all proportion by the media, whereas more realistic assessments (for example, ref. 7) are ignored. Negative propaganda against genetic manipulation ensures that pesticide treatments of UK farmland will continue. Field insect numbers remain low and many songbirds die prematurely. Who are the environmentalists now?

Spread by pollen

The concern that GM plants could contaminate far-off fields with huge numbers of transgenic plants has arisen because, using the polymerase chain reaction test, minute quantities of GM pollen have been detected kilometres away from GM trial fields (see ref. 3). But pollen is known to move much further than genes. Pollination distances beyond which growing siblings are not produced were painstakingly measured by ecologists 20 years ago[8] and, as a result, a separation distance of about 50 metres is used internationally to maintain separate lines of the same crop at greater than 99.5% purity. Very rarely, individual seeds can be spread by birds over long distances (as pointed out by Darwin in the nineteenth century), but the transgenic crop seeds so far produced have low fitness with poor survival possibilities.

Another way to prevent the distribution of transgenes by pollen is to insert the gene into chloroplast DNA, as the pollen of most crop plants contains no chloroplasts and thus no plastid DNA. Transformation systems for chloroplasts are well established[9,10]. Very high expression of transgenes can be achieved and there is just one insertion site. But if chloroplast GM plants were produced commercially, I would expect many opponents to maintain their opposition. Is this simply GM technophobia (see box, overleaf)?

The achievements of the negative GM-food campaign have been to engender unsubstantiated fear among the UK public about GM food. One, no-doubt-unintended casualty of such a mood was Axis Genetics, a

small company making medical GM products such as the cholera-vaccine-expressing banana. Cholera kills millions of young people in the Third World every year. A banana tree expressing cholera vaccine in each village would have offered the possibility, now denied to many, of a full life.

The international charity Christian Aid, in a report[11] on farming and hunger in the developing world, attacked 'green revolution' agriculture and genetic manipulation, stating that politics, and not lack of food, is the main cause of hunger. Yet the report ignored the population explosion, claiming that more people were malnourished after the green revolution than before. According to the United Nations' Food and Agriculture Organization, in 1970 there were 935 million malnourished people in Africa, South America and the Far and Near East; after 20 years of green revolution agriculture their numbers had been reduced to 730 million (ref. 12). These numbers are still unacceptable, but in the same 20 years the population in these areas almost doubled from two billion to about four billion[13]. The green revolution fed this increase by a doubling of wheat and rice yields per hectare. At least one billion extra people had sufficient to eat who would have starved using traditional agriculture. Further increased cereal yields via conventional breeding are now unlikely[13].

The Christian Aid report also claimed that genetic manipulation is not needed because the world can grow enough food without it. But no food supply is guaranteed. Devastating crop diseases occurred in US corn in 1971 and led to mass starvation in Ireland in the 1840s. By 2025, the world population will have increased by a further 2.3 billion, which will require an average annual increase in food production of 1.3% (ref. 14). In the past few years, the increase in world food output has dropped below that crucial figure, and many poorer countries are living on the residual excess of the green revolution.

The future is threatened by global warming and unpredictable climate change. The old enemies of locusts, floods, disease, drought and pests still exist. In the face of these adversaries, diversity in technology becomes a strength and a necessity, not a luxury. We have developed genetic manipulation of food and plants only just in time. Companies and scientists may fumble in its use, but now is the time to experiment, not when a holocaust is upon us. Opposition to the technology is both short-sighted and potentially dangerous.

The organic way

As populations rise, inefficient farming will destroy a much greater quantity of wilderness and its associated wildlife than is necessary. Greenpeace has announced its bid for the future, but in reality this is a lurch into the past. It has opted for pre-1950 agriculture — 'organic' farming — in which average crop yields on a variety of soils are about half those of intensive farming[15–17].

For very obscure reasons, organic farmers eschew the use of most minerals. Instead, cow manure is used as the primary fertilizer. Extra land is needed to support the required cow population, so land-use efficiency of organic crops is further reduced. Going organic worldwide, as Greenpeace wants, would destroy even more wilderness, much of it of marginal agricultural quality[15].

The organic philosophy is negative and restrictive in its rules and regulations. It started as a movement simply to eliminate pesticides from food, and it is indeed beneficial to use pesticides sparingly, as organic farmers do. But the philosophy was founded on a fallacy. Food was thought to be somehow pure and pristine to which dangerous man-made chemicals were added by intensive agriculture. But almost all (99.99%) of the carcinogens routinely consumed by people are made by plants to inhibit predation, and are present in variable amounts in all food[18].

Most organic rules and treatments have never received proper biological investigation as to human safety. In one case in which they have — the use of *Bt* spores as an insecticide — there are reports of potentially serious consequences for human health[19]. Mycotoxin contamination, and infection from the potentially lethal *Escherichia coli* 0157, are additional problems[15].

Organic farmers reject GM plants, regarding them as unnatural. In the past 50 years, however, 'unnatural' combinations between many different species of crops have been constructed using embryo rescue and cell culture[20]. Well-known examples include crosses between wheat and rye (to produce triticale, grown on one million hectares worldwide), between rice and sorghum, agropyron and wheat. Organic farmers do not reject these 'unnatural' plants.

Greenpeace regards organic approaches as working with the grain of nature, a truce in a hypothetical war of humans with nature. This concept is simply wrong. We live on a planet where the ecology is constructed on a competition for resources. Competition is the vital spark that energizes evolution and generates vitality and creativity. We are not at war with nature, but striving towards a new dynamic equilibrium in which our unique biological characteristic, the human spirit, must take its place.

Looking to the future

The future will demand agriculture to be both flexible and diverse in technology, but efficient in land use. Farmers will have to be highly skilled at using technologies that must sustain farming for thousands of years[13]. Increasingly, farm resources will need to be recycled; green manure and crop rotation will underpin soil fertility. Integrated pest-management systems and zero tillage will be essential to minimize losses due to pests and weeds, and to limit soil erosion. Water will become an increasingly expensive commodity, and a premium will emerge on crops that use water efficiently without loss of yield[16]. In all this future agriculture, genetic manipulation has a unique and intimate role. Let's have some ideas. ■

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Is there a test for GM technophobia?

- Natural glyphosate resistance exists in rape, and the resistance gene has been isolated. Fields of naturally resistant rape can be grown. Gene flow from such a field would carry the resistance gene into relatives. Pollen containing the resistance gene could be detected on organic farms kilometres away. Reduction in weed number on treatment with glyphosate would curtail insect populations and reduce associated songbird numbers.
- If that isolated gene is now inserted by genetic manipulation into rape and an equivalent field grown and treated, in what way are gene flow, pollen distribution and ecology different from those in the natural field? Based on previous experience, activists and organic farmers would complain about the second field but not the first.
- Is this simple technophobia? The second GM field can be produced with one-tenth of the expenditure and one-tenth of the time it takes to produce the naturally resistant rape because of the enormous backcrossing required to eliminate undesirable traits.
- Synchrony beans, naturally resistant to sulphonyl urea herbicides, indicate the reality of this process. Fungus- and pest-resistance genes isolated from resistant individuals are also being inserted back into the same crop species by genetic manipulation.

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