MORE FROM LESS – A LASTING SOLUTION

11

Genetic improvement and sustainable intensification

Necessity of genetic improvement

Meeting the food needs of a rising global population while adapting to the threats of climate change and reducing our environmental footprint presents the global agricultural community with an unprecedented challenge. Without the genetic improvement of crops by a combination of conventional breeding, marker-assisted selection (MAS) and genetic modification (GM), it is difficult if not impossible to see how this challenge can be met.

There are several components, though, to a sustainable farming future, not just genetically improved seed. More effective land and water use, integrated pest management strategies and fewer harmful chemical inputs are all essential. Sustainability, in other words, is multi-factorial.

Health effects

No technology is sustainable if it is harmful to human or environmental health. There is broad scientific consensus that, after nearly two decades of cultivating GM crops planted over a cumulative total of more than 1.5 billion hectares, there have been no apparent adverse effects on people's health from the new biotechnologies. Nor have they demonstrably damaged the environment.

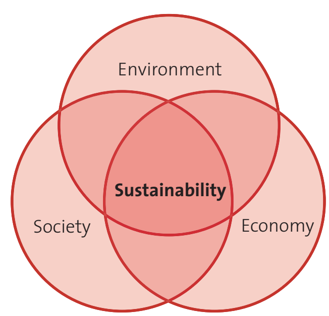
The USA's National Research Council and the European Union's Joint Research Centre have both concluded that they have enough knowledge to address the safety of GM foods. They state that the processes of genetic engineering and conventional breeding are effectively alike in terms of any unintended consequences to human and environmental health.

That is not to say that every new variety – whether produced by GM or conventional methods – will automatically be benign. Each new GM crop has to be assessed individually through a strict multi-agency process. As it happens, conventional crops are not regulated in this way, and, to date, the only compounds that have been shown to harm human health have originated in foods developed through conventional breeding. One example is the family of naturally occurring toxic compounds found in conventionally bred varieties of celery – psoralens, which

KEY THEMES

- Elements of sustainability.
- Benefits of genetically modified crops.
- More from less in the future.

The three pillars of sustainable agriculture.



BOX 11.1 What is sustainability?

The idea of sustainability rose to prominence after the concept of sustainable development was explored by the Brundtland Commission in its 1987 report *Our Common Future*. The report defined sustainable development as: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

"Sustainability" has since been applied in many contexts, and is a guiding principle for any human endeavour, including agriculture.

Sustainable agriculture basically means farming founded on sound ecological principles, rooted in the relationships between organisms – plant and animal – and their environment. It implies an integrated system of production practices tailored to environmental conditions that will endure over the long term.

Practices that might cause long-term damage to the soil such as excessive tilling leading to erosion, might be termed unsustainable. So too might the use of synthetic fertilisers that, although appearing to sustain local production over time, could have severe effects away from the farm such as polluting rivers or coastal waters.

In considering sustainability one needs to take a broad view and embrace issues that go beyond agriculture itself. One is energy – essential all along the production line from cultivation through crop processing to storage and transport. Climate change issues, dwindling supplies of fossil energy and rising costs make this of major concern when considering agricultural sustainability.

Then there are socio-economic factors to take into account. Inefficient agricultural methods that deplete finite natural resources to the point where they become unaffordable has huge implications for food security.

International policy is important as well. Sustainable agriculture is very much on the international agenda, especially in the context of the threats posed by climate change.

Urban planning too plays a part. Debates are taking place on which forms of human habitat fit best with the sustainability ambition. High-population towns and cities, or eco-communities that closely link producers and consumers?

Any genetically improved crop must, therefore, be integrated into an ecology-based farming system and judged on its environmental, economic and social merits: the three pillars of sustainable agriculture.

deter insect pests. But they have also been found to cause some farm workers to develop severe skin rashes.

New biotechnology and health

Ever since the American conservationist Rachel Carson, in her 1962 book *Silent Spring*, drew the world's attention to the dangers to humans and the environment of

CASE STUDY Californian alfalfa

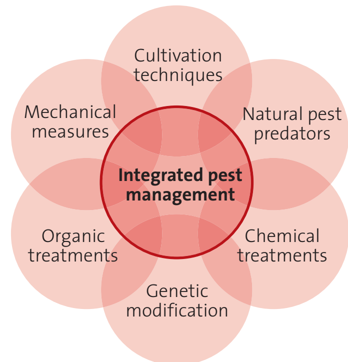
In California's Central Valley most alfalfa farmers have been using the herbicide diuron to control weeds. This is one of a class of toxic chemicals that can contaminate groundwater as well as persist for a long time in the environment, to the detriment of biodiversity.

Now, though, they have started to plant new herbicide-tolerant varieties that make it possible to use less toxic herbicides, which is expected to improve water quality and enhance biodiversity. The Animal and Plant Health Inspection Service is currently evaluating these varieties with a view to extending their use.

unthinking pesticide use, researchers have been looking for ways to reduce reliance on insecticide sprays.

This was the driving scientific motivation behind the first generation of GM crops, such as *Bt* maize and cotton engineered to control caterpillar and beetle pests without the need for insecticides. Although the *Bt* toxins worked well on their target organisms, they caused little or no harm to other, beneficial insects, wildlife and people. Indeed, *Bt* toxins in sprayable form were used long before the new GM crops were developed, and are still extensively deployed today by organic growers and others. So, before granting approval to *Bt* crops, the US Environmental Protection Agency and the Food and Drug Administration had decades of human exposure on which to base their decision.

Crops engineered to discourage insect or plant pests are part of the broader picture of integrated pest management, which combines a range of techniques to achieve a healthy crop with the least possible disruption to natural agro-ecosystems.



Human health also benefits from the new generations of herbicide-tolerant crops. Glyphosate herbicides, used appropriately, are the least toxic ever developed – they rapidly break down in the environment and do not persist in groundwater. Novel GM crops including maize and cassava have been engineered to tolerate glyphosate so that growers can use this herbicide to control weeds without harming their crop, farm workers or the wider environment.

Many of the sprays used over the past 100 years are to a greater or lesser extent toxic to humans and animals alike. Bordeaux mixture, for example, a combination of copper sulphate and slaked lime invented in the Bordeaux region of France in the late 19th century and still in use as a fungicide in vineyards, fruit farms and gardens to prevent infestations of mildew and other fungi, is harmful to farm workers as well as to fish, livestock and earthworms due to a build-up of copper in the soil.

Biodiversity: another goal of sustainability

The planting of *Bt* crops has been shown to support increased biodiversity. An analysis of 42 field experiments in the USA showed that insects, spiders, mites and other pests that are not targeted by the novel crops were more abundant in *Bt* cotton and maize fields than in conventional fields managed by insecticides.

Less developed countries too show biodiversity benefits from *Bt* crops. Chinese and Indian farmers growing GM cotton or rice have dramatically reduced their use of insecticides – thereby helping to sustain non-targeted insects.

Between 1996 and 2011 there was an 18.3 per cent reduction in the environmental impact of herbicides and insecticides worldwide through the use of GM crops (Table 4.4, page 43).

Economic advantages

Applying lower levels of insecticides has obvious advantages for the environment. At the same time, the new crops drive another essential component of sustainability: economic benefits. This is particularly true when the pressures put on plants by pests are high. The US Department of Agriculture's Economic Research Service found that farmers derived significant financial gain from lower pesticide use and less insect damage, which more than made up for the higher cost of genetically engineered

BOX 11.2 Summary of sustainability benefits

Research into the sustainability impacts of genetically modified crops shows the following benefits:

- significantly lower levels of insecticides in the environment;
- improved soil quality and reduced erosion;
- farmers saved from losing their crops and livelihoods;
- health advantages to farmers and families;
- economic gains to local communities;
- enhanced biodiversity of beneficial insects;
- fewer pest outbreaks on neighbouring farms;
- higher profits for farmers;
- yield increases;
- reduced losses to pests and diseases;
- more efficient production on the same area of land.

The key to achieving these, however, does not lie in planting novel crops alone. The real benefits come from combining the new genetics with innovations in farming practices: together they create a synergy for sustainability.

seed. It is estimated that Arizona cotton growers saved more than US$ 200 million between 1996 and 2008 thanks to a 70 per cent reduction in insecticide use.

Maintaining topsoil

One further move towards sustainability is low- or no-till agriculture, which leaves fertile topsoil intact and protects it from wind and rain erosion. New herbicide-tolerant maize and soybeans have helped reduce tilling, resulting in a reduction in fuel consumption and greenhouse gas emissions from tractors.

In Argentina, for example, tillage operations for soybeans have been reduced by 25–50 per cent. Combined with similar levels of reductions in the USA, this means that total cuts in carbon emissions are equivalent to taking nearly 7 million cars off the roads – about a quarter of all the private cars in the UK, for example.

Reductions in tillage operations for soybean cultivation in the USA and Argentina have reduced total CO2 emissions equivalent to taking about a quarter of the UK's private cars of the roads.

Virus-resistant crops

Although by far the largest area of GM crops is devoted to insect- and herbicide-resistant varieties, others have been commercialised which have shown themselves to be effective tools in the drive towards sustainability. One is the GM papaya developed in response to the destruction of virtually the entire crop on the Hawaiian island of Oahu by papaya ringspot virus – PRSV.

Dennis Gonsalves and his co-researchers engineered papaya to carry a transgene from a mild strain of PRSV that had the effect of "immunising" the plant against further infection. Yields increased by a factor of 20 compared to non-GM trees, production rose rapidly and, quite quickly, 90 per cent of farmers began to plant the new crop. Today, 80–90 per cent of Hawaiian papaya is genetically engineered.

Future prospects

Dozens of useful genetically engineered crop traits are in the pipeline – all of which would aid sustainability.

Crops that use nitrogen more efficiently, for example, would lower the cost of synthetic fertiliser inputs, reduce water pollution and cut the greenhouse gas emissions that result from chemically synthesising fertilisers. There is a transgenic plum variety, HoneySweet, resistant to plum pox – a virus that also infects peach, nectarine, apricot and cherry plants. This technology could prevent major disruptions in production of all of these fruits. Non-browning Arctic® apples are an engineered solution to the real-world problem of apple browning caused by the enzyme polyphenol oxidase, which has real economic costs for each link in the supply chain from tree to consumer.

Other promising applications of the new biotechnology are in staple crops such as rice, which is grown in 114 countries and on six of the seven continents. Given the huge impact on the lives of the poor – and the environment – of even modest changes to a crop's stress tolerance or nutritional content, this research has immense importance. One example here is submergence-tolerant rice produced by both conventional marker-assisted breeding and GM. There are already GM varieties that currently provide an excellent solution to flooding in, say, Bangladesh and India. In the future, though, global warming is likely to bring more extremes of flooding, so a new, "submergence-plus" variety is under development.

Conversely, more research is going on with drought-tolerant varieties to improve on today's GM crops such as maize – Africa's key staple – and other food crops.

More from less?

Without the development of high-yielding crop varieties over the past few decades, up to four times as much land would have been needed for agriculture to produce the same amount of food. Can this progressive increase in agricultural efficiency be sustained? If not, the world's cropland will need to double by 2050 to maintain current per-capita food consumption.

One analysis suggests that, if global average yields could be driven up to the levels currently achieved in North America, there could actually be a considerable sparing of land needed by agriculture.

The transgenic plum Honeysweet contains a gene that makes it highly resistant to plum pox virus.

USDA

The challenge is to raise yields without further damaging the environment. To meet it, an integrated approach will be required that combines ecology-based farming practices with the cultivation of newly developed seed varieties. In many countries, this will mean modifying government policies to build local educational, technical and research capacities along with appropriate food processing and storage facilities, in effect treating plant breeding as a public good.

Rural transport, communications and water infrastructure will need to improve as well, as will the ability to handle the many intellectual property and regulatory issues that these game-changing technologies imply. With all this in place, sustainable agriculture in the future is possible on a global scale.