Feed the world?

The promise of more food from increased yields is driving the appeal for more GM crops, but that promise is theoretical and unfulfilled, argue **Dr Ricarda A Steinbrecher** and **Antje Lorch**

Since the 1980s, biotechnology companies have promised that genetic engineering would produce crops that deliver higher yields. No such crops have ever been produced, but as fossil fuel supplies dwindle and food prices rise, the belief that higher-yielding GM crops could solve both our fuel and food problems has gained momentum and prominence among policymakers, government officials and the media.

At present, such promises are little more than speculation. None of the existing GM crops in commercial cultivation is engineered specifically for yield increases. While it is claimed current crops that are engineered to be herbicide-tolerant or to produce insecticides yield more, this is not supported by independent field assessments. For some specific GM crops, reports even show lower yields.

The discussion is made more complex by the fact that the terms 'yield' and 'yield increase' can mean different things in different agricultural systems. In monocultures, yield is generally defined as the amount of primary product of the crop (the grain, for instance). Such a narrow definition ignores other products such as straw, which is useful as animal feed and bedding. In addition, one can distinguish between direct and indirect mechanisms of yield increase.

The kind of direct increases that could be gained are related to more biomass – in other words, to bigger oats or more or larger fruit. Indirect increases could be gained by changes in other characteristics that might make the crop perform better under adverse conditions (e.g. weed pressure and pest infestation). These 'increases' can more appropriately be described as 'avoidance of loss or reduction'. For example, a GM herbicide-tolerant crop might produce an increased yield due to less competition from weeds as an indirect effect of a change in agricultural practices. If the weeds don't pose a problem or are dealt with by other means, however, the GM trait is present in the crop without resulting in a yield increase.

Such yield-based approaches mainly apply to systems that focus on the production of one product and where adverse effects on other parts or characteristics of the plant are not considered relevant. Experiences with the 'miracle crops' from the Green Revolution showed that an increase in the primary product (e.g. grains) may be accompanied by a reduction in secondary products (e.g. straw).

In polyculture systems, yield is an even more complex issue. Farmers using crop rotation will grow several different crops over subsequent seasons, therefore yield increase is not confined to a single crop over one year, but over a number of years. For example, recent US data has shown that cotton yield can be increased by the nitrogen-fixing qualities of the legumes grown the year before. In intercropping and companion planting, several crops are grown on the same field at the same time. Examples range from fruit trees as shade trees for coffee plantations to push-pull systems where additional crops (e.g. fodder grass, desmodium) are grown to deter pests from the previous crop (e.g. maize). In these cases, yield increase can best be described as an increase in farm-land productivity.

Because monoculture and polyculture farming systems are so dissimilar, the concept of a land-equivalent ratio (LER) was devised to enable comparison. LER describes the ratio of monoculture to polyculture land required to give equal yields. In Brazil, the root vegetable *arracacha* and onions grown in monocultures needed nearly 50 per cent more land to produce the same yield as when grown together on the same field. In Ethiopia, researchers observed that the yields of wheat and faba beans grown together were about 20 per cent higher than when grown on two separate fields; the mixed (intercropped) field also had 20 per cent less weeds, and viral damage to the beans was reduced by a third. Yields and food supplies can also be increased by better farm management, integrated pest management and changes in storage practices to avoid post-harvest loss. A study evaluated comparative trials from Wisconsin, US, from 1990-2002 and found that in the majority of cases organic production systems yield as much as conventional systems, and more for dry matter forage.

A 2001 study of family farming in Honduras and Guatemala found that agroecological methods – such as using green manures, cover crops, contour grass-strips, in-row tillage and animal manures – led to fourfold yield increases. Other research has shown that in the developing world, organic systems produce 80 per cent more than conventional systems, with organic inputs (e.g. animal and green manure, nitrogen-fixing plants) more easily accessible in poor countries. The authors also calculated that the use of leguminous cover crops (e.g. pulses, soya, groundnuts) could replace the amount of synthetic nitrogen fertilisers currently in use.

Confining the discussion and research into food production to 'higher yields' in the sense of 'more kilos of grain per hectare' is therefore narrowing the discussion about food production to just one aspect of farming practice.

Do existing GM crops increase yields?

There is no solid data available about the yields of most GM crops, and reports of studies, field trials and farmer experiences are often contradictory. Direct and indirect yield increases can be investigated by simple comparative

studies of GM crops and their non-GM equivalents (e.g. siblings, or true isolines). Most of the few existing studies on yields of GM crops are not well-enough designed to deliver solid results, however. Often they only take place over one season, not under controlled conditions, and/or do not use isolines. Independent comparative studies with GM crops are also hindered if the companies don't permit the use of patented varieties or if isolines do not even exist for cross-bred GM varieties.

Where yield is defined as farm-land productivity, more complex research programmes are needed, investigating a larger number of factors including farming practices.

Crop yields have for decades been slowly increasing through conventional breeding, as well as by improvements in agricultural practices. According to data from the American Soybean Association, US soya yields (in kilograms per hectare) increased on average by 1.16 per cent per year between 1986 and 2007. Before the introduction of GM in 1997, the annual yield increase was 1.53 per cent, but since then it dropped to 0.64 per cent. Even though the public argument is often that GM crops could be developed faster than conventional breeding, the opposite is usually true. And while the development of a GM crop takes a considerable amount of time, other breeders continue with conventional breeding of improved varieties.

GM crops often show a 'time lag', therefore, resulting in a yield difference between the newest conventional varieties and the GM varieties as they finally come on the market. With the increasing consolidation of the seed market, concerns have been raised that breeders might not release new, conventional high-yielding varieties any more, but instead release them as GM variants. »

● **HERBICIDE-TOLERANT SOYA** As reported in 2001, and for reasons not yet understood, Monsanto's herbicide-tolerant RR (Roundup-ready) soya showed a 5 per cent yield decrease compared with its non-GM isoline. US research in 2008 established that RR soya will only deliver as good a yield as conventional varieties if manganese is added to the fertiliser, so perhaps the modification led to unexpected changes in plant metabolism, or it could be that the herbicide (glyphosate) interferes with manganese availability in soil.

Monsanto's new RR2Y soya (MON89788) is to be launched in 2009 in the US. Using the high-yielding Asgrow variety A3244 as the new background line, Monsanto claims RR2Y has an 'increased yield' of 7-11 per cent as compared to the first RR generation, and 4-7 per cent as compared to old RR in the new background variety. We could not obtain information about whether the latter is a comparison between the RR2Y and the old RR crossed into A3244. In this case, one could expect some negative effect on yield carried along from the original, lower-yielding RR variety.

According to Monsanto's data, the bacteria-derived transgene in RR2Y is the same as in RR soya, but the regulatory sequences (promoters) used are different, as is the location of the transgene within the soya genome and the methods used to modify the soya plant genetically. Monsanto gives little scientific information on RR2Y, so it remains an open question which, of all these factors, produce a yield increase.

This consideration is less academic than it might sound. In a risk assessment of a GM crop, it is not only the new trait that needs to be studied, but also the potential effects of the transformation process itself, since this has the potential to lead to both desired and undesired effects. So far, however, companies and many regulators claim the process used would be of no relevance, so this would not be necessary.

● **BT MAIZE** A three-year trial in Canada in 2005 compared the performance of three to seven commercial maize hybrids with their transgenic Bt near-isolines. Some Bt hybrids had a 12 per cent lower grain-yield than their conventional counterparts, and no Bt line had a yield advantage over non-Bt.

Based on International Service for the Acquisition of Agri-biotech Applications data from a survey of Philippine maize farmers in 2006, positive economic impacts of Bt maize were reported, such as increased yield and income for Bt maize-users, with the average farm-size of Bt users being almost double that of non-users. Because the study only covered one year and failed to identify any non-Bt varieties used, only limited conclusions can be drawn.

In a 2008 Spanish study of three provinces over three years, scientists found a yield increase of 11.8 per cent – but only in one province that had been particularly affected by stem borers. In the other two provinces, where there were lighter pest infestations, no yield increase could be detected. These two studies did not include scientific comparisons of GM and non-GM isolines, however.

● **HERBICIDE TOLERANT CANOLA** As early as 1999, researchers studying several GM canola varieties with tolerance to different herbicides reported a yield deficit for Monsanto's RR canola (glyphosate tolerance), and no yield advantage for Liberty canola varieties (glufosinate tolerance) compared with conventional canola varieties. This is in line with the outcome of Australian trials in 2003, as well as with the Canadian experience. Canada's average yield data for canola between 1987 and 2007 showed an average yield increase per year of between 0.8 and 1.1 per cent, with no visible increase correlated with the widespread introduction of GM.

New crops in the pipeline

Since the 1990s, research into genes and gene combinations that might enhance yield has followed a number of avenues. The focus at present is on several aspects of cell regulation and cell division, with the aim of increasing size or number of seeds or fruits as direct yield increases. Two companies appear to be leading the research and development (R&D): Targeted Growth and Mendel Biotechnology, both in collaboration with Monsanto. On its website, Monsanto states that it is working on 'higher-yielding' corn, canola and soybeans (in a 'phase of early product development').

Besides general statements and website announcements, there is no information available about the scientific basis of this work. Without such information it is impossible to assess scientifically the progress of such approaches, their agricultural potential and their risks. Risks must be expected, however, since cell regulation is a highly complex system beyond the capacity or control of genetic engineering technology as we have seen it to date.

While companies and policymakers make claims about increased yields, little progress appears to have been made in this direction. Instead, companies pin their hopes on the theoretical possibility of increasing yields indirectly: by increasing photosynthetic output, for instance, thus increasing carbohydrate content; or through proposed varieties such as 'green super rice', with multiple traits such as disease-resistance, drought-resistance, more nutrients.

Yields at what costs?

Independent of what specific traits are in the GM pipeline, the question of higher yields, or even of 'feeding the world', cannot be reduced to single traits or R&D systems that focus solely on the traits contained in the seed. As the 2008 UN/World Bank International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) report states: 'An increase and strengthening of agricultural knowledge, science and technology towards agroecological sciences will contribute to addressing environmental issues while maintaining and increasing productivity'.

While the yield and yield potential of individual crop varieties is important, it is only one aspect of what should be considered when it comes to evaluating crops, especially GM crops. Other relevant issues go beyond the question of how much a variety or even a whole field can yield. To understand the whole picture of food production, one also has to assess under what conditions yield increases are attained – for example, higher use of agrochemicals, higher use of fossil fuel products, diminished diversity, loss of land rights and small-scale farming. It seems obvious: if higher yields are truly desired in order to feed the world and not only to make a market profit, then the goal has to be higher farmland productivity and food sovereignty, using sustainable methods.

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