SEARCH

Summary

In the last issue of World Agriculture, Vol. 4, No. 1, Dr Helen Wallace of GeneWatch UK wrote a highly critical analysis of the role of GM crops in world agriculture (1) .

By selectively quoting only critical sources, Dr Wallace constructed a misleadingly negative case against a valuable technology. In this review, we examine her case point by point.

There are costs and benefits to every human activity and it is important that all are considered and form the basis of any scientific assessment.

Unlike her, we conclude that appropriately approved transgenic events, while by no means a panacea to all problems of feeding a potential nine billion, can make a significant contribution towards a safe, sustainable and secure food supply over the rest of the 21st Century.

Keywords

Genetic modification, plant breeding, food security, agricultural policy.

Abbreviations

DNA deoxyribonucleic acid; dsRNA double-stranded RNA; Bt Bacillus thuringiensis; EFSA European Food Standards Authority; GHG Greenhouse Gas; GM genetic modification; IRRI International Rice Research Institute; LEAF Linking Environment And Farming; N Nitrogen; rDNA recombinant DNA; RNA ribonucleic acid

Glossary

Cisgenesis – Altering an organism's genome using genetic material from a closely-related species. This differs from transgenesis in that the genetic transfer could also have occurred through natural cross-breeding because the species in question are sexually compatible. Some researchers would like cisgenesis to be subject to less stringent regulation than genetic modification in which the transfer of genetic material could not happen in the wild.

Cry proteins – A class of crystalline proteins expressed by the soil bacterium Bacillus thuringiensis, which are toxic to some types of insect.

Embryo rescue – An in vitro seed breeding technique which allows the progeny of diverse parents, which would not normally survive, to be brought to maturity.

F1 hybrid – The first generation of plants produced by crossing two distinct parental types. The resulting seeds often demonstrate very desirable characteristics, but fresh seed has to be produced each season, as the uniformity is lost in succeeding generations.

Intragenesis – As for cisgenesis, this is a breeding technique which transfers genetic material only between closely related species. However, it differs from cisgenesis in that it allows for the use of new gene combinations created by in vitro rearrangement.

Introgression – The transfer of genetic material from one species to another via hybridisation and repeated backcrossing.

Landrace – A locally-adapted strain of a cultivated plant, less genetically uniform than a conventional variety.

Mycorrhizae – A symbiotic association between soil fungi and plant roots.

No-till agriculture – A method of farming in which crops are drilled straight into the ground after the previous crop has been harvested, without disturbing the soil by ploughing. This reduces energy use, helps to increase soil organic matter and moisture retention and reduces erosion.

Selection pressure – The response of a population of living organisms to an external negative factor. More tolerant individuals survive and pass on greater resistance (to, for example, a herbicide) to future generations.

Wildlife – A common English expression covering the non-domesticated animal, bird and insect species naturally present in the environment.

Introduction

The case made against GM crops

Dr Wallace's article makes a number of specific criticisms of GM crops, which we will address individually below.

These are:
* The limited range of GM crops currently available

* The reducing effectiveness of herbicide-tolerant crops, as resistance develops.

* The patenting of traits, preventing farmers from saving seed for replanting.

* Possible negative effects on human health.

* Cross-contamination and liability.

* Negative environmental impact.

* Lack of delivery of promised traits in the next generation of products.

* Loss of autonomy for farmers and consumers.

But first, by way of introduction, we should appreciate that there are two main types of objection to GM crops: ideological and those arising from a pessimistic world view.

To illustrate the ideological component, consider the answers given by Lord Melchett (then Executive Director of Greenpeace UK) to questions posed in a House of Lords enquiry (2):

Question 101: 'Lord Melchett, in relation to genetic modification, what do you object to and why?'
Lord Melchett, Head of Greenpeace, UK: 'My Lord Chairman, the fundamental objection is that there are unreliable and unpredictable risks.'

Question 105: 'How far are you prepared to carry your objections to these developments?'

Lord Melchett: 'I am happy to answer for Greenpeace [...] Greenpeace opposes all releases to the environment of genetically modified organisms.'

Question 107: 'Your opposition to the release of GMOs _that is an absolute and definite opposition? It is not one that is dependent on further scientific research or improved procedures being developed or any satisfaction you might get with regard to the safety or otherwise in future?'

Lord Melchett: 'It is a permanent and definite and complete opposition based on a view that there will always be major uncertainties. It is the nature of the technology, indeed it is the nature of science, that there will not be any absolute proof. No scientist would sit before your Lordships and claim that if they were a scientist at all.'

The attitude of anti-GM activists is not that this is a technology which holds promise but needs more development, but a flat rejection of its potential. Rather than see well-planned scientific trials take place to address concerns about human and environmental safety, they want to close down R&D and prevent products getting to market.

Figure 1 shows a field trial being destroyed in a high-profile act which led to the arrest of the protestors, including Lord Melchett. Such crop-trashing has even extended more recently to fields of golden rice, developed to provide much-needed Vitamin A in the diets of the children of poor farmers in Asia (3)

There is no certainty in life for anything apart from the proverbial death and taxes. So the desire for certainty for GM crops is not a realistic critique but just an attempt to block something that Greenpeace doesn't like.

There is no risk-free world, but in the estimation of risk it is contingent on those who suggest alternatives to estimate the risk of that alternative. Lord Melchett's responses betray a deep-seated anti-science world view and an unfortunate pessimism about the human race's creativity and adaptability.

It is undoubtedly the case that no scientist will claim certainty of safety about anything, but that includes Melchett's preferred alternative of organic farming too.

In 2011 51 people died in northern Germany from eating organic produce, with thousands physiologically injured, possibly for life (4).

In a form of agriculture whose main source of N is very commonly animal manure, contamination risks will always be present. Other similar cases are in the medical literature. All GM products receive detailed safety scrutiny and there is no record of anyone dying from consuming them.

GM technology has advanced well beyond the early simple traits of herbicide resistance and Bt insect resistance. Two transformation techniques, cisgenesis and intragenesis, have been used successfully to produce plants transformed with genetic material derived only from the species itself, or related species that can normally hybridise with it (5) Foreign genes are absent in these products.

Furthermore, genetic transformation can now take place at a chosen defined base sequence in the genome which is opened and modifications made.

A number of crops produced in this way are in field trials, have gained good public acceptance and created problems for regulators. Are they really GM crops? Does the same ideological objection still hold?

The pessimism which began to flourish in the decades after World War II is encapsulated in this quote: "The battle to feed all of humanity is over. In the 1970s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate ..." (6)

Debilitating pessimism like this can stifle and thus impede creativity. It is fortunate that this statement by Ehrlich was ignored by Normal Borlaug (7) and the development of the Green Revolution.

Figure 2 shows how grain yields have risen steadily since 1960, while the area cultivated has remained essentially the same. While attempting to predict the future is sensible, strict limitations must apply to its usefulness, particularly over the long term.

New technologies cannot by their nature be predicted and because the world continues to change remorselessly what the future context would be like for any supposed projection remains unknown.

Stating the problem and focussing on it usually drives potential solutions and changes the future anyway. The present buzz word of the Club of Rome is sustainability.

But the assumptions that underpin those sentiments along with the precautionary principle, a principle largely used by green organisations to halt progress, imply a lack of faith in future generations being able to find adequate solutions to the problems they face.

Thoughts of sustainability of a particular activity should be limited to one or two generations. Beyond that, it is likely that technological advance will have made the concept irrelevant.

The Green Revolution harnessed scientific plant breeding and synthetic fertilisers to allow vastly increased cereal productivity in Asia and Latin America. (8) Now, a global population of over 7 billion has more calories available per capita than half that number not much more than 40 years ago.

Nearly a billion people remain chronically malnourished, but this is a function of poverty, lack of infrastructure and poor governance rather than agricultural productivity, and is outside the scope of this review.

The Green Revolution is a particularly clear example of how technology can and must be used in the agricultural sector. With the world's population set to rise by a further 2 billion or more by mid-century, farmers need access to all technologies available to raise productivity without ploughing more virgin land.

The concept of ‘sustainable intensification’ nicely encapsulates the preferred approach and is now widely used by stakeholders in the food supply chain (9).

There are big gains to be made by bringing best practices to some of the lowest yielding areas of farmland, but this will not be enough by itself to guarantee food security in a world where demand for animal products and overall energy will continue to grow faster than population itself.

To have the best chance of achieving this in a way which is sustainable in the long term, all available technologies must be deployed as appropriate. Today, genetic modification is the cutting edge of agronomic technology, capable of delivering benefits which are beyond other more established breeding techniques.

Like any other technology, it carries risks as well as benefits, but we cannot afford to bypass it.

The limited range of GM crops available
Nearly all the commercially available GM crops have one or both of two important agronomic traits, herbicide tolerance and insect resistance.

They are also limited primarily to the major "broad-acre" crops: soy, maize, oilseed rape (canola) and cotton (10)

Nevertheless, as figure 3 shows, these two key traits have led to a large and sustained year-on-year growth in the cultivation of GM crops.

The main use for most of the soy is for animal feed while the maize goes to the same market but, in the USA, is also used for biofuel production. However, Dr Wallace implies that the extent of the technology's potential is for farmers in industrialised countries to supply the animal feed and biofuels market, with there being little to offer towards global food security.

This most surely is not the case. Numerous herbicide-resistant crops resistant to a range of pesticides are available through conventional breeding. However the problem with all conventional breeding is the difficulty in removing unwanted traits. So it is no surprise that glyphosate-resistant GM crops have dominated use.

At the levels of exposure and use, glyphosate is remarkably innocuous to human health, but good at killing weeds. Extensive use of such crops has led to the much greater advantageous use of no-till agriculture.

No-till farming reduces fuel consumption and  not only avoids soil compaction, loss of organic matter, reductions in microbe populations and other valuable organisms like mycorrhizae and large soil invertebrates, but properly done, virtually eliminates erosion and increases wildlife populations.

Most crucially, no-till reduces GHG emissions to less than one third that of organic farms and one sixth that of conventional soils. Continuous no-till needs to be managed very differently, but is clearly sustainable in all senses of the word.

No-till lends itself readily to large scale mechanical management of large areas of farmland, but could only seriously develop with the easy control of weeds.

Any technology is essentially neutral and it is the socio-economic environment which determines how it is used. Genetic modification emerged at a time when existing public sector breeders – for example PBI Cambridge – were being privatised, so it was inevitably the private sector which led its commercialisation.

In addition, the stringent regulatory requirements encouraged by many environmentalists have made the approvals process so expensive that only major international companies have the resources to bring GM crops to market.

Because of the need to see a return on their investment, they naturally used the technology to develop crop varieties which would be bought in large volumes by farmers with the resources to benefit from them.

In fact, following the original introduction of Roundup Ready™ soy to American farmers by Monsanto in the mid-1990s, there was a quite rapid uptake of the same crop in South America. The development of Bt cotton has seen millions of small-scale farmers in China, India, South Africa and other developing countries also benefitting from the technology.

This is not to forget golden rice, finally approaching the market after many years of development, initially in Zurich but latterly at the IRRI in the Philippines (11)

Seed will be made available free to small-scale farmers, with all rights to receive patent licence fees waived by the participating companies.

For a technology which has been commercial for less than two decades, that is good progress and more developments aimed at developing-country farmers can be expected, for example from projects funded by the Gates Foundation (12)

These, too, will be donated free of charge to poor farmers.

The reducing effectiveness of herbicide-tolerant crops, as resistance develops Herbicide-tolerant GM crops are essentially all engineered to resist treatment with glyphosate, an extremely useful and widely used broad-spectrum herbicide (although there are other crops resistant, for example, to glufosinate, which can be used in rotation.

Similarly, pest-resistant crops express one or more cry proteins found in Bacillus thuringiensis. These crops have not introduced new crop protection agents to farming, but have allowed their use to be extended.

The possibility to use broad-spectrum herbicides across fields of established crops, to control weeds without harming the crop itself, makes weed management much easier.

Bt crops, on the other hand, control certain pests which attack them, without harming non-target insects. Such crops also allow maintenance of a larger population of pest predators.

These traits are very valuable to farmers, as the rapid and sustained growth in the sales of both shows. However, it is a fact of life that pests develop resistance to crop protection agents over time, and GM crops are no exception.

That glyphosate is so effective (and environmentally benign) means that its use is quite ubiquitous; Roundup Ready™ crops will likely have increased its use to some extent, but from an already high baseline.

Inevitably, some weeds (in North and South America) have become resistant, but this is part of the continuing cycle which requires the constant development of new herbicides to replace those which become less effective.

In practice, any problem weeds can be removed using alternative herbicides or by hoeing. The practical evidence that suggests this is not a big problem for most farmers is that sales of glyphosate-tolerant varieties remain high.

Farmers would not pay a premium for a trait which did not continue to give them a worthwhile benefit in terms of crop management.

As for pest-resistant crops, the fact that widespread resistance has not developed after a decade, or more, of exposure of insects to (for the most part) a single Bt toxin shows that the management strategy (planting a refuge of a certain percentage of non-Bt plants in a field to minimise the selection pressure for Bt-tolerance) has been very effective.

The trait, as commercialised, has been used to target particular major pests and was never intended to give complete protection from insect attack.

The benefit of these traits to American farmers is well illustrated in figure 4, which shows how corn (maize) varieties, having both herbicide tolerance and insect resistance, have come to dominate the market over just a few years.

The revolution in genomics has changed the ease with which specific pest species can be selectively controlled. Specific small sequences of RNA, derived from double-stranded RNA degradation, switch off the expression of specific genes (13).

Pests that ingest a crop engineered with a specific dsRNA have specific developmental genes switched off that are specific to the organism, which then fails to mature.

If Bt ever becomes ineffective, alternatives are already available.

Dr Wallace recognises that resistance develops in conventional farming systems, but views this in a negative light, as encouraging a ‘pesticides treadmill’ whereby farmers apply larger amounts of pesticide or turn to more toxic ones.

Although overall pesticide use is growing, much of this is due to the adoption of modern farming practices in the developing world.

In many countries, farmers are becoming more careful about their use of agrochemicals of all types as they realise they can save money and minimise unwanted environmental impacts (for example, the greater use of precision farming in industrialised countries).

Similarly, Dr Wallace sees the development of a ‘seed treadmill’ in which farmers are locked into buying inputs from off the farm rather than being self-sufficient.

In fact, as long as farmers can make an informed choice and are not dragged into unnecessary debt, their farms are likely to become considerably more productive.

Her argument seems to be more about the iniquities of modern farming rather than genetic modification per se, and is effectively a reformulation of the ‘conventional’ (intensive) versus ‘organic’ (extensive) debate.

Organic farms almost certainly benefit from the control of pest numbers by proximity to conventional farms.

The patenting of traits, preventing farmers from saving seed for replanting
Clearly, the advent of patented traits allows suppliers more control of their technology than the pre-existing (and continuing) system of plant breeders’ rights.

For example, in the UK, farmers are permitted to save seed for replanting on payment of a fee to the breeder. In the case of at least the current generation of GM seeds, the farmer pays a technology fee for the transgenic trait and enters into a contract which does not permit him to save and sow seed the following season.

However, even where saving seed is an option, it is not always desirable. Farmers who quite legitimately save seed one year will often buy fresh seed after a season or two, simply to guarantee freedom from disease or to take advantage of new varieties.

Farmers in some developing countries have often not had the option of high quality seed available to them and have continued to save seeds of their own adapted varieties, or landraces, as part of a cycle of low productivity subsistence farming.

As they become able to afford fertiliser, pesticides and better tools, so they will be looking to have more productive crops and would be more open to buying protected varieties (including GM).

In developed countries, farmers have become used to buying seed each year as F1 hybrids have entered the market, initially for maize and latterly for oilseed rape and a wide range of vegetables.

The yield advantages of these more than offset the additional expense of purchase. There is no reason why farmers in the developing world should not move more towards a similar model, where more expensive seed and other inputs are seen as being the key to more productive and profitable cultivation.

Possible negative effects on human health
It is argued that ‘Controversy remains about potential unintended effects of GM foods on human health…’ In reality, a number of hypothetical concerns are raised, for some of which one-off studies of dubious value are cited as support, for example the work of Ewens and Pusztai (14).

Although such stories continue to be reported from time to time, the great majority of plant scientists and toxicologists do not see any hard evidence that any tests have shown harm to be caused by GM ingredients.

Recently, for example, Professor Anne Glover, chief scientific adviser to the President of the European Commission, dismissed opposition to GM crops as 'a form of madness' (15).

The European Academies Science Advisory Council also published a report in June 2013 which supported a move to bring policy more in line with the scientific consensus on the safety and benefits of genetically modified crops (16), The great majority of dossiers submitted to EFSA, for example, are recommended for approval by the independent scientists who review them, but a number of

Member States routinely fail to follow this advice and a qualified majority in favour of approval is never achieved.

Concerns about the very minor changes in genomes produced by rDNA technology seem based on a matter of principle ('unnaturalness') rather than practical reality.

Opposition by campaigning organisations such as Greenpeace and GeneWatch is a matter of philosophy rather than science.

What is still referred to as 'conventional' breeding produces combinations of genes which are only revealed by their patterns of expression and, in the case of non-GM techniques such as embryo rescue, results in progeny which would not be seen by natural crossing.

Mutagenesis, the products of which are happily accepted by the organic movement, scrambles genomes to produce a range of undefined mutations.

GM traits, on the other hand, are subject to intense scrutiny and more is known about both their genetic makeup and composition than of any other crops we grow.

Cross-contamination and liability
Agricultural crop varieties inevitably get mixed to some extent, whether by cross-pollination between related species or by contamination in the supply chain.

This fact is recognised by its acceptance along the food chain, subject to specific limits, usually of the order of a few percent.

However, opposition to GM crops has resulted in a much more stringent regime. In the EU, food ingredients must be labelled as GM unless they are certified as having less than 0.9% content of approved transgenic material.

This is achievable, but at a cost. In fact, most GM crops are used for animal feed, with only co-products – oil, protein, lecithin etc – entering the human food chain. Although animal feed must be labelled as to its GM content, there is no requirement for meat, milk or eggs to be so labelled.

A problem arises if a grower or trader suffers economic loss because small amounts of transgenic material have inadvertently been mixed in. For farmers, this is a rare occurrence, as separation distances are set to minimise the risk of cross-pollination.

Further down the supply chain, cross-contamination can occur, but traders have systems in place to minimise such risks (as for any segregated commodities).

Risks are insured in the same way as for other bulk commodities which do not meet the customer's specification.

The contamination events which have occasionally hit the headlines have been caused by unapproved transgenic events entering the supply chain at some point.

These have caused major recalls and resulted in seed companies paying out large sums in compensation. However, the seriousness of such incidents is due only to the strict legislation and limits which have been put in place; no harm to humans, animals or the environment has been caused by such releases.

This is in stark contrast to the occasional contamination of foods by toxins or food poisoning micro-organisms.

Negative environmental impact
Dr Wallace's article again raises concerns about the impact of GM crops on the environment.

She cites, in particular, the UK government-sponsored Farm Scale Evaluations (17). These trials have been the only reported attempt to study the impact of farm management systems in such detail, but their conclusions apply to the particular herbicide regime used rather than how the specific tolerance was introduced into the crop variety.

It was widely reported that the cultivation of herbicide-tolerant crops – oilseed rape and sugar beet specifically – could reduce weed growth and leave fewer food sources and habitats for birds and other wildlife.

However, this conclusion only tells part of the story. It is well known that cultivated fields are, by and large, not the best places to find wildlife, with most species being offered better habitat and more food sources at field margins and away from farmland.

Any differences between 'conventional' management, use of herbicide-tolerant crops, or of organic management, are in any case, swamped by the differences between crops.

The field trials in the UK are, however, a trivial part of an enormous amount of research on GM safety recorded by (18). These scientists constructed a compilation of 1,783 research papers published between 2002 and 2012 on crop safety.

Their general conclusion is "that the scientific research conducted so far has not detected any significant hazards directly connected with GM crops".

In brief the conclusions of this enormous survey were:

1. Little to no evidence that GM crops harm native animal species.

2. The formation of hybrids between GM crops and wild relatives certainly happens. But this happens all the time with conventional crops including mutagenised crops used by organic farmers. It is the result of growing any crop in any area with sufficiently close wild relatives where introgression can occur. The consequence may be replacement of local wild genotypes, something that of course happens anyway and is called natural selection.

3. No detrimental effect from consumption of GM crops by any animal has yet been detected. Substantial equivalence places constraints on the actual use of GM crops. They should be nearly identical in nutrient composition and in the complement of natural pesticides, for example.

4. Every publication that has examined the question of potential incorporation of GM DNA into the human, or animal, genome has rejected it as a potential problem. Humans on average consume a gram of DNA per day containing hundreds of thousands of different genes with no indication of possible transfer through evolutionary history. This is despite recent evidence which suggests that complete genes from food may be found in human blood (19). Bacteria in the soil certainly exchange genes and occasionally with plants, but again this has continued for hundreds of millions of years.

Another problem cited by Dr Wallace is the potential impact of Bt toxins on non-target organisms. In fact, the only insects affected are those which begin to eat the crop and so ingest the expressed cry protein.

By this means, any effect on other, more beneficial species is avoided. Finally, her paper also talks of the decline of Monarch butterflies in North America partly due to loss of agricultural milkweed (sole food for the larvae), coincident with the increased use of glyphosate-tolerant maize and soy.

However, most of the milkweed on which the larvae feed is outside field margins, where it is not treated with herbicide. It is also clear that Monarch populations are very sensitive to weather conditions in Mexico, where they overwinter (20).

Indeed, populations of butterflies and other insects fluctuate widely and are dependent on a range of factors.

Overall, there is no evidence to suggest that GM crops offer any more chance of negative impact on the environment than conventionally-bred varieties.

All farming, whether extensive or intensive, itself has a major impact on the environment. No form of farming is natural since most use the plough.

The nearest to natural conditions is no-till which mimics the annual growth and decay of vegetative material as seen in all uncontrolled meadows.

Lack of delivery of promised traits in the next generation of products
As with any new technology, some early forecasts for new transgenic traits have been shown to have been over-optimistic.

Salt-tolerance and nitrogen-fixation are quoted as examples of the promise of GM technology not having been fulfilled....yet. But progress on both is well under way.

Transgenic crops represent the present best hope for introduction of such globally-useful traits, which other breeding techniques have failed to do.

Because of the complexity and cost of bringing a new GM trait to market, companies will not follow this route if simpler alternatives are available.

Genetic modification is not a magic wand, but it is a tool which allows breeders much more scope to develop traits which will minimise our use of natural resources while helping to increase food security.

To dismiss it because forecasts have proved unreliable is not sensible.

Alternatives to genetic modification

The International Assessment of Agricultural Knowledge, Science and Technology for Development (21) is sometimes cited as a consensus view by experts on the potential for agro-ecological approaches to improving yields.

Crop rotation, inter-cropping, improved conventional breeding and waste reduction are also given as examples of approaches which can increase food security without the supposed risks of transgenics.

It is perfectly true to say that all these approaches can help. The pitifully low yields and occasional harvest failures of many subsistence farmers can be improved by even the simplest technologies.

But this is not an either-or issue: all relevant technologies can, and should, be used in the pursuit of sustainable intensification. To talk of alternatives is to create a false dichotomy.

Table 1 shows the yields of rice and wheat in a number of Asian countries, with selected high-yielding country data for comparison.

There are not yet any commercially cultivated GM varieties of either rice or wheat, so these large yield differences are due to a range of other factors, including better varieties, optimal fertilization and irrigation and modern crop protection.

However, future improvements will be generated by using all available technologies, and to ignore genetic modification for doctrinaire reasons would be foolish.

The difficulties presented by the membership of the IAASTD include its poor lack of balance. These were highlighted in an article in Science (22). IAASTD is viewed instead as having an underlying political agenda, largely against industrial agriculture.

The document cost $12million to produce and singularly failed to recognise that the only way to save tropical rainforest and other wild land from exploitation, arising from the pressures of increased population, is for agriculture on the remaining farmland to be as efficient as it possibly can be, within the constraints of environmental maintenance, including that of wildlife.

In its promotion of small farming, in its ultra conservatism, the IAASTD, in its broadest extent, represents the desire of a green and reactionary paternalist class to maintain small farmers in their present state, instead of allowing them the choice to farm in their own way and enrich themselves by uses of whatever means they see fit to use.

Assumptions
We quote from a translation of a court judgement made in the Philippines on Bt aubergine trials from a case brought by Greenpeace and others.

“The deliberate genetic reconstruction of the eggplant is to alter its natural order which is meant to eliminate one feeder (the borer) in order to give undue advantage to another feeder (the humans). The genetic transformation is one designed to make Bt aubergine toxic to its pests (the targeted organisms). In effect, Bt aubergine kills its targeted organisms. Consequently, the testing or introduction of Bt aubergine into the Philippines, by its nature and intent, is a grave and present danger to (and an assault on) the Filipinos' constitutional right to a balanced ecology because, in any book and by any yardstick, it is an ecologically imbalancing event or phenomenon. It is a wilful and deliberate tampering of a naturally ordained feed-feeder relationship in our environment. It destroys the balance of our biodiversity. Because it violates the conjunct right of our people to a balanced ecology, the whole constitutional right of our people (as legally and logically construed) is violated”. (23)

Effectively this judgement states that pests have a right to destroy crops planted and needed for humans to survive. The judgement is entirely misanthropic, anti-science, but represents Greenpeace philosophy and indeed most of those that ideologically oppose GM crops.

It sees the ecology of everything else as more important than its primary species, us. Those that promote organic farming, promote the waste of land and in the third world promote inevitable poverty.

History has seen a progressive change replacing ideology with pragmatism, folklore with science. There will always be need for change and improvement, no method of farming is perfect, all have different problems.

At present the aim must be to reduce the area of land under cultivation, but increase yield. Leaving more land to nature will be beneficial in terms of emissions and the services that organisms other than pests provide. We have already mentioned no-till, a method ideally suited to GM crops.

Integrated farm management as practised by LEAF farmers (24) seems in our eyes to present the right combination of pragmatism with the requirements of yield and care of local wild life. “Organic” will and should remain a niche agriculture for those that wish to farm or eat it.

Its yields in practice are poor and its safety must remain suspect. In our view organic is not a scientific programme, but one embedded in unrealistic romanticism.

Genetic modification, despite the criticisms of Dr Wallace and others, is a powerful and valuable tool which, properly applied and regulated, has the potential to make a very real contribution to a secure supply of affordable food this century.

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## Figures

Figure 1.

Figure 1. Greenpeace protestors uproot GM crops in Norfolk (from Greenpeace) (http://www.greenpeace.org.uk/media/press-releases/greenpeace-decontaminates-gm-field-lord-melchett-arrested)

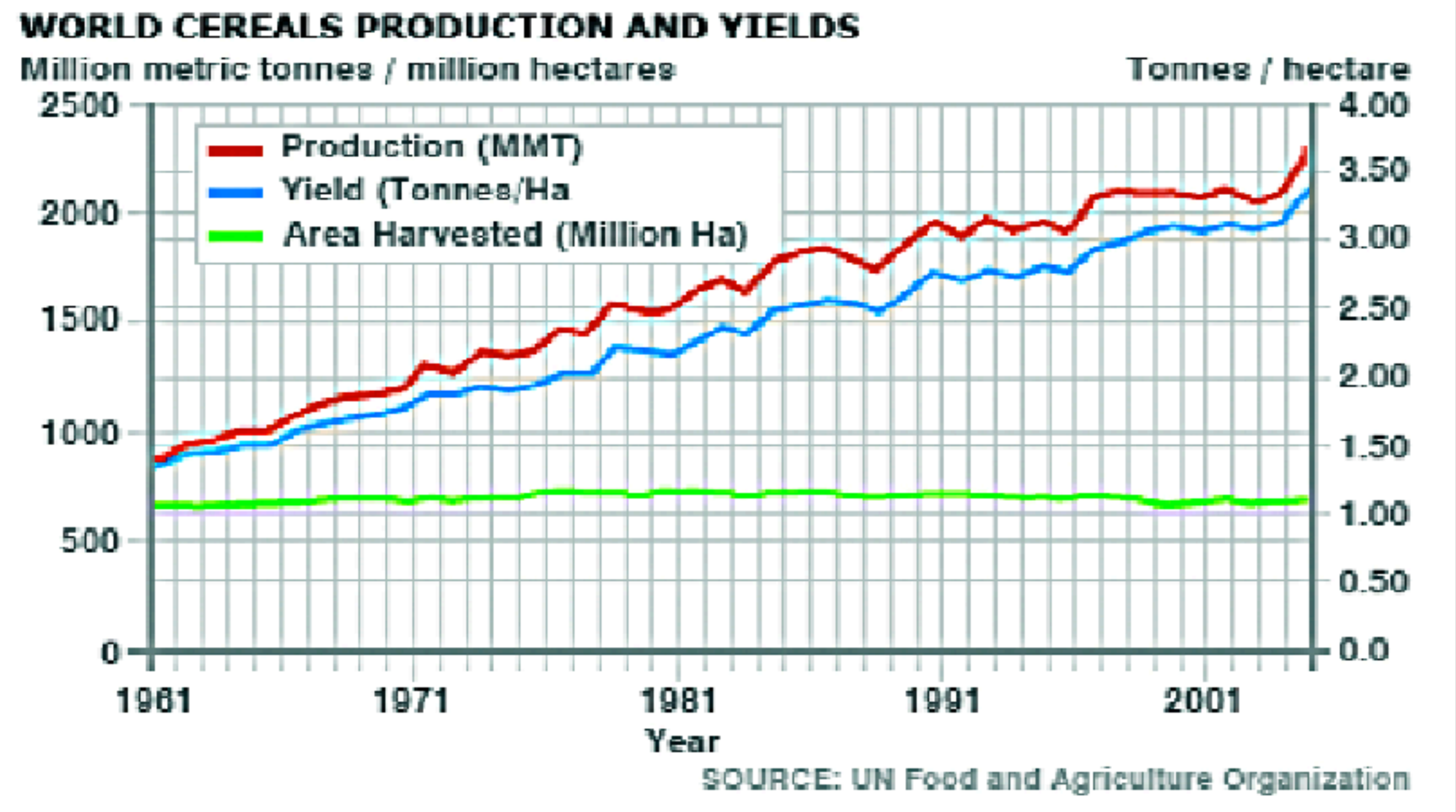


Figure 2.

Figure 2. Rising world cereal yields (right axis) and total production (left axis) while total area planted remains static (left axis) (from FAO) (http://newsimg.bbc.co.uk/media/images/42730000/gif/_42730027_world_cereals_416.gif)

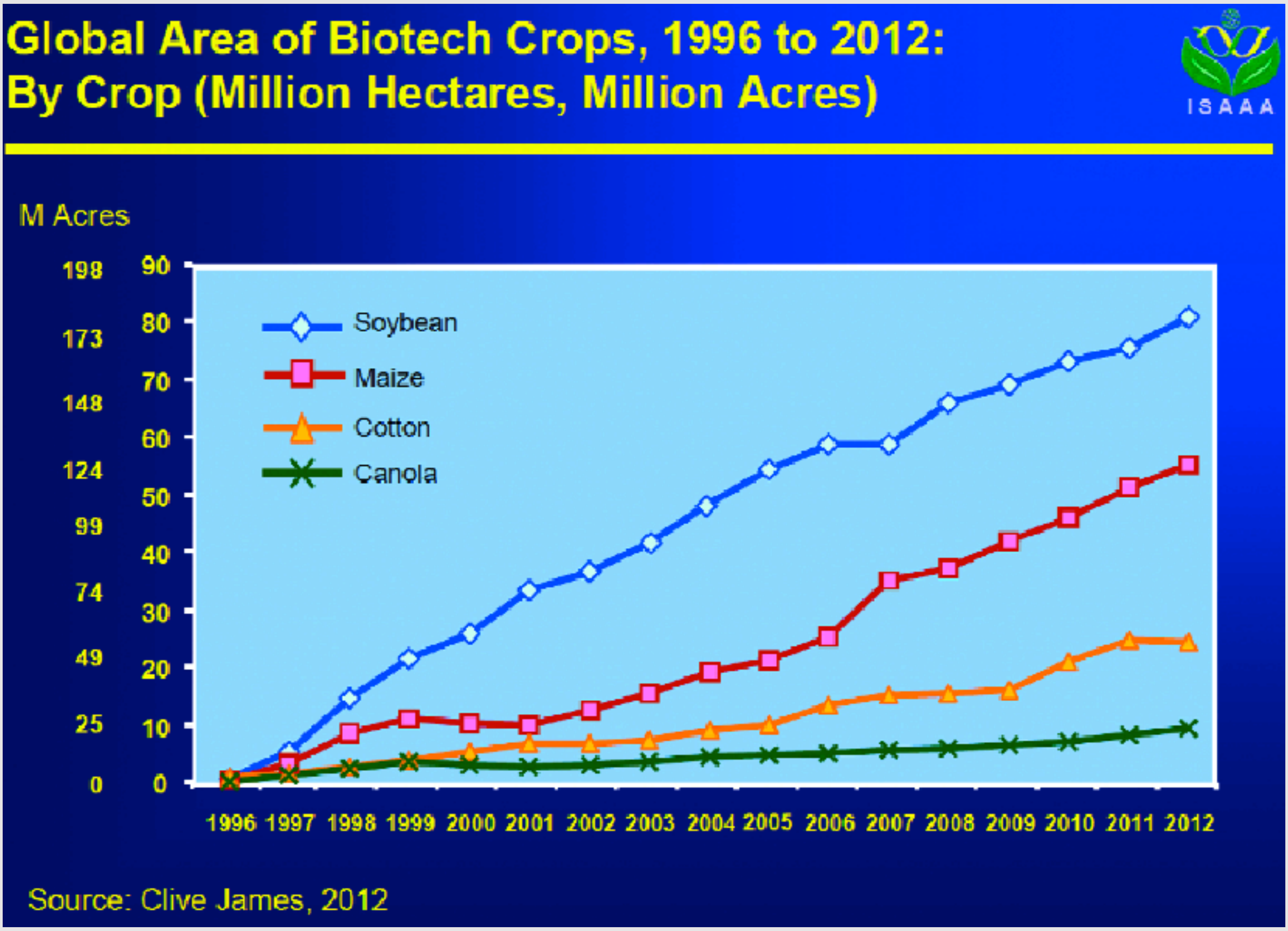


Figure 3.

Figure 3. The evolution of the world market for GM crops (from ISAAA) (http://www.isaaa.org/resources/publications/briefs/43/pptslides/default.asp

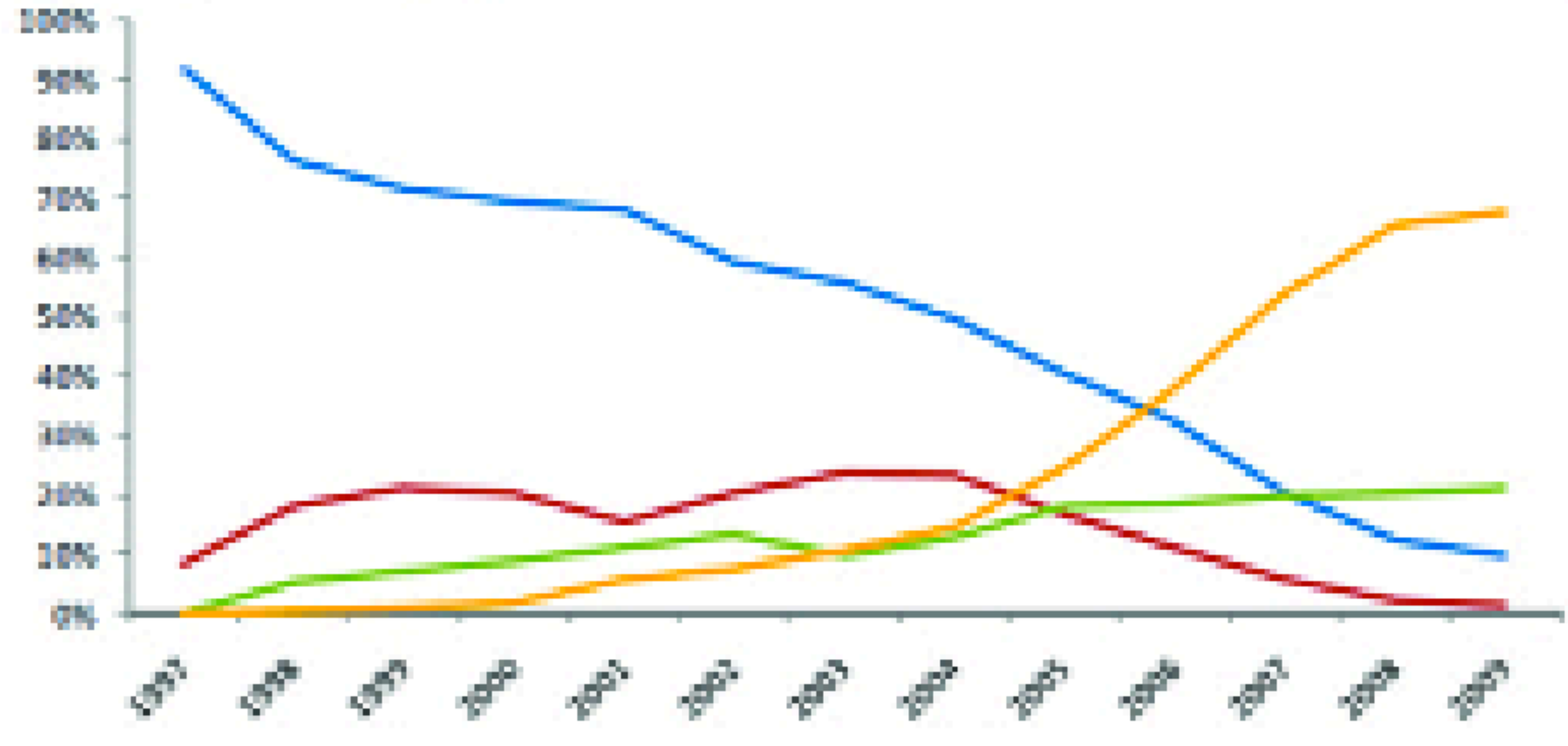


Figure 4.

Figure 4. US market share of maize seed: conventional hybrid (blue); GM Insect Resistant (IR, red); GM Herbicide Tolerant (HT, green); GM stacked IR+HT (yellow) (from Seedbuzz.com) (http://www.seedbuzz.com/knowledge-center/article/product-life-cycles-and-innovation-in-the-us-seed-corn-industry)

| | Wheat yield, t/ha | Rice yield, t/ha |
|---|---|---|
| Afghanistan | 1.9 | 3.2 |
| Bangladesh | 2.4 | 4.3 |
| Bhutan | 2.2 | 3.1 |
| India | 2.8 | 3.4 |
| Nepal | 2.1 | 2.7 |
| Pakistan | 2.6 | 3.1 |
| | | |
| China | 4.7 | 6.6 |
| USA | 3.1 | 7.6 |
| UK | 7.7 | |

Figure 5.

Table 1. 2010 yield data for wheat and rice in a number of Asian countries (FAO figures)

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Martin Livermore,

Professor Anthony Trewavas

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## Comments