General Certificate of Education
Advanced Level Examination
June 2010

Science in Society SCIS4/PM

Unit 4

Preliminary Material

- This Source Material should be opened and issued to candidates on 1 May 2010
- A clean copy of the Pre-released Source Material will be provided at the start of the Unit 4 examination.

Information

- This case study source material consists of extracts from five sources (A-E) on the subject of GM crops and food supply.
- This material is being given to you in advance of the Unit 4 examination to enable you to study the content of each extract in preparation for questions based on the material in the examination. Consider the scientific explanations and the ideas about how science works that are involved, as well as the issues raised in the sources.
- You may write notes on this copy of the case study source material, but you will not be allowed to bring this copy, or any other notes you may have made, into the examination room. You will be provided with a clean copy of this case study source material, together with one additional source F, at the start of the Unit 4 examination.
- You are not required to carry out any further study of the topic than is necessary for you to gain an understanding of the ideas described and to consider the issues raised. You are not required to understand any detailed **science explanations** beyond those outlined in sources A-E and those in the Science in Society specification.
- It is suggested that a minimum of three hours detailed study is spent on this pre-release material.

SOURCE A

Extracted from article by Ian Sample, science correspondent, The Guardian, Monday 8 September 2008

Hunger in Africa blamed on western rejection of GM food

The rise of organic farming and rejection of GM crops in Britain and other developed countries is largely to blame for the impoverishment of Africa, according to the government's former chief scientist.

Sir David King says anti-scientific attitudes towards modern agriculture are being exported to Africa and holding back a green revolution that could dramatically improve the continent's food supply.

King, who is due to give the presidential address at the British Association's Festival of Science in Liverpool this evening, will criticise non-governmental organisations and the UN in his speech for backing traditional farming techniques, which he says cannot provide enough food for the continent's growing population. "The problem is that the western world's move toward organic farming - a lifestyle choice for a community with surplus food - and against agricultural technology in general and GM in particular has been adopted across the whole of Africa, with the exception of South Africa, with devastating consequences."

Last week, King, who is now director of the Smith school of enterprise and the environment at Oxford University, said genetically modified crops could help Africa mirror the substantial increases in crop production seen in India and China. "What was demonstrated [there] was that modern agricultural technologies can multiply crop production per hectare by factors of seven to 10." But traditional techniques could "not deliver the food for the burgeoning population of Africa".

King said a recent report chaired by Professor Robert Watson, the government's chief scientific adviser at the Department for Environment, Food and Rural Affairs, was shortsighted. The report concluded that GM crops had only a minor part to play in eradicating world hunger. The research, based on the findings of 400 scientists, noted that food was cheaper and diets better than 40 years ago, but that while enough food was produced to feed the global population, still 800 million people went hungry. "You cannot argue that Africa has hunger because it doesn't have GM today," said Watson. "We have more food today than ever before but it isn't getting to the right people. It's not a food production problem, it's a rural development problem."

SOURCE B

An online article from the Science and Development Network, www.scidev.net

GM crops deserve more reasoned debate

16 October 2008

Debates around the potential benefits of GM crops for developing countries must be reasoned and evidence-based, says *Albert Weale*.

The World Bank recently estimated that a doubling of food prices over the last three years could push 100 million people in low-income countries deeper into poverty. And the future does not look brighter. Food prices, although likely to fall from their current peaks, are predicted to remain high over the next decade.

As the world considers how to respond, the debate about genetically modified (GM) crops has inevitably reared its ugly head. 'Ugly' because the public exchange about this technology has usually seen extreme viewpoints gaining the most airtime. For example, in the United Kingdom, Prince Charles' spirited but ill-informed attack on GM crops this summer led to a flurry of opinionated responses. We could have been back in the polarised debates of the earlier part of this decade.

Since 1999, my organisation, the UK-based Nuffield Council on Bioethics, has twice examined the ethical issues raised by GM crops. In a 2003 report, the Council specifically focused on developing countries. Two of the conclusions are still particularly relevant today.

Ethical obligation

First, the council concluded that there is an ethical obligation to explore whether GM crops could reduce poverty, and improve food security and profitable agriculture in developing countries. In coming to this conclusion, the council considered differing perceptions of risk. When people have enough food, as in developed countries, consumers and producers will feel free to avoid risk — even if that risk is theoretical rather than real. But developing nations, struggling with widespread poverty, poor health, limited pest control and poor agricultural sustainability, have a different risk-benefit calculation. This is perhaps why the acreage of GM crops has tripled in developing countries over the past five years, compared to just doubling worldwide.

Consumers in prosperous countries are being asked to suppress their doubts about GM crops so that research relevant to the developing world continues. In effect, they are being asked to concede that any potential losses to them are outweighed by potential gains to poor countries, where yields are declining and conventional agriculture is increasingly unsustainable.

This does not belittle other factors needed for poverty reduction and food security — such as stable political environments, appropriate infrastructures, fair international and national agricultural policies, and access to land and water. GM crops are just one part of a large and complex picture. But we will not know how important a part until we explore their potential.

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Case by case consideration

The Nuffield Council's second key conclusion was that the wide range of GM crops and situations must be considered individually. Those who oppose or support GM crops *per se* make an unhelpful generalisation.

Each time, the gene or combination of genes being inserted, and the nature of the target crop, must be assessed. It is also important to compare a GM crop with local alternatives.

For example, Golden Rice — enhanced for β-carotene to help fight vitamin A deficiency — is not needed where people have sufficient vitamin A from leafy greens, or ready access to vitamin supplements. But where this is not the case, the crop may significantly improve nutrition.

Similarly, herbicide-resistant soybeans can reduce demands for local labour. This may be devastating if a community relies on wages from manual weeding. But it may help communities struggling with a labour shortage due to high prevalence of diseases such as HIV/AIDS.

The role of research

Scientific and other evidence must be central in the debate, and over the past few years evidence about GM crops has grown.

For example, according to a recent news report in *Science*, soon-to-be-published research will clarify the amount of Golden Rice a child would need to eat each day to prevent vitamin A deficiency. This kind of research is vital if governments and farmers are to make informed decisions about GM crops. Indeed, before new research is funded, national and regional bodies in developing countries should be consulted about their priorities for crops and desirable GM traits.

In the United Kingdom, the government has committed £150 million (US$263 million) over the next five years to research aimed at making agriculture more resilient to the pests and diseases affecting poor farmers, and increasing smallholders' agricultural productivity.

Research efforts are also growing in the developing world, with South African scientists developing and working to commercialise virus-resistant maize, and countries like Kenya and Nigeria hosting projects to develop virus-resistant varieties of key African crops

Striking a balance

Many people worry about possible environmental risks from GM crops, such as gene flow to other plants, and this is something that scientific research must clarify. But alarm-raising without evidence is as helpful as calling 'fire' in a crowded theatre. Similarly, demanding evidence of zero risk before allowing a new technology is fundamentally at odds with any practical strategy for investigating new technologies. Mobile phones or aeroplanes might never have seen the light of day if such stringent demands had been placed on them.

In the case of GM technology it is clearly crucial to ask what the risks of adopting GM crops are. But it is also important to ask what the risks of not doing so are. Realistic cost-benefit analyses that consider local social and environmental conditions and development goals are needed on a country-by-country basis.

Heated debate about the food crisis must not detract from an evidence-based assessment of biotechnology's potential for improving agricultural productivity in developing countries. The benefits of GM crops must not be overstated. But neither can poor arguments be allowed to obscure strong arguments for a good cause.

Professor Albert Weale is chair of the Nuffield Council on Bioethics and professor of government at the University of Essex, United Kingdom.

SOURCE C

One of the resources provided by the Science Museum on its website to encourage informed debate about future foods, as part of its collection of topical exhibits.

Who benefits from GM?

All the GM crops grown around the world at the moment have been developed by large, multinational companies. This makes many people wary, as they think the companies are more concerned about making a profit than about investing in the right technology to benefit farmers and consumers. Critics argue that money spent on GM would be better spent elsewhere – on less risky and more effective technologies.

Why have big companies dominated GM technology to date?

It'll cost ya
Developing genetically modified plants is pricey. Highly trained scientists have to work with expensive equipment for many years before they identify the right genes to transfer into crops. After this, lengthy and expensive field trials make sure the new crops do what the scientists predict.

Regulations vary from country to country. In Europe governments demand very strict field and food safety regulations. It can take more than ten years to get crops approved for growing and eating – and time costs money.

Getting your money back
Only big companies and large research centres can afford to spend enough money and resources on developing crops that cannot be sold for many years.

But even they would not be able to do the work if they did not make back the money they invested. Companies do this by patenting genes or new crops. A patent means that other people cannot benefit from the technology without paying a fee to the company.

Patently ridiculous?
What does the patent system mean for farmers?

When farmers buy genetically modified seeds from companies, they sign a contract promising they will not save any seeds from their crops for planting the following year, unless they pay a fee. These arrangements are strictly enforced, and some farmers have been fined heavily for breaking their contracts.

So how does this differ from non-GM crops?

Same old story
Patents give companies a lot of power, and many people use this as an argument against GM. However, seeds from conventionally bred plants that most farmers grow often aren't used in following years either. This is because the bought seeds produce identical plants, but when these plants breed together they produce different characteristics in the next generation. The farmer gets a haphazard mixture of plants of different shapes, sizes and qualities.

So many farmers buy new seeds every year, whether they grow GM or conventionally bred crops.

Saving seed
However, small farmers in developing countries do save and reuse their seeds to cut costs. So because the patents mean that GM seeds cannot be saved, this makes them too expensive for some to afford.

GM critics claim that the technology isn't appropriate for these small farmers because it doesn't allow them to gather seeds as they have always done. Buying new seeds each year reduces their profits.

But this situation may be changing...

Where are we going?
Some companies are now involved in research projects which will sell seeds royalty free to small farmers. A number of universities are working on collaborative programmes with scientists in the developing world to create crops that are designed to benefit particular regions. And breakthroughs in the technology mean genetic modification may become quicker, easier and cheaper to do. This may make it more accessible for smaller research groups, rather than just huge agricultural companies.

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SOURCE D An article from *Philosophical Transactions of the Royal Society of London*

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Phil. Trans. R. Soc B (2008) 363, 905-913
doi: 10.1098/rstb.2007.2191
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The role of biotechnology for agricultural sustainability in Africa

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Sub-Saharan Africa could have a shortfall of nearly 90 Mt of cereals by the year 2025 if current agricultural practices are maintained. Biotechnology is one of the ways to improve agricultural production. Insect-resistant varieties of maize and cotton suitable for the subcontinent have been identified as already having a significant impact. Virus-resistant crops are under development. These include maize resistant to the African endemic maize streak virus and cassava resistant to African cassava mosaic virus. Parasitic weeds such as Striga attack the roots of crops such as maize, millet, sorghum and upland rice. Field trials in Kenya using a variety of maize resistant to a herbicide have proven very successful. Drought-tolerant crops are also under development as are improved varieties of local African crops such as bananas, cassava, sorghum and sweet potatoes.

1. INTRODUCTION

Africa is a continent rich in natural and human resources. More than 900 million people live here, two-thirds in small towns and villages scattered throughout rain forests, deserts and vast grasslands. Yet it is also a place where, because of famine, disease and growing populations, almost 200 million people are undernourished and 33 million children go to sleep malnourished and hungry every night. More than 60% of malnourished Africans live in Eastern Africa. Parts of West Africa have shown decreases in the prevalence of malnutrition in recent years (Inter-Academy Council 2004).

African agriculture has a unique set of features that make it very different from Asia where the Green Revolution has had a pervasive impact. These include

- lack of a dominant farming system;
- predominance of rainfed agriculture as opposed to irrigation; and
- prevalence of soils of poor fertility.

There is a vast difference between farming practices on the fields of a farmer growing just one of two different crops to another growing a range of crops on less than one hectare in Africa. The former will use varieties developed from highly inbred lines and adapted to relevant climate. The latter, often a woman, will grow many different crops that minimize her risk of failure. For example, she might plant some maize and beans in case rainfall is plentiful, and perhaps some sorghum, cassava and cowpea in case of drought. Cost considerations will prevent her from using even marginally acceptable levels of fertilizer or pesticides. These differences almost guarantee that any crop bred in the 'North' will not be adapted to her growing conditions (Delmer 2005). In Africa, crop production per unit of land cultivated is the lowest in the agricultural world.

In this paper I will address some of the biotechnological interventions being supported by the African Agricultural Foundation (AATF). This Foundation, based in Nairobi, was launched in June 2004. It is a private not-for-profit organization dedicated to increasing the productivity of resource-poor farmers in sub-Saharan Africa. .....

2. INSECT-RESISTANT AFRICAN MAIZE VARIETIES EXPRESSING ONE OF THE BACILLUS THURINGIENSIS (Bt) Cry GENES CODING FOR INSECT-SPECIFIC TOXINS

Maize is one of the most important sources of calories for the poor in Africa, second only to cassava. It forms a significant part of the diets of millions of smallholder subsistence farmers, who grow it primarily in mixed cropping systems. Small- to medium-scale farmers, who cultivate 10 hectares or less, grow 95% of the maize produced in Africa. Stem borers cause significant yield losses in all African ecosystems where the crop is grown. Losses range from 15 to 40%, but when conditions favour insect infestation, total crop failure can occur (AATF 2005).

Insect-resistant genetically modified maize, expressing the Bacillus thuringiensis (Bt) toxin, has been commercialized only in the Republic of South Africa (RSA), where it is grown both by small-scale and commercial farmers. By the 2002/2003 season, 20% of yellow maize but only 2.8% of white maize was Bt.

Can small-scale farmers benefit from Bt white maize? With price differentials of $83/ kg for Bt maize seed compared with $52 /kg for non-Bt seed, the answer is probably no. It is estimated that only 10% of small scale farmers use hybrid seeds, the rest planting open pollinated varieties and saved seeds of open-pollinated varieties. These are varieties bred specifically to allow farmers to replant seeds for a limited number of seasons before buying fresh seed again. None of these varieties have been genetically modified, largely because the profit margins are very low.
A survey was conducted among 368 small-scale farmers in six sites in RSA during the 2001/2002 growing season (Gouse et al. 2005). The evidence suggests that Bt maize has potential benefits for such farmers (figure 1). Another important finding was that the farmers also liked the quality of the maize produced by the Bt variety, Yieldgard. When asked what they liked best about the Bt hybrid maize, farmers at three sites chose better quality, while higher yield was the most important reason at the other three sites. The farmers did not put much importance on the benefits from pesticide reduction (probably because only half of them used pesticides).' Whether poor farmers unable to afford pesticides will be prepared to pay extra for hybrid Bt maize remains to be seen.

Can Bt maize spread to a larger share of small-scale farmers in RSA? One solution would be for seed companies to charge a lower technology fee to these farmers compared with commercial farmers. One company is already doing this with conventional hybrid maize seed. Another way would be for private–public partnerships to introduce the Bt gene into open pollinated varieties. This would enable small-scale farmers to save their seed and still get the benefit of Bt.

To bring insect-resistant maize to the rest of Africa, a consortium is undertaking a project entitled IRMA (Insect-Resistant Maize for Africa). This aims to provide sub-Saharan Africa smallholder maize producers with access to suitable Bt maize varieties that are resistant to the major stem borers that limit maize productivity in the region. A combination of traditional plant breeding and genetic modification is being used in this project. An alternative to Bt maize is to plant crops that will attract insect borers. One example is the use of Napier grass, pioneered by Kenya's International Centre for Insect Physiology and Ecology. Rows of Napier grass planted around a maize field will attract up to 70% of egg-laying moths, depending on the ratio of maize to Napier grass.

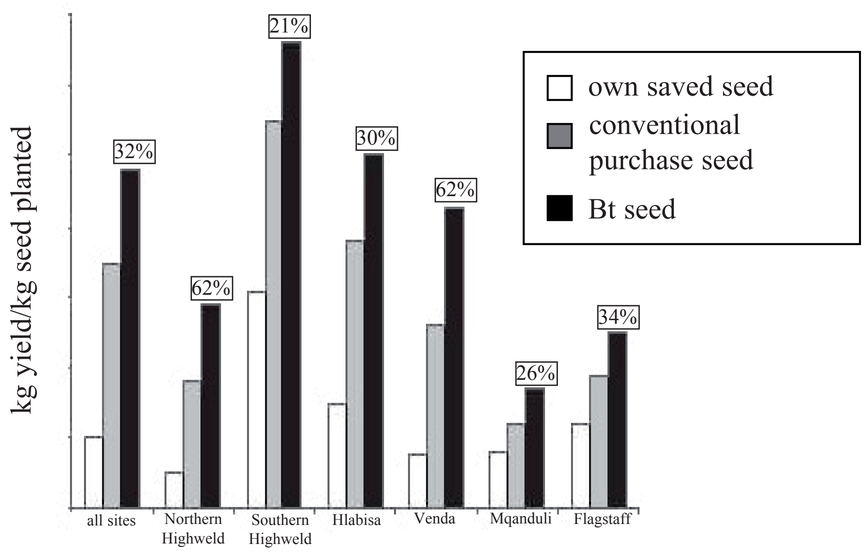

Figure 1 Small-scale farmers' yields per kilogram of seed, by seed type for six sites in 2001/2002 (Gouse et al 2005)

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SOURCE E

Extracted from *Science* 8 June 2007: Vol. 316. no. 5830, pp. 1475 – 1477

A Meta-Analysis of Effects of Bt Cotton and Maize on Nontarget Invertebrates

Michelle Marvier,[a] Chanel McCreedy,[a] James Regetz,[b] Peter Kareiva[a,c]

Abstract
Although scores of experiments have examined the ecological consequences of transgenic *Bacillus thuringiensis* (Bt) crops, debates continue regarding the nontarget impacts of this technology. Quantitative reviews of existing studies are crucial for better gauging risks and improving future risk assessments. To encourage evidence-based risk analyses, we constructed a searchable database for nontarget effects of Bt crops. A meta-analysis of 42 field experiments indicates that nontarget invertebrates are generally more abundant in Bt cotton and Bt maize fields than in nontransgenic fields managed with insecticides. However, in comparison with insecticide-free control fields, certain nontarget taxa are less abundant in Bt fields.

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[c] The Nature Conservancy, 4722 Latona Avenue NE, Seattle, WA 98105, USA.

Introduction
Public debate regarding risks and benefits of genetically modified (GM) crops continues unabated. One reason for the unrelenting controversy is that disagreements about new technologies often have little to do with scientific uncertainty but instead arise from differing personal values and differing levels of trust in public institutions. However, in the case of GM crops, scientific analyses have also been deficient. In particular, many experiments used to test the environmental safety of GM crops were poorly replicated, were of short duration, and/or assessed only a few of the possible response variables. Much could be learned and perhaps some debates settled if there were credible quantitative analyses of the numerous experiments that have contrasted the ecological impact of GM crops with those of control treatments involving non-GM varieties.

Here, we describe a meta-analysis of field studies involving *Bacillus thuringiensis* (Bt) crops, which represent the predominant modification entailing the novel production of pesticidal substances (Cry proteins) in crop plants. The incorporation of bacterial-derived Cry genes into plants means that a wide variety of species are exposed, on a relatively continuous basis, to pesticidal Cry proteins. We restricted our analyses to lepidopteran[1]-resistant cotton expressing Cry1Ac protein, lepidopteran[1]-resistant maize expressing Cry1Ab protein, and coleopteran[2]-resistant maize expressing Cry3Bb protein, because the aggregate collection of field experiments assessing these Bt crops is large enough to draw some compelling conclusions.

1 Lepidoptera are butterflies and moths. Stem borers on maize are the larvae of a moth.
2 Coleoptera are beetles. The larvae of some beetles attack maize roots.

The standard approach to assessing nontarget effects entails measurements of abundance, survival, or growth of nontarget species when exposed to a GM variety versus when exposed to the same or similar variety lacking the genetic modification. We focused on field studies, and the response variable we analyzed is the abundance of nontarget invertebrates, sampled in a variety of ways. For each experiment, we recorded many attributes, including locations, durations, plot sizes, and sample sizes. Experiments relied on two different types of control treatments, each reflecting a different philosophy of risk assessment: (i) controls entailing non-GM varieties grown under identical conditions but treated with insecticides and (ii) controls entailing non-GM varieties grown under identical conditions and with no insecticides applied.

We report a weighted mean effect size. Negative values indicate lower abundance (whereas positive values indicate higher abundance) in Bt plots compared with abundance in control plots.

Results

For all Cry1Ab maize events[3], the overall mean abundance of nontarget invertebrates was significantly lower in Bt compared with that in control fields that lacked insecticide applications (Fig. 1B; leftmost white bar). However, the mean abundance of nontarget invertebrates was greater in Cry1Ab maize than in non-GM maize sprayed with pyrethroid insecticides (Fig. 1B; leftmost hatched bar). Effects measured by using these two different types of control treatments differed significantly. Qualitatively different patterns emerged when analyses were restricted to single transgenic events. For MON810, effect sizes measured using controls with versus without insecticides did not significantly differ. For Bt176, the two control types yielded significantly different effects, but there was no significant reduction in abundance observed with the insecticide-free controls (white bar, 95% CI overlaps with $d = 0$).

For Cry3Bb maize, the mean abundance of nontarget invertebrates was not significantly different in Bt fields compared to abundance in non-GM maize either with or without pyrethroid applications. This same pattern held when analyses were restricted to event MON863.

[3] Maize expressing Cry1Ab has been produced in several different experiments. Each of these is called an event and may result in slightly different GM maize.

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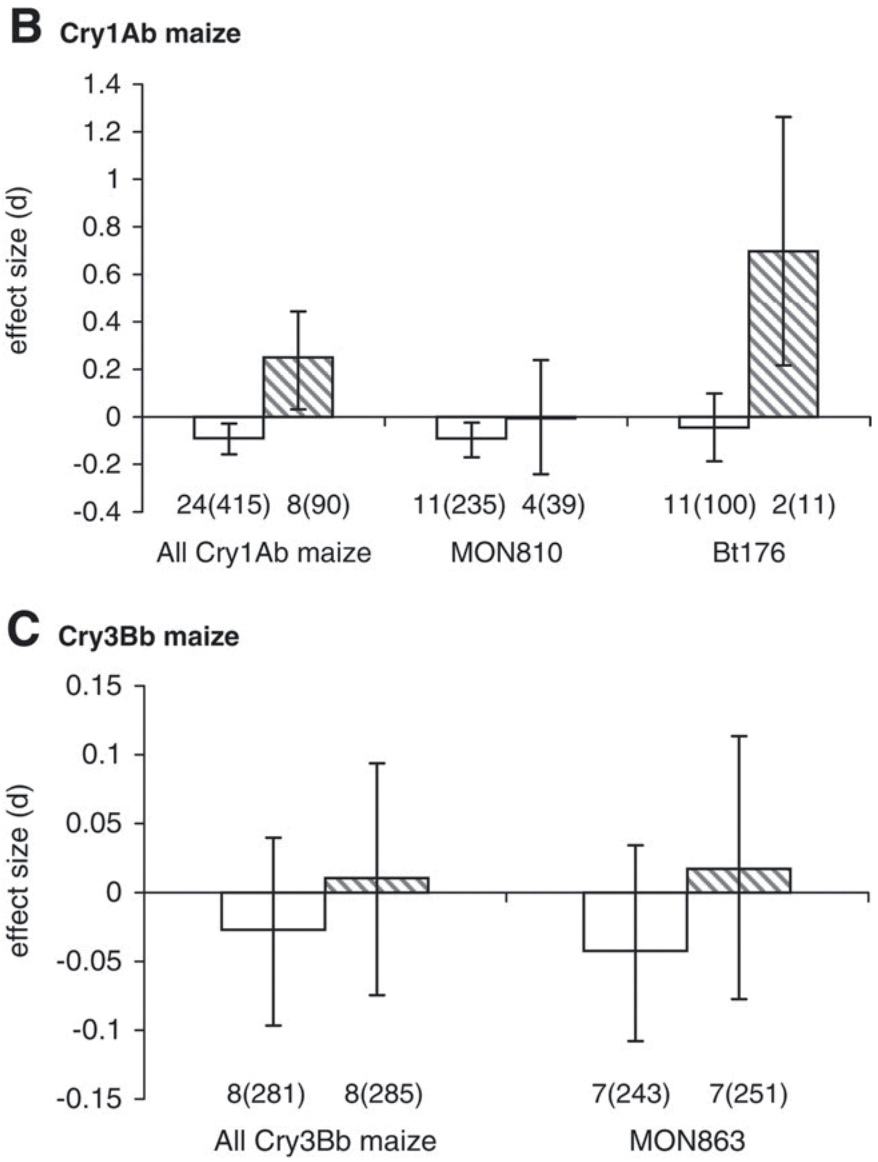

Fig. 1. Meta-analysis of field studies assessing abundance of nontarget invertebrate species for (**B**) lepidopteran-resistant Cry1Ab maize, and (**C**) coleopteran-resistant Cry3Bb maize. Effect size is shown and error bars represent 95% confidence interval, CI. Values below each bar indicate the number of different papers or reports and, in parentheses, the number of lines of data summarized (each line of data represents a comparison of a group's average abundance in a Bt versus control treatment). White bars compare the abundance of nontarget invertebrates in Bt and non-GM varieties, without insecticide applications. Hatched bars compare the abundance of nontarget invertebrates in insecticide-free Bt varieties versus non-GM varieties managed with applications of pyrethroids.

Discussion

The general indication of our analyses is that if agriculture with insecticide applications is the standard of comparison and if adoption of Bt crops truly reduces insecticide applications, then Bt crops may increase the abundance of nontarget invertebrates overall. Alternatively, if the comparison is made to farming systems without insecticides, some nontarget groups are significantly less abundant in Bt than in control fields. Hymenopterans[4] are less common on average in Cry1Ab and Cry3Bb maize compared with hymenopterans in non-GM, insecticide-free controls respectively). For the Cry1Ab comparison, data on hymenopterans mostly comprised parasitic wasps . For Cry3Bb maize, data included parasitic wasps and ants. It is unclear whether the reduced abundance of these groups (coleopterans, hemipterans, and hymenopterans) is due to direct toxicity or is a response to reduced availability of prey in Bt crops.

To facilitate additional syntheses, we have created a publicly accessible, searchable database, detailing methods and results of lab and field studies examining nontarget invertebrates and Bt crops While assembling this database, we found numerous studies that did not report measures of variance to accompany treatment means (40% of 64 reports of field studies), did not clearly present the sample size (20%), or improperly used subsamples to calculate measures of variance (22%). By corresponding with authors, we were often able to resolve these issues. If regulatory agencies were to require researchers to enter details regarding their study methods and results into a similar database, it would be easy to spot omitted information and postpone approval of pesticidal crops until complete records were submitted.

Our analyses provide some support to the claim that GM plants can reduce environmentally undesirable aspects of agriculture, particularly the nontarget impacts of insecticides. However, we examined only one type of genetic modification, and most of the underlying studies entailed controlled field experiments with small spatial scales as opposed to actual farming systems, where continued insecticide use sometimes occurs with Bt crops. Secondly, the conclusion that adoption of Bt cotton or maize may entail ecological benefits assumes a baseline condition of insecticide applications.

Studies such as those synthesized here investigate whether changes in invertebrate abundance are statistically significant. Whereas the lack of a difference is generally considered a signal of environmental safety, it is harder to interpret whether statistically significant differences in abundance translate into ecologically important changes. Regardless of one’s philosophical perspective on risk assessment for GM crops, enough experimental data has accumulated to begin drawing empirically based conclusions, as opposed to arguing on the basis of anecdote or hand-picked examples.

References and Notes

This article had 14 references and notes. These have been removed for clarity.
Footnotes 1-4 have been added by AQA.

[4] Hymenopterans are wasps, bees, sawflies or ants

END OF SOURCES

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