Science for Environment Policy
DG Environment News Alert Service
SPECIAL ISSUE

GMOs

Issue 10 December 2008

Editorial

Balancing the views on GM crops

Genetically modified organisms (GMOs) affect the broader social, economic and ethical aspects of life. Honest, open public debate, which involves a wide range of people is necessary to build confidence in policy decisions made on behalf of all citizens

Recognition of public concerns is being addressed through ongoing scientific research, especially the effects of GMOs on human health and the environment. In this thematic issue, recent research is presented on important issues surrounding the use of GMOs in agriculture.

The article 'Public participation in the GM debate: the case for sustainability reporting' proposes the use of voluntary sustainability reporting to frame constructive discussions.

As greater areas of European agricultural land are likely to be used to cultivate GM crops in the future, new approaches to investigating the broader ecological implications are a valuable contribution to risk assessment. For example, understanding how far insects can carry pollen is explored in 'Bee behaviour helps us understand transgene escape', whilst 'The bigger picture: GM contamination across the landscape' examines short and long distance pollen flows in fields of GM maize. The need to take into account the broader ecological impact of GM crops can also be seen in 'GM rapeseed can mix with weeds', which researched the transfer of transgenes from GM crops into nearby wild relatives.

The impact of GMOs on organisms living in soil ecosystems is the focus of the paper 'Earthworms decompose GM maize'. While this study does not show any negative effect of GM maize on earthworms, the effects of GMOs on various relevant soil organisms have to be studied in a scientific risk assessment process.

GM crops have been modified to improve resistance to particular insects or certain herbicides, allowing, in certain cases, less chemical control during the growing cycle. But how, for example, does the use of GM herbicide resistance affect agricultural practice in general? The article 'GM crops could reduce the need for herbicides' investigates some of these issues. It might be the case that the benefits gained by using GMOs lead to some negative effects on overall agricultural practices on the other hand.

Finally, there is a continued need for a precautionary approach in the application of GM crops. Careful implementation is achievable by acknowledging positive impacts of GMOs, while respecting social and ecological issues. Clarifying uncertainties through ongoing research must continue to play a key role in the wise use of GMOs.

Dr Helmut Gaugitsch
Head of Unit, Land Use & Biosafety
Umweltbundesamt (Federal Environment Agency, Austria)

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Public participation in the GM debate: the case for sustainability reporting

Use of genetically modified organisms (GMOs) in agriculture remains controversial, particularly in the European Union. Researchers suggest that all members of society need to be engaged in the debate on GMOs to achieve agreement on policy decisions. They propose voluntary sustainability reporting as a suitable method for conducting public dialogue.

Contact: pvergragt@tellus.org and hbrown@clarku.edu
Theme(s): Agriculture, Biotechnology, Environmental Information Sources

"Public concerns make it essential for the whole of society to participate in policy decisions about GMOs. The risks and science behind genetic engineering need to be debated on an ongoing basis."

A number of public concerns continue to be raised about the impacts of genetically modified plants on the environment, including: unknown effects on human health, ethics of interfering with nature, freedom of consumer choice and patenting life forms. These concerns make it essential for the whole of society to participate in policy decisions about GMOs. The researchers argue that understanding the risks, management of these risks and the science behind genetic engineering need to be debated in society on an ongoing basis.

Debate about GMOs could be framed as a sustainability issue, using the method of voluntary sustainability reporting as practised by some businesses when setting out their corporate accountability and social responsibilities. The advantage of this approach is that it is necessary to include the participation of a wide range of multiple stakeholders, including the manufacturing and service sectors, investors, banks and insurance representatives, religious, environmental and labour organisations and governments.

A framework for voluntary sustainable reporting, the Global Reporting Initiative (GRI)[1] already exists. The benefits to society of using the GRI are that it enables all stakeholders to hold a dialogue with a company and make that company accountable for its actions. Reporting within the guidelines centres around three sustainability indicators: social, economic and environmental performance.

The study suggests that a specific set of GRI guidelines could be produced for GMOs used in agriculture. This could be used as a guide during the debate of relevant issues, leading to new perspectives on this controversial topic.

One expectation of using a GRI-type approach is that there will be greater transparency during the early research and development stages. It is thought that debate at this point could shape the development of the technology and behaviour of the company by wider society. This technique, known as Constructive Technology Assessment, should also benefit companies because it is less costly to make changes at these early stages.

Costs to companies developing new technologies are often substantial. These costs are usually recovered through patents and intellectual property rights, which give companies exclusive use of their products and processes. This is a major obstacle to using the sustainability reporting method and is an issue that needs to be resolved. It is one of the reasons why financial stakeholders are key to the GMO debate.

[1] See: http://www.globalreporting.org/Home The Global Reporting Initiative (GRI) sets out the principles and indicators that organizations can use to measure and report their economic, environmental, and social performance. See the following for further information on sustainability reporting:

- Brown, H.S., de Jong, M. and Lessidrenska, T. (2009). The Rise of Global Reporting Initiative (GRI) as a Case of Institutional Entrepreneurship. Download from: http://www.hks.harvard.edu/mrcbg/CSRI/publications/workingpaper_36_brown.pdf
- Brown, H.S., de Jong, M., and Levy, D. Building Institutions . Based on Information Disclosure: Lessons from GRI's Sustainability Reporting. In print by Journal of Cleaner Production.

Source: Vergragt, P.J. and Brown, H. S. (2008). Genetic engineering in agriculture: New approaches for risk management through sustainability reporting. *Technological Forecasting and Social Change.* 75: 783-798

Bee behaviour helps us understand transgene escape

Bees could potentially spread pollen from genetically modified (GM) crops to wild plants within a ten kilometre radius of the GM crop, according to recent research conducted in Kenya. Pollen movement is the main route for transferring genes between insect-pollinated plants and this research provides key insight into bee behaviour which can help us understand the ecological impact of GM crops on their wild relatives.

Contact: rpasquet@icipe.org or hh@millennium-institute.org
Theme(s): Agriculture, Biotechnology, Risk Assessment

"These data, along with many others, suggest that transgene escape would be inevitable if GM-cowpea was cultivated in West Africa."

The cowpea *(Vigna unguiculata)* is one of the most important food legume crops in semi-arid tropical regions, especially in African lowlands. The planned introduction of insect-resistant GM cowpea crops is likely in West Africa, with Burkina Faso, Ghana and Nigeria targeted by the AATF programme[1]. Transgenes in the pollen of GM crop plants can be transferred to closely related wild plant species via pollinating insects so determining the foraging range of bees is of major importance.

The researchers attached minute radio transmitters to carpenter bees (the main cowpea pollinator) to establish the distance these insects can travel to find nectar. A total of 134 "flower to nest" flights of carpenter bees were recorded, with distances ranging from 50 metres to 6040 metres. Homing tests were also carried out, where bees were captured, marked and released at a range of distances from their nests. These tests showed a potential flight range of up to 10 kilometres, but for most flights bees travelled no further than 5 kilometres.

They found that bees were attracted from further afield by large quantities of flowers. These large floral displays are more likely to take place in cultivated cowpea fields, where the flowers bloom at the same time, than in the wild populations which have fewer blooms.

Individual flight records showed that foraging bees rarely moved between wild and domesticated patches of cowpea on the same trip, provided the patches are clearly separated and the two groups of plants are not mixed. However, the researchers do not believe that strict isolation of GM cowpea crops from their wild relative is feasible as a way of ruling out the escape of transgenes into the wild. These data, along with many others, suggest that transgene escape would be inevitable if GM-cowpea was cultivated in West Africa. It is therefore considered important to ensure that escaped transgenes do not have a negative impact on wild plants.

The research was carried out over a period of three years, under a variety of weather conditions. The researchers believe that radio-tracking is an effective way to measure pollinator foraging distances, particularly as transmitters become smaller. The transmitters used in this experiment weighed 0.35g (around a third of a bee's weight), and had a 14cm antenna. The results are very similar to those obtained in studies of other species of bee, including honey bees and bumble bees.

[1] The African Agricultural Technology Foundation (AATF) is coordinating the Cowpea Productivity Improvement project.
For details see: http://www.aatf-africa.org/aatf_projects.php?sublevelone=10&subcat=5

Source: Pasquet, R. S., Peltier, A., Hufford, M.B. *et al.* (2008). Long-distance pollen flow assessment through evaluation of pollinator foraging range suggests transgene escape distances. *Proceedings of the National Academy of Sciences.* 105(36): 13456-13461.

The bigger picture: GM contamination across the landscape

Ensuring the purity of conventional crops grown in the vicinity of genetically modified (GM) crops depends on understanding both short and long distance pollen flows. New research shows that current guidelines on the safe isolation distances for GM maize may not adequately prevent cross pollination of conventional crops.

Contact: Claire.lavigne@avignon.inra.fr
Theme(s): Agriculture, Biotechnology, Risk Assessment

"Long-distance dispersal of GM pollen can contaminate fields of non-GM crops and potentially raise the impurity rate above 0.9 per cent."

Contamination of conventional crops can occur where GM pollen cross-fertilises non-GM maize. The proportion of cross-contaminated seeds in the conventional field is the 'impurity rate' for that crop. Under European Union rules[1], if the accidental proportion of GM to non-GM seeds exceeds 0.9 per cent then the crop must be reclassified and labelled as GM. Existing safe distances were largely established using 'paired field' comparisons, where contamination from a GM field is measured in a specific nearby field. The distances between the two 'paired' fields can then be adjusted to determine a 'safe' distance between fields. However, on a landscape level, other GM or non-GM maize crops in the vicinity may have an effect on pollen flow.

French researchers modelled the spread of pollen in a landscape containing a patchwork of GM and non-GM maize fields, as well as other non-maize fields. By taking into account the pattern of both short and long distance dispersal of GM pollen, the study explored the additional impact of more distant GM maize fields (i.e. not the closest GM field) on the impurity rate of the non-GM maize. For comparison, the impurity rates in a conventional field were also calculated using only the distance to the closest GM field.

Overall, the study showed that pollen from GM fields closest to conventional fields and the size of the conventionally planted fields have the greatest impact on the degree of contamination. However, as the proportion of GM maize to non-GM maize increases within the landscape, the impurity rate of conventional fields also increases. This increase was caused by long distance pollination from GM fields further from the conventional fields and suggests that if GM maize becomes more widely adopted by farmers, then existing models will underestimate the 'safe' distance between GM and non-GM crops. Importantly, the level of underestimation increased as more GM maize was included in the modelled landscape and when the isolation distance between GM and non-GM fields increased.

The researchers therefore suggest that, as long-distance dispersal of GM pollen can contaminate fields of non-GM crops and potentially raise the impurity rate above 0.9 per cent, pollen from all GM fields in the landscape needs be considered when setting isolation distances between fields of GM and non-GM crops. Further research is required to determine how to model these effects at the landscape level.

Source: Lavigne, C., Klein, E.K., Mari, J-F. *et al.* (2008). How do genetically modified (GM) crops contribute to background levels of GM pollen in an agricultural landscape? *Journal of Applied Ecology.* 45: 1104-1113.

[1] See: for a comprehensive overview of regulation of Genetically Modified Organisms in the European Union: (dated 06/02/2006) http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/06/58&format=HTML&aged=0&language=EN&guiLanguage=en

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GM rapeseed can mix with weeds

A recent study examined the fate of a herbicide (glyphosate) resistance transgene from genetically modified (GM) rapeseed in a wild relative. The study found that the gene could persist in the wild relatives for several generations, persisting in the population for up to six years in a small number of plants.

Contact: warwicks@agr.gc.ca
Theme(s): Agriculture, Biotechnology, Risk Assessment

"There is no evidence to suggest that the presence of a herbicide-resistant transgene in wild plants is inherently problematic."

Crops have exchanged genes with their weedy relatives for centuries in a process called hybridisation, and the same may occur with GM crops. With the introduction of GM crops, genes with novel properties can now be introduced into ecosystems. There are fears that this could create issues for both conservationists and farmers, although such problems are yet to be identified.

New research assessed hybridization between GM rapeseed, *Brassica napus*, and its wild relative, *Brassica rapa*. The hybrid was found in Québec, Canada in 2001. Although *B. napus* has many wild relatives worldwide, there is only a high potential for hybridisation with *B. rapa*.

Several generations of hybrids were allowed to grow in field settings; glyphosate was not applied during the study period. This removed any selective pressure on the hybrid to retain the transgene. The researchers collected samples of the hybrid plants annually. These were assessed for the presence of the herbicide resistance (HR) trait, male fertility and species-specific genetic markers from both parental species plants. This allowed the researchers to build a picture of the potential of the transgene to persist in the environment in the absence of any selective pressures that would favour retention of the transgene.

The research found that while some hybrids had the HR trait as well as reduced fertility and species-specific markers, the number of hybrids decreased drastically over the period of monitoring, from 85 out of 200 plants in the first year of monitoring to only 5 out of 200 plants, 5 years after the GM crop and wild plants were first in contact with one another. However, the presence of even a small number of transgenic hybrids may ensure persistence over time.

There is no evidence to suggest that the presence of an HR transgene in wild plants is inherently problematic. The study suggests that wild hybrids containing the transgene are only likely to be present in large numbers in agricultural areas where herbicides are applied frequently and appropriately. This is because application of herbicides provides a selective pressure favouring these hybrids.

The study concludes that the risks of hybridisation depend on the trait in question, with some traits likely to cause more problems than others. Where the plants are located or which other genes they are combined with will also influence the risk-factor.

Source: Warwick, S. I., Legere, A., Simard, M-J., James, T. (2008). Do escaped transgenes persist in nature? The case of an herbicide resistance transgene in a weedy *Brassica rapa* population. *Molecular Ecology.* 17(5):1387-1395.

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Earthworms decompose GM maize

Pest-resistant genetically modified (GM) maize makes up an increasing proportion of maize grown commercially in the EU. A new study shows that earthworms may help break down the toxins produced by GM maize.

Contact: stefan.schrader@vti.bunde.de
Theme(s): Agriculture, Biotechnology, Soil

"Earthworms may help microorganisms in the soil decompose GM plant matter containing the toxin, by releasing compounds that enhance microbial activity."

GM maize (Bt-maize) plants are engineered to produce "cry" proteins that are toxic to the European corn borer, a major insect pest responsible for corn crop losses. Recent studies have shown that planting Bt-maize can increase yields and grain quality, as well as profitability. However, there is concern that cry toxins may have an impact on other species besides the corn borer. It is therefore essential to understand the fate of these toxins in soil.

As widespread soil-dwelling species, earthworms are important indicators of soil quality. Their burrowing and feeding activities may also have an impact on any toxins released into the soil. However, until now it has been unclear exactly how earthworms affect cry toxin levels – whether they stabilise or reduce concentrations. New research shows that earthworms may in fact help to enhance the decline of cry toxins in soils planted with GM maize.

The researchers studied two species of earthworm, *Lumbricus terrestris* (the 'common earthworm' or 'night crawler'), and, *Aporrectodea caliginosa*, (the 'grey worm'). These were added to soils to which GM plant matter (leaves and roots) had been added. Five weeks after leaves were added to the soil concentrations of the toxin, Cry1Ab, were at least 4 per cent lower in soils containing earthworms compared with soils without earthworms. Where earthworms where fed on roots instead of leaves, they reduced concentrations of the toxin by at least 3 per cent.

According to the researchers, earthworms may help microorganisms in the soil decompose plant matter containing the toxin, by releasing compounds that enhance microbial activity. There were some differences to be found between the impacts of the two species of worm, however, which may be due to their different eating habits. The *A. caliginosa* proportionally ingests more soil than the *L. terrestris* which in turn increases concentrations of clay material. Clay can help stabilise levels of the Cry1AB toxin in the soil. While this could increase its effects on the corn borer, it also raises the possibility that the Cry1Ab could be available to other, non-target, organisms for a longer time period. Further research is needed to explore the effects of soil type and worm activity on the persistence of toxins in the soil.

Such studies may provide insights into how soils should be managed where Bt-maize is cultivated and will become more important to agricultural practice in the EU as commercial cultivation of GM crops continues to rise. In 2007, the area covered by GM maize in the EU rose by more than three quarters, from 62,000 hectares to 110,000, with Spain producing a quarter of all its maize from genetically modified crops.

Source: Schrader, S., Münchenberg, T., Baumgarte, S., Tebbe, C.C. (2008). Earthworms of different functional groups affect the fate of the Bt-toxin Cry1Ab from transgenic maize in soil. *European Journal of Soil Biology.* 44: 283-289.

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GM crops could reduce need for herbicides

Analysis of large-scale European field trial data reveals that lower quantities of herbicides are applied to crops genetically modified for herbicide-resistance compared with conventionally grown crops. However, the data also suggest that biodiversity may be reduced if genetically modified (GM) crops are grown widely.

Contact: Contact: gijs.kleter@wur.nl
Themes: Agriculture, Biotechnology, Risk Assessment

"Cultivation of glyphosate-resistant crops could provide an alternative method of weed management with positive effects for the environment, as long as measures for maintaining biodiversity are taken."

Transgenic crops are currently grown in 22 countries across the world, including seven EU member states: Spain, France, the Czech Republic, Portugal, Germany, Slovakia and Romania. However, cultivation of GM crops in the EU represents a small proportion of the more than 100 million hectares grown worldwide.

Cultivation of crops resistant to glyphosate, a commonly used herbicide, is limited in the EU[1], though such crops are imported and processed. Only Romania has cultivated glyphosate-resistant (GR) transgenic soybean on a large scale, and this occurred before its inclusion in the EU.

The study looked at a number of weed-management strategies, including the use of glyphosate and GM, for three crops: sugar beet, soybean and oilseed rape. The findings reveal that the weed-sensitive crop, sugar beet, is more easily cultivated as a GM crop than a conventionally grown crop and that less herbicide is applied to the GM variety. Studies in the USA and Canada suggest that herbicide applications are reduced in other crops that have been modified for herbicide resistance, including soybean, maize and oilseed rape.

GM crops may also offer benefits in terms of climate change. A life cycle analysis (LCA) of the herbicide production chain, including transportation and field applications, has revealed that adoption of GR beets could reduce energy use by up to 50 percent and global warming potential by 19 per cent.

The study cites data derived from assessments using the Environmental Impact Quotient (EIQ)[2] which estimates and compares the environmental impacts of pesticide spray programmes. This accounts for potential impacts on farm workers, consumers and the environment. EIQ data suggest that negative environmental impacts caused by herbicides are lower for GR crops. However, the UK's farm scale evaluation (FSE) trials with GR beets suggest that the reduction of weed and insect species could possibly undermine biodiversity and have impacts on species higher up the food chain. This includes birds that are reliant on insects as a food source.

The authors conclude that cultivation of GR crops could provide an alternative method of weed management with positive effects for the environment, as long as measures for maintaining biodiversity are taken. In addition, it would be necessary to prevent herbicide resistant plants becoming 'volunteer' weeds (plants that have not been planted deliberately) in subsequent crop rotations. The cross-pollination of GM varieties with closely related plant species is also a concern. Therefore, if GM crops are to be adopted on a wider scale, changes to wider agricultural practices are needed. For example, the use of other herbicides may be needed to control volunteers.

Source: Kleter, G., Harris, C., Stephenson, G. and Unsworth, J. (2008). Comparison of herbicide regimes and the associated potential environmental effects of glyphosate-resistant crops versus what they replace in Europe. *Pest Management Science*. 64: 479-488.

[1] http://ec.europa.eu/environment/biotechnology/authorised_prod_2.htm

[2] http://nysipm.cornell.edu/publications/eiq/default.asp

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A selection of articles on GMOs from the *Science for Environment Policy* News Alert

GM rapeseed could reduce fertiliser usage (17/7/08)

Nitrogen fertiliser used in crop production is a substantial source of environmental pollution, contributing to around one third of the total greenhouse gas emissions from the world's agricultural sector. Recent research on a genetically modified (GM) variety of rapeseed, which has been made more nitrogen-efficient, suggests that yields comparable with conventional varieties can be obtained using significantly less fertiliser.

Key research findings were:

- growing GMNUE canola reduced energy consumption by 22 per cent compared with the conventional variety
- GMNUE canola emitted 16.3 per cent less greenhouse gases per unit of crop produced than the conventional variety
- GMNUE canola had a reduced acidification potential of 16.2 per cent
- GMNUE canola emitted 17.3 per cent and 15.4 per cent less terrestrial and aquatic toxic emissions than the conventional variety

Genetic engineering could cut the cost of biofuels (3/7/08)

Plant genetic engineering could play a major part in reducing the cost of biofuel production from food crop wastes such as rice straw or from non-food crops such as willow and poplar. A recent study suggests further research is needed to determine whether plants developed through genetic modification are better suited for biofuel production. This technology is closely regulated. Any products arising from ensuing research must be thoroughly assessed in accordance with the relevant legislation in order to ensure their safety to humans, animals and to the environment.

According to the study's author, biofuels have the potential to reduce the political instability and environmental issues that come with reliance on oil. The United States government and some commercial organisations are actively promoting and funding research into new sources of energy including biofuels. However, there are major obstacles which prevent the widespread use of biofuels including: the cost of the production process on an industrial scale; problems with transporting ethanol, the most common biofuel, which corrodes pipes, and the impact of using agricultural land to grow crops for biofuels instead of for food.

GM seeds can remain in fields longer than previously thought (29/5/08)

Despite management practices designed to reduce the risk of genetically modified (GM) volunteer plants setting seed, new research shows that rogue GM plants occur in fields which were planted with GM oil seed rape 10 years earlier.

Strategies have been developed to minimise the occurrence of volunteer GM plants, following field trials of GM crops. In the case of oil seed rape, these include shallow stubble tillage which encourages seed germination, followed by late ploughing to eliminate seedlings. However, this new research found evidence of modified genes in oil seed rape seedlings 10 years after a GM field trial. The extensive control of volunteers at the study site suggests that these seedlings sprouted from 10 year old seeds.

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