An FAO e-mail conference on GMOs in the pipeline in developing countries: The moderator's summary

John Ruane
Research and Extension Branch,
UN Food and Agriculture Organization (FAO),
Viale delle Terme di Caracalla,
00153 Rome, Italy

Executive Summary

From 5 November to 2 December 2012, the UN Food and Agriculture Organization (FAO) hosted a moderated e-mail conference on "GMOs in the pipeline: Looking to the next five years in the crop, forestry, livestock, aquaculture and agro-industry sectors in developing countries".

A total of 770 people subscribed to the conference and, of these, 59 (i.e. 8%) submitted at least one message. Of the 109 messages that were posted, 36% came from people living in Asia; 26% from Europe; 24% from North America; 10% from Latin America and the Caribbean; and 5% from Africa. The messages came from people living in 24 different countries. The greatest number were from people living in India (31 messages), followed by the United States (25); United Kingdom (eight); Belgium, Brazil, the Netherlands, Peru, Spain and Switzerland (four messages each); and Iran and Nigeria (three messages each). A total of 55 messages (i.e. 50%) were posted by people living in developing countries. Regarding their workplace, 30% of messages came from people working in universities; 18% from participants in non-governmental organizations; 17% from people in research centres; 12% from people in the private sector; 11% from people working as independent consultants; and 8% and 2% from people in Governments and FAO respectively.

This document summarizes the main issues that were discussed by participants during the four weeks of the conference. It was the 18th e-mail conference hosted by the FAO Biotechnology Forum since its launch in the year 2000. FAO traditionally uses a broad definition of biotechnology, so that the term encompasses a large number of technologies that are used for different purposes in crops, livestock, forestry, fisheries and aquaculture, and agro-industry. One of these biotechnologies is genetic modification and, unlike the other biotechnologies, there has been considerable controversy and debate about its current and potential benefits and implications.

Genetic modification is therefore much more in the public spotlight and demands far more attention from policy-makers than all the other biotechnologies. It is also an area of major research & development investment and it is predicted that the range of genetically modified traits and species that will be commercially available to farmers in developing countries in the future will be far wider than it is today. For these reasons, this e-mail conference was held to look into the near future in order to inform the debate about genetically modified organisms (GMOs) in the pipeline. Specifically people were asked to address two main topics in the conference. First, what new GMOs are likely to be commercialized in developing countries within the next five years (i.e. before the end of 2017) in the crop, forestry, livestock, aquaculture and agro-industry sectors? Second, what are the likely implications of these new GMOs for developing countries?

As described in the conference background document, the current situation regarding GMOs in food and agriculture is that large land areas are cultivated with GM crops in different countries worldwide; a small number of GM trees are grown in China; no GM livestock or fish have been released for food purposes; and GM micro-organisms are used in food processing, production of food ingredients, animal nutrition and development of vaccines to manage livestock and fish diseases.

During the conference, most of the messages focused on the crop sector, where participants shared extensive amounts of information regarding GM crops in the pipeline. Whereas almost all of the global GM crop area, both currently and in past years, has involved four crops (soybean, maize, cotton

and canola) and two traits (herbicide tolerance and insect resistance), participants thought that the new GMOs likely to be released within the next five years in specific developing countries would involve the same crop species and agronomic traits but also a broad range of additional species by trait combinations. Specific details were provided on the GM crop pipeline in individual countries, including Argentina, Bangladesh, Brazil, Burkina Faso, China, Egypt, India, Iran, Kenya, Nigeria, Pakistan, South Africa and Uganda. There was also considerable debate about Bt brinjal (eggplant) in India, where a moratorium was placed on its commercial release in 2010.

There was minor discussion about GM trees. Work on high yielding eucalyptus is progressing in Brazil and the goal is to submit a dossier for approval within the next five years. Discussion about GM livestock in the pipeline was also very limited, indicating that there is little likelihood of their commercial release in developing countries for food purposes in the near future. Release of GM livestock for production of human pharmaceuticals was considered likely in at least one country, Iran. Regarding fish, discussions suggested that two kinds of GM fish, both with a growth hormone gene, were candidates for potential commercial release for human consumption within the next five years i.e. a carp in China and an Atlantic salmon whose embryos would be produced in Canada and grown out in central America. New GM fluorescent aquarium fish are expected to be released. Progress in developing GM insects for pest control was described by a participant who predicted they would be available for the control of insect pests in agriculture and human health within the next five years. There were no messages about GM micro-organisms during the conference.

Messages from participants indicated that the public sector, the private sector as well as public-private partnerships will all contribute to development of the new GMOs, albeit to different degrees in different countries. In some developing countries with strong GMO programmes, such as Brazil, China, India and Iran, the public sector is playing a key role.

As mentioned in the conference background document, the topic of GMOs is controversial and has been at the centre of a highly-polarized debate since the 1990s. Many messages in the conference were dedicated to the implications of releasing Bt brinjal in India and the fast-growing Atlantic salmon, two specific GMOs that have been in the pipeline for several years now and which may be commercialized within the next five years. Particularly for Bt brinjal, discussion was intense and detailed regarding the different potential hazards and benefits and participants reached no consensus on any major point. The conference provided no evidence of a reduction in the intensity and polarization of the GMO debate. Apart from these two GMOs, there was little discussion about the likely implications of specific pipeline GMOs for developing countries. At the generic level, it was argued that new GM crops addressing developing country needs and conditions should bring positive impacts to developing countries.

A couple of issues which received minor attention during the conference were how to define a ‘GMO’ in the pipeline (as distinctions between a GMO and non-GMO can be blurred when new products are developed using non-GM techniques and subsequently crossed with older GM varieties or using new techniques such as cisgenesis) and whether GMOs in the pipeline contain antibiotic resistant marker genes.

From the e-mail conference, a picture emerged of a GMO pipeline that contains a considerable quantity and variety of products that may be commercialized in developing countries within the next five years. As noted in the conference, whether or when they actually will be commercialized depends to a large extent on the GMO regulatory framework in the country.

In conclusion, the conference indicated that the new GMOs likely to be released in developing countries within the next five years will continue to be dominated by the crop sector, where a broad range of new crop by trait combinations are in the pipeline, but may also see increased focus on new areas such as GM fish, insects and trees. The long-running polarized debate about GM crops is expected to continue and to expand into these areas, further engaging policy makers in developing countries in this high profile subject in the near future.

1. Background to the e-mail conference

In 2010, FAO organized an international technical conference on "Agricultural biotechnologies in developing countries: Options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change" (ABDC-10) in Guadalajara, Mexico (FAO, 2011). ABDC-10 was dedicated to "agricultural biotechnologies", a term representing a broad range of technologies used in crops, livestock, forestry, fisheries and aquaculture, and agro-industry. They are used for a variety of different purposes such as the improvement of plant varieties and animal populations to increase their yields or efficiency; characterization and conservation of genetic resources; plant or animal disease diagnosis; vaccine development; and production of fermented foods.

One of these biotechnologies is genetic modification and it is used to produce genetically modified organisms (GMOs), which are organisms in which one or more genes (called transgenes) have been introduced into their genetic material from another organism using recombinant DNA technology. For example, so-called "Bt crops" are crops containing genes derived from the soil bacterium *Bacillus thuriengensis* coding for proteins that are toxic to insect pests that feed on the crops.

While there has been little controversy about any of the other biotechnologies, there has been considerable debate about the current and potential implications that genetic modification and GMOs have for food security, the environment, biodiversity, human health, farmers income, the global food system and other issues. They are much more in the public spotlight and demand far more attention from policy-makers than all the other biotechnologies. They also represent an area of major research & development (R&D) investment and it is predicted that the range of modified traits and species that will be commercially available to farmers in developing countries in the future will be far wider than it is today. For these reasons, the FAO Biotechnology Forum (http://www.fao.org/biotech/biotech-forum/) dedicated this e-mail conference to "GMOs in the pipeline: Looking to the next five years in the crop, forestry, livestock, aquaculture and agro-industry sectors in developing countries" from 5 November to 2 December 2012. The conference was organized by the FAO Working Group on Biotechnology and moderated by John Ruane from the FAO Research and Extension Branch.

About a week before the conference began, the moderator sent a short background document (FAO, 2012) to the conference subscribers. The document provided an overview of GMOs that are currently commercialized in food and agriculture. It also briefly discussed the research-to-commercialization pathway; the choice of a 5-year time horizon for the e-mail conference; and some GMOs that are in the pipeline in the different sectors. It concluded with some specific guidance about the two main topics that participants were requested to address. The first was about what new GMOs are likely to be commercialized in developing countries within the next five years (i.e. before the end of 2017) in the crop, forestry, livestock, aquaculture and agro-industry sectors. Specific questions they could address regarding these new GMOs included their species; their traits; whether they will be developed by the public sector, the private sector or through public-private partnerships (PPPs); whether they will be produced in the developing country itself or elsewhere; and what kind of intellectual property management options will be exercised by the bodies commercializing these new GMOs. The second was about the likely implications of these new GMOs for developing countries, specifically for food security and nutrition, socio-economic conditions, sustainable management of natural resources and for adaptation to climate change.

In the opening message to the conference, the moderator welcomed the participants to the conference and briefly reminded them of some of its main guidelines, i.e. that participants should introduce themselves briefly in their first posting to the conference; they are assumed to be speaking on their own behalf and not on behalf of their employers; and messages should not exceed 600 words.

Section 2 of this document presents the moderator's summary of the main issues that were discussed by participants during the conference. Section 3 gives a brief analysis of participation in the

conference – including where the participants come from and what kind of work they do. Section 4 provides the references, abbreviations and acknowledgements.

2. Summary of the main issues discussed in the conference

During the 4-week conference, a total of 109 messages were posted to all the subscribers by e-mail. For people wishing to consult them, we recommend using the PDF file http://www.fao.org/fileadmin/user_upload/biotech/docs/conf18msgs.pdf (0.9 MB), where the messages have been formatted for easier reading (e.g. the moderator's comments are in italics). Alternatively, all of the original messages (in plain text format) are available at https://listserv.fao.org/cgi-bin/wa?A0=Biotech-Room2-L where the message archives are searchable, with a 'free text' search button on the right hand side of the webpage. The original messages can also be viewed in chronological order (latest on top) for November and December at https://listserv.fao.org/cgi-bin/wa?A1=ind1211&L=Biotech-Room2-L&O=D&H=0&D=1&T=1 and https://listserv.fao.org/cgi-bin/wa?A1=ind1212&L=Biotech-Room2-L&O=D&H=0&D=1&T=1 respectively.

Messages were numbered from 1 to 109 in order of posting to allow easy cross referencing during the conference. Some of the individual messages are referred to in this document, where the number of the message is provided within brackets (normally with the author's surname). These messages, as well as all the others posted in the conference, can be read in their entirety through the web links provided above.

In this Section, the goal is to summarize discussions on the main issues that received most attention in the conference. Most of the messages addressed the first of the conference's two main topics, i.e. what new GMOs are likely to be commercialized in developing countries within the next five years in the crop, forestry, livestock, aquaculture and agro-industry sectors. Of the different sectors, the vast majority of messages were dedicated to crops. Section 2.1 covers GM plants (crops and trees) while Section 2.2 covers GM animals (including livestock, fish and insects). Section 2.3 is dedicated to discussions on whether the new GMOs will be developed by the public sector, the private sector or through PPPs. Section 2.4 covers the likely implications of these new GMOs for developing countries. Finally, Section 2.5 considers three other issues that were also raised by participants in the conference.

2.1 GM plants in the pipeline

2.1.1 GM crops

During the conference, participants shared extensive amounts of information with the conference regarding GM crops that are in the pipeline in developing countries. Falck-Zepeda (49) provided a table of GM crops undergoing confined field trials in Africa, suggesting that some, but not all, may be commercialized within five years. The 27 entries covered six countries (Burkina Faso, Egypt, Kenya, Nigeria, South Africa and Uganda) and nine crops (banana, cassava, cotton, cowpea, maize, potato, sorghum, sugarcane and wheat). For each entry, the traits, stage of development and partners involved were also provided. Shoham (56) presented a table with GM crops in the private sector pipeline which he maintained could be launched in developing markets over the next few years, covering seven crops (canola, cotton, maize, rice, soybean, sugarcane and wheat) and four kinds of traits (herbicide tolerance, insect resistance, disease resistance/agronomic traits and processor/consumer traits).

Participants also pointed out that numerous publicly available databases provide information on GM crops in the pipeline, including those from the Indian Government's Department of Biotechnology (Predeepa, 36; Manjunath, 68); International Service for the Acquisition of Agri-biotech Applications (Nickson, 24; Choudhary, 94); Monsanto (Nickson, 24); and Syngenta Foundation for Sustainable Agriculture (Shoham, 56).

Several messages addressed the GM crop pipeline for specific developing countries. For Argentina, Gadaleta (72) anticipated that the GMO pipeline for the next years would include species like cotton, maize, potato, rice, soybean, sugarcane and wheat, and traits like insect and virus resistance, herbicide tolerance, drought resistance and modified fatty acid profile. In Bangladesh (Shahjahan, 73; Choudhary, 94), Bt brinjal (eggplant), late blight resistant potato and golden rice are in development (golden rice refers to rice that have been modified to produce beta carotene [Dubock, 11; Glover, 22]). For Brazil (Santana, 76; Ramos, 82; Parrott, 97; Sampaio, 106), the national agricultural research system (EMBRAPA) has developed golden mosaic virus resistant common beans that have been approved for commercialization, and expected to be on the market within the next couple of years, and is also working, in partnership with Japanese institutions, on drought tolerance and heat tolerance in soybean, cotton, sugarcane, maize and common beans (soybean experiments started earlier and initial field trials for sugarcane should start in 2014 [Sampaio, 106]). Release of new GM crops from the private sector is also expected (Santana, 76).

Regarding China, Tillie (21) suggested it had the dominant position as a developer of GM crops among developing countries. He provided information on the pipeline of GM crops with quality traits (nutritional benefits) relevant to animal nutrition, only considering those for which there was at least one clear "proof of concept". The majority were from China, involving maize, rapeseed, rice, soybean and wheat with high lysine and/or low phytate content. For Choudhary (94), the most advanced products that were nearing commercial release in China included low phytate content and herbicide tolerant (HT) maize, HT soybean, Bt rice and fungal resistant wheat. Glover (70) specifically wondered about the status of Bt rice in China, given that it reportedly had received biosafety clearance in 2009.

For Iran, Ghareyazie (79) provided a detailed overview of the background and status regarding GM crop development. He informed the conference that Bt rice had been officially released in 2004 and that the recent approval of the National Biosafety Law meant that the Government would now actively facilitate the release and use of this and other GMOs. He suggested that the GMOs to be commercialized in Iran would be HT rice and Bt rice (again) and that Bt cotton, Bt sugar beet, HT canola and Bt alfalfa would be the next GM crops to be released within the next five years.

In Pakistan, Zafar (62) thought that GMOs likely to be commercialized within the next five years might include GM cotton (virus resistant, insect resistant, HT, drought/salt tolerant), maize (insect resistant, HT), sugarcane (drought/salt tolerant) and wheat (HT and drought/salt tolerant). In Tanzania, Farrelly (8) suggested the pipeline GMOs are disease resistant cassava, Bt cotton and Bt/drought resistant maize. Choudhary (94) also reported that the GM crop pipeline contained Bt cotton, Bt/HT maize and drought tolerant sugarcane in Indonesia; Bt brinjal, Bt cotton, Bt/HT maize and golden rice in the Philippines; and Bt/HT maize as well as Bt rice in Vietnam.

Most messages in the conference came from participants in India and, not surprisingly, some of them were dedicated to the GM crop pipeline in their country. Kumar (34) thought the GM crops likely to be released in the next five years were Bt brinjal, Bt chickpea and Bt pigeon pea. Karwa (63) envisaged that the Krishidhan Seeds Group using indigenous GM technologies would commercialize Bt brinjal; heat tolerant and drought resistant crops of different species; and insect resistance and HT maize within the next five years. Manjunath (68) provided a detailed table of GM crops in India that were at different stages of field evaluation, covering 17 crops and eight traits, and suggested that Bt brinjal is foremost among the crops awaiting final approval while Bt rice and Bt okra have undergone multi-location research trials. Choudhary (94) said there was rigorous field testing of many GM crops in India, including Bt brinjal, Bt/HT cotton, Bt/HT maize, high yielding mustard, Bt okra, Bt/HT rice, high iron rice, golden rice, Bt chickpea, Bt pigeon pea, Bt cabbage, Bt cauliflower, HT wheat, nitrogen use efficiency cotton and groundnut, many of which were also included in Manjunath's table (68).

About one third of messages in the conference were dedicated to discussions of a single GM crop, i.e. Bt brinjal (*Solanum melongena*) in India (16, 19, 23, 25-31, 33, 35, 37, 40, 42, 44-46, 50, 51, 53, 57, 58, 60, 64, 65, 67, 78, 84, 87, 95, 96, 99, 100, 102, 105). Developed by inserting the cry1Ac gene from

the bacterium *Bacillus thuringiensis* to provide insect resistance, Bt brinjal is the result of a PPP involving the private company Mahyco and three public sector institutions (University of Agricultural Sciences, Dharwad; Tamil Nadu Agricultural University, Coimbatore; and Indian Institute of Vegetable Research, Varanasi). In October 2009, the Genetic Engineering Appraisal Committee (GEAC), a statutory body of the Ministry of Environment and Forests, recommended its environmental release. The Minister of State for Environment and Forests then called for public consultations, which took place at seven locations during January-February 2010, before taking a final decision. In February 2010, the Ministry of Environment and Forests announced the decision to impose a moratorium on the release of Bt brinjal, without specifying how long it would last.

There were strong differences of opinion between participants regarding the potential benefits and consequences of releasing Bt brinjal. The main issues debated included the potential impacts of Bt brinjal on biodiversity; the possibility of cross-pollination and gene flow between Bt brinjal and its wild relatives; impacts of Bt brinjal on the medicinal properties of brinjal; the safety of consuming Bt brinjal; whether the moratorium had been placed on scientific or political grounds; and how rigorous and credible the Indian GMO regulatory system is. From the debate, there was no evidence of participants reaching an agreement or understanding on any of these issues.

If the moratorium is lifted, Bt brinjal will be the first GM food crop to be released in India. Its importance was underlined by participants, such as Rodrigues (64) who declared "the case of Bt brinjal is the test case for India" and Choudhary (42) who noted that it is of "particular interest" for a number of reasons, including the fact that its regulation in India might impact regulation of Bt brinjal in Bangladesh and the Philippines.

2.1.2 GM trees

Compared to the large number of messages about GM crops, there were very few about GM trees, reflecting the big difference between these two sectors regarding GMO development (Muralidharan, 91). Nevertheless, it was suggested (Ramos, 82; May, 83) that GM eucalyptus are in the pipeline in Brazil. May (83) described the R&D initiatives of the private company FuturaGene regarding GM eucalyptus in Brazil, including development of trees modified to contain the endo-1,4-beta-glucanase gene from *Arabidposis thaliana* to increase biomass yields. He informed the conference that yield-enhanced GM eucalyptus is currently undergoing environmental safety assessment in advanced regulatory trials at a variety of agro-ecologically distinct locations around Brazil and that, within the next five years, the company intends to submit a dossier for approval of commercial launch. Muralidharan (91) suggested that the only tree in the GMO pipeline in India (although not in the next five years) is GM rubber (*Hevea brasiliensis*) developed for drought tolerance and tapping panel dryness by the Rubber Research Institute of India.

2.2 GM animals in the pipeline

2.2.1 GM fish

FAO (2012) mentioned the commercial release of ornamental GM fluorescent fish. Scotto (20, 90) noted that fluorescent zebrafish was one of only two GMOs approved in his country, Peru. He pointed out that they get a good price and that other colour variants are being commercialized.

Regarding GM fish for human consumption, some participants (Li, 41; Clifford, 103; Wray-Cahen, 109) mentioned ongoing projects in China, particularly those led by the Institute of Hydrobiology, Chinese Academy of Sciences. Li (41) reported that about 30 years ago, researchers at that institute developed the world's first GM fish, containing the fish growth hormone gene, and that in recent years they had developed GM carp with better growth rates and feed conversion efficiencies. He was unsure whether GM fish would be commercialized in China in the next five years.

Most discussion on GM fish in the conference focused on GM Atlantic salmon (1, 12, 32, 43, 52, 54, 61, 69, 74, 80, 85, 88-90, 98, 101, 103, 109). The GM Atlantic salmon (*Salmo salar*), containing the growth hormone gene from the Chinook salmon (*Oncorhynchus tshawytscha*), was developed by a private company AquaBounty Technologies and has been submitted to the United States Food and Drug Administration (FDA) for regulatory approval. According to the FDA application, the salmon will be reared entirely in freshwater and it is envisaged that the fish eggs be produced in Prince Edward Island, Canada and that grow-out of the fish takes place in land-based contained culture systems with multiple, redundant containment barriers in Panama.

The major issue discussed about the GM salmon was its potential environmental impact and the efficiency of the different biological (i.e. sterile and single sex fish), physical (screens, nets, filters and containment devices) and ecological (thermal barriers and competitive disadvantages) containment measures proposed to confine the fish and prevent its proliferation (32, 43, 61, 69, 74, 90, 98, 103). Participants also discussed its production characteristics, particularly growth rate and feed conversion ratio, compared to non-GM salmon (12, 80, 85, 88, 101, 109) and its potential benefits for developing countries (12, 20, 80, 85, 101). As for discussions on Bt brinjal (Section 2.1.1), albeit to a lesser degree here, participants expressed some divergent viewpoints on many of these issues.

2.2.2 GM livestock

Based on discussions in the conference, there seems to be little likelihood that GM livestock will be commercialized for agricultural purposes in developing countries within the next five years. Murray (1,12) described three GM livestock developed in North America which he said might be useful in developing countries, namely GM pigs developed in Canada, containing the phytase gene from the bacteria *Escherichia coli,* to utilize phosphate from plant material in their diet and decrease the environmental footprint of pork production; GM pigs developed in the United States, containing the bovine alpha-lactalbumin gene, to increase pork production by increasing the growth of piglets pre-weaning; and GM goats developed in the United States, containing the human lysozyme gene, to produce milk with increased shelf life and antimicrobial activity that may help to combat childhood diarrhea. Apart from the message from Scotto (20), who thought they would not be relevant for his country, Peru, there was no further discussion of these specific GMOs. Participants from Argentina (Gadaleta, 72), Bangladesh (Shahjahan, 73) and Iran (Ghareyazie, 73) indicated that GM livestock for food production purposes would not be commercialized in their countries in the near future.

As described in FAO (2012), and in more detail by Edwards (13), GM livestock can also be used as bioreactors for production of human pharmaceuticals in plasma/milk/other harvestable tissues or of other components for human health applications. To Edwards' question (13) of whether such applications might be of interest in developing countries, Namur (15) and Al-Bayatti (18) were not convinced while Chávez (17) seemed more positive. Ghareyazie (79) informed the conference that this work was well advanced with GM goats in Iran, suggesting that goats producing human factor IX and tissue plasminogen activator will be in the market within the next 2-3 years and that goats producing erythropoietin and albumin are expected to be commercialized in the next five years.

2.2.3 GM insects

A single message on GM insects (Beech, 48) gave insights into the development of GMOs in this class of the animal kingdom. Insect pests cause agricultural/horticultural losses and transmission of human diseases. Beech (48) suggested that GM insects for the control of insect pests in agriculture and human health will be available within the next five years. The strategy for their use is based on that of the well-established sterile insect technique (where insect pests are mass-reared and made sterile, usually through irradiation, and then released to mate with wild insect pests). She informed the conference that the company Oxitec had developed an approach which inserted genes that confer a dominant conditional lethality to insect pests so the progeny of matings with released GM insects do not survive to adulthood; that open field trials of GM *Aedes aegypti* (the mosquito that transmits dengue fever) had already been carried out in Grand Cayman, Malaysia and Brazil; and that GM strains had been

developed of five agricultural insect pests (diamondback moth, pink bollworm, Mediterranean fruit fly, Mexican fruit fly and olive fruit fly).

2.3 Public, private or PPP development of new GMOs

One of the questions that participants were asked to consider during the conference was whether the new GMOs they considered likely to be commercialized within the next five years in developing countries will be developed by the public sector, the private sector or through PPPs. Messages from participants indicated that all three pathways will contribute to the new GMOs, albeit to different degrees in different countries.

In Argentina, Gadaleta (72) said the some of the GM crops in the pipeline were developed by the private sector overseas and others through PPPs in Argentina. In Brazil, participants noted that the public sector organization EMBRAPA is playing an important role in development of GMOs, on its own, in collaboration with the private sector or with research institutions in other countries (May, 83; Choudhary, 94; Sampaio, 106).

In China, the role played by the public sector was emphasized (Tillie, 21), where it was reported that in 2008 the Chinese government launched a US$3.5 billion R&D initiative on GM plants (Choudhary, 94). In India, the table provided by Manjunath (68), as well as other messages (e.g. Kumar, 34; Karwa, 63), shows that all three sources are contributing actively to the GMO pipeline. According to Choudhary (94), over the last five years in India, about US$300 million per year was spent on development of GM crops by the public sector (Indian Council of Agricultural Research; Department of Biotechnology; Council of Scientific and Industrial Research; and state agricultural universities) and up to US$200 million per year by the private sector. In Iran, all the GM crops and GM goats in the pipeline are coming from the public sector (Ghareyazie, 79). In Pakistan, Zafar (62) thought that, apart from maize and hybrid cotton, the new GMOs will be produced by the public sector. Among the GM crops in the pipeline in six countries in Africa (Falck-Zepeda, 49), many are from PPPs and public-public partnerships.

While noting the large activity ongoing in the developing countries themselves, Shoham (56) argued that the bulk of R&D investment in GM crops comes from the leading seed companies (Monsanto, Syngenta, DuPont/Pioneer, Bayer, Dow and BASF), with an estimated combined annual investment of around US$1.5 billion. He described the new GMOs they were developing which might be released in developing countries in the next five years.

Glover (71), following up on his earlier message (22), asked whether large private sector companies like Monsanto were likely to release GM crops in the near future targeted to subsistence production systems in developing countries. In reply, Shoham (75) noted that major R&D based companies are bound to focus on the larger and more commercial crops in order to get the best returns and to address the financial obligations to their shareholders. He also suggested, however, that there was a trend for them increasingly to address the sort of targets Glover (71) described, because of advances in biotechnology (e.g. genomics); diversification of the crops which the private sector addresses; the increasing importance of corporate social responsibility; and the growth potential offered by developing countries. In a further reply, Nickson (81) said there was reason for optimism, noting the importance of government policies to provide an enabling environment. He cautioned, however, that even with the enabling environments “the fact is that the primary developer of new traits for developing country needs will probably remain the public sector”. Both replies (75, 81) provided examples of PPPs involving GM subsistence crops.

2.4 Implications of the new GMOs for developing countries

During the conference, participants mainly addressed the first of the two main questions, i.e. what new GMOs are likely to be commercialized, and there was much less emphasis on the second one, i.e. what are the likely implications of these new GMOs for developing countries, specifically in four areas:

food security and nutrition, socio-economic conditions, sustainable management of natural resources and adaptation to climate change.

Apart from GM Atlantic salmon (Section 2.2.1) and, particularly, Bt brinjal (Section 2.1.1), where divergent viewpoints were exchanged regarding their potential benefits and consequences if released, there were just a few messages about the potential implications of other new GMOs in the pipeline. For the specific GM crops they thought likely to be commercialized in India and Pakistan, Kumar (34) and Zafar (62) respectively envisaged that they would have positive implications in all four areas. Ghareyazie (79) thought that GM rice in Iran would save the farmer practices/money and would reduce the environmental footprint through decreased use of agrochemicals. For the GM crops in the pipeline in six African countries, Falck-Zepeda (49) argued that as many of them have an increased emphasis on food security and nutritional considerations, and some are expected to also raise incomes, the expectation is that their economic impact will be at least the same, if not better, compared with existing technologies.

Shoham (92) noted that it was difficult to address the socio-economic and environmental dimensions of the new GMOs as these depend very much on the country specifics and are intrinsically difficult to quantify. At a generic level, he argued that unless a new GM crop provides the farmer with economic benefit it is unlikely to be launched, so if successfully launched it is very likely that it will make a positive contribution to food security (and nutrition in the case of biofortification) and improve the socio-economic conditions in the country by improving farmer incomes. Similarly, he argued that any new crops which increased yields in an environmentally sustainable manner or which addressed environmental challenges (such as drought/heat/salt tolerance) will have environmental benefits and help with climate change adaptation respectively. Also at the generic level, Falck-Zepeda (49, 108) argued that analysis of the literature provided evidence for higher economic performance, albeit with quite heterogeneous impact, from adoption of GM crops in developed and developing countries and that if the new GM crops address binding constraints for crops and traits of interest to developing countries, there would be significant potential for capturing significant impacts that can benefit resource poor farmers and consumers in developing countries.

2.5 Other issues

During the conference, a number of other issues relevant to GMOs in the pipeline were also raised.

One concerned precisely how one would define a ‘GMO’ in the pipeline, where Murphy (66) suggested that crop varieties with new or improved traits were being developed by biotechnology companies using non-GM methods (such as mutagenesis, wide crossing or marker-assisted selection) and then crossed with older GM varieties so they can benefit from strengthened intellectual property rights because of the presence of the transgene. Thus, even though the new traits were developed by non-GM methods, the variety is considered a GMO. Similar blurring of the distinction between a GMO and non-GMO can arise from the use of a number of new techniques, such as cisgenesis, involving the transfer of a gene from a sexually compatible organism of the same or closely related species (Breyer, 5; Moderator’s comment, 66; Cummins, 69).

Another was the use of antibiotic resistant marker genes (ARMGs) in new GMOs. Breyer (2, 5) noted that the presence of ARMGs in GMOs was sometimes perceived to be an issue of concern and wondered whether they were being used for production of new GMOs in the pipeline in developing countries. In response, Gupta (3) argued that the issue and potential risks of using ARMGs for development of GMOs had been overblown. While supporting this position, Dubock (4, 11) noted that golden rice did not contain any ARMGs and argued “if they can be avoided then that's one less reason for emotional concern by some people”. Similarly, Ghareyazie (86) agreed with Gupta (3) but noted that it had recently been decided at his research institute in Iran that, to the extent possible, ARMGs should be avoided in developing new GMOs, because the issue is a concern for some people. Little additional information was provided on this topic during the conference, apart from the fact that some

of the GMOs in the pipeline in Iran, such as Bt rice and Bt cotton (Ghareyazie, 86), as well as the GM rubber tree in India (Muralidharan, 91) contain ARMGs.

Finally, although regulation of GMOs was purposely excluded as a discussion topic for this conference (because it is a major topic in its own right and because Conference 9 of the FAO Biotechnology Forum was previously dedicated to the issue [FAO, 2006]), some messages noted the key role that governmental regulation plays in determining whether or when specific GMOs may be commercialized in developing countries. For example, participants reported that in some countries, such as Ecuador (Erazo, 107) and Peru (Chávez, 17; Scotto, 20), there is a GMO moratorium while in others, such as Iran (Ghareyazie, 79), the Government is actively supporting GMO release. Shoham (56) noted that many developing countries have no regulatory framework for GMOs and argued that, if developed, this could contribute to uptake of GM crops in these countries. Manjunath (68) presented information on different GM crops that were approved for regulatory field evaluations in different years in India but concluded: "these are the products in pipeline, but considering the prevailing regulatory uncertainty in the country, it is difficult to forecast when these will be approved". In a similar vein, Parrott (95) wrote at the end of the e-mail conference: "Although several products have been mentioned as being in the pipeline and potentially available in the past 5 years, regulatory issues will prevent most from leaving the lab".

3. Participation in the conference

The conference ran from 5 November to 2 December 2012. It was open for anyone to join and there were 770 subscribers. Of these, 59 (i.e. 8%) submitted at least one message. Of the 18 conferences that have been hosted by the FAO Biotechnology Forum since 2000, it had the 2nd highest number of subscribers and the lowest percentage of people posting messages. In addition, almost none of the participants un-subscribed themselves once the conference began, so they received all of the 109 messages posted during the four-week conference. This indicates that a lot of people are interested in getting factual, neutral information about the status of GMOs and that most of the people who subscribed to the conference may have joined in order to 'listen and learn' about GMOs in the pipeline.

People posting messages were asked to introduce themselves in their first message and they typically provided their full work address and a description of their professional background and current occupation. Based on this, an analysis was carried out by country, geographical area and work. Note, the analysis is based on where people were living when they posted the message and does not indicate where they come from originally.

Of the 109 messages that were posted, 36% came from people living in Asia; 26% from Europe; 24% from North America; 10% from Latin America and the Caribbean; and 5% from Africa. A total of 55 messages (i.e. 50%) were posted by people living in developing countries.

The messages came from people living in 24 different countries. The greatest number were from people living in India (31 messages), followed by the United States (25); United Kingdom (eight); Belgium, Brazil, the Netherlands, Peru, Spain and Switzerland (four messages each); and Iran and Nigeria (three messages each).

Participants in the conference also came from a wide range of work environments. A total of 30% of messages came from people working in universities; 18% from participants from non-governmental organizations; 17% from people working in research centres; 12% from people working in the private sector; 11% from people working as independent consultants; 8% from people in Governments; and 2% in FAO.

4. References, abbreviations and acknowledgements

FAO, 2006. Regulating GMOs in developing and transition countries. Chapter 4 in "Results from the FAO Biotechnology Forum: Background and dialogue on selected issues". http://www.fao.org/docrep/009/a0744e/a0744e00.htm

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FAO, 2012. GMOs in the pipeline: Looking to the next five years in the crop, forestry, livestock, aquaculture and agro-industry sectors in developing countries. Background Document to Conference 18 of the FAO Biotechnology Forum (5 November to 2 December 2012). http://www.fao.org/docrep/016/ap109e/ap109e00.pdf (60 KB)

Abbreviations: ABDC-10 = FAO conference on 'Agricultural Biotechnologies in Developing Countries'; ARMGs = Antibiotic resistant marker genes; Bt = Bacillus thuringiensis; EMBRAPA = Brazilian Agricultural Research Corporation; FAO = UN Food and Agriculture Organization; GM = Genetically modified; GMOs = Genetically modified organisms; HT = herbicide tolerant; PPP = Public-private partnership; R&D = Research and development.

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