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COLLABORATIVE PROJECT

AMIGA
Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

D8.1 Review of Integrated Pest Management options for GM crop traits in Europe

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PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
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Summary

A range of currently available and close-to-the-market GM crops were examined for their potential contribution to biological control and integrated pest management. Most GM crops and their new traits have the potential to improve crop production especially under heavy pest, disease and weed pressure. In particular insecticidal and virus-resistant crops can help to keep pests and diseases in check, to lower the chemical pesticide load in the environment, and to support complementary IPM tactics such as the active use of biocontrol agents, and increased reliance on natural control. The agroecological benefits of herbicide-tolerant crops remain more controversial, as no clear decrease of pesticide inputs can be demonstrated. Intensified simplification of the agroecosystem hampers ecosystem services such as biocontrol and pollination. The theoretical benefits to IPM of pest and disease resistant GM-crops seldom seem to be realized in a sustainable way in reality: GM-crops usually are seen by the growers as a stand-alone technology without any real attempt to integrate them as a component in integrated pest management. This leads to short-term, unsustainable agroecological benefits, and eventual loss of these benefits as has been observed in parts of the USA by the return of the growers to conventional maize varieties. Similarly, mechanical weeding is increasingly needed in HT-GM cotton. Thus, the "reality gap" appears to erode the contribution of GM-crops to IPM, and results in the wastage of rare opportunities to increase the sustainability of our food production by short-sighted production strategies.

Introduction

The promise of GM crops has been to provide (i) more efficient pest, disease and weed control, (ii) lower use of pesticides, (iii) improved biological control, and (iv) improved possibility for integrated pest management.

GM crops have been taken up by growers at a phenomenal rate, with about 70-80% of global plantings in some main crops (soya, cotton) being GM (James, 2014). Theoretically, most GM crops and their new traits have the potential to significantly improve crop production especially under heavy pest, disease and weed pressure. In particular insecticidal and virus-resistant crops can help to keep pests and diseases in check, to lower the chemical pesticide load in the environment, and support complementary integrated pest management tactics such as increased reliance on natural control. It should be noted, however, that GM crops available for commercial use do not increase the yield potential of a variety, but rather, under low pest pressure yields may even decrease.

The big picture of the reality is slightly different: Herbicide-resistant crop technology has led to a 239 million kilogram increase in herbicide use in the United States between 1996 and 2011, while Bt crops have reduced insecticide applications by 56 million kilograms (Benbrook, 2012). Overall, pesticide use in the first 15 years of commercial use increased by an estimated 183 million kg, or about 7%.

GM crops and biological control

Two major traits have been commercialized so far: insect resistance and herbicide tolerance. A number of reviews (e.g., Lundgren et al., 2009) have shown that insect resistance in GM crops (i) reduces dramatically pesticide inputs, (ii) improves biological control of other pests (iii) conserves pollination services, and (iv) improves crop productivity under high target pest pressure. On the other hand, herbicide tolerance (i) increases usually pesticide inputs (herbicides), (ii) interferes with biocontrol and pollination by removing nectar and pollen resources, but (iii) improves crop productivity under high weed pressure.

Pathways through which natural enemies may be affected by GM crops (Lundgren et al. 2009) include (i) toxicity-based pathways such as toxicity of non-prey foods from GM crops, and toxin-containing prey on GM crops; (ii) GM crop-induced changes to the crop environment, such as unintended alterations to the crop plant, GM-induced reductions in prey quality and density, and changed plant communities associated with herbicide-tolerant crops; (iii) conservation tillage and its implications (usually positive) on biological control, (iv) prey-mediated effects of insect-resistant crops (including impacts on predators, parasitoids and entomopathogens), (v) toxicology of herbicides associated with GM crops, affecting arthropod natural enemies and entomopathogens. Further issues include resistance management in insect-resistant crops, biological control of non-target pests, and biological control and habitat management in herbicide-tolerant crops.

Reality Gap in IPM

In reality, also the theoretical benefits of pest and disease resistant GM-crops seldom seem to be realized in a sustainable way, because GM-crops are seen by the growers as a stand-alone technology for pest and disease control, without any real attempt to integrate it as a component in integrated pest management. This leads to short-term, unsustainable pest control benefits, and eventual loss of the benefits as has been observed already in parts of the USA by the return of the growers to conventional maize varieties.

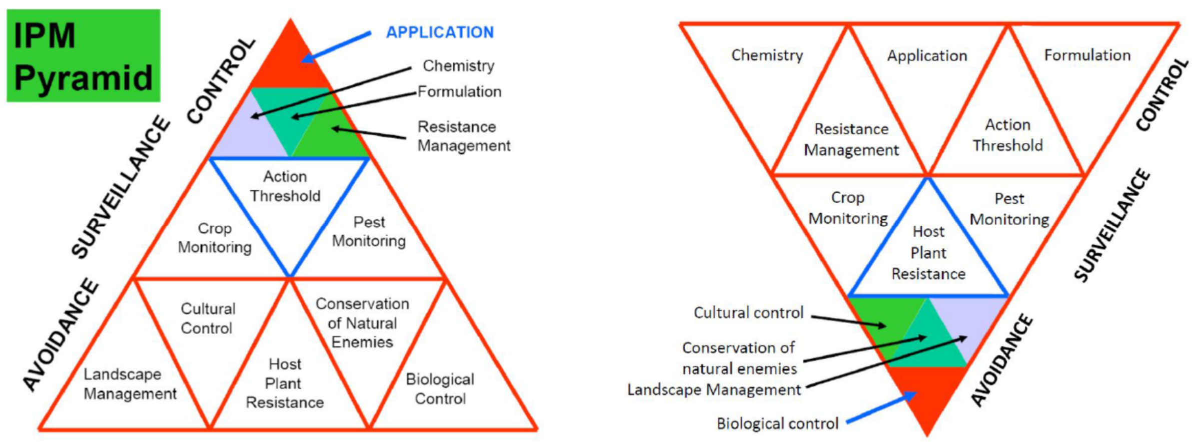

Figure 1. The "reality gap" in pest management: Ideal IPM as promoted for > 50 years (left), and current reality in mainstream pest management (right).

This can be illustrated by considering the reality between the traditional “IPM pyramid”, and the actual situation in mainstream pest management (see Figure 1): ideally, pest management is based to a large extent on avoidance, and the use of chemical pesticides is just a small tip of the pyramid. In reality the pyramid is upside down, where most of the actual pest management is done by the use of chemical pesticides. It becomes obvious that this method of pest management cannot be stable and sustainable. When GM crops are seen by growers equally as a stand-alone pest management tool, its fate will be the same as that of chemical pesticides: unstable and unsustainable.

There are severe signs already that this is happening. For example, herbicide resistant weeds arise at an accelerating rate, and it is a paradox that in herbicide tolerant cotton growers have to resort to hand weeding: *Amaranthus palmeri* needs to be hand weeded in HT cotton in the USA. Hand weeding in HT cotton was in 2000-2005 was practised by 17% of growers on a total of 5% cotton acres in the USA at the cost of $2.40/A, while in 2006-2010already 92% of growers hand-weeded 52% cotton acres, at the cost of $23.70/A (Culpeper, 2015). Similarly, Tabashnik et al. (2013) have shown how the first reports of field evolved resistance in Lepidoptera to Bt-crops appeared ten years after commercial cultivation of these crops, and more species have been added to that list annually, so that in 2011 at least six different species had reduced sensitivity to Bt corps around the world.

GM crops within an IPM system

GM crops are currently grown over 180 million ha, on all continents - but where is the IPM? It is possibly illustrative that at the recent conference, the 8th International IPM Symposium [IPM: Solutions for a Changing World] March 23–26, 2015 in Salt Lake City, Utah, USA. only two out of 47 separate Symposia dealt specifically with GM crops. These focussed solely on the problematics of herbicide tolerant weeds, and actually did not put them in IPM context, either. Therefore, in the USA and internationally, GM crops do not seem to be an issue in the discussions on IPM, nor are the crops put into IPM context even at scientific conferences:

As a first step in that direction, we propose to analyse the possible contributions of GM crops and their traits to IPM relevant functions in a comprehensive manner, such as outlined in Table 1. Here we provide a first estimate of the potential, or usefulness of all currently available traits (and near-market traits), to support biological control practises, to allow better use of cultural control methods (e.g., changes in soil management made possible by HT crops and possibly benefiting overwintering parasitoids and entomopathogens in the soil; Hokkanen et al. 1988), to improve possibilities for resistance management, to reduce pesticide use, and to allow better land use management to support vital ecosystem functions such as biocontrol and pollination.

Table 1. Overview of current GM-traits available, and their potential to contribute to IPM relevant functions in the agroecosystem.

Traits available, or close to market	Potential contributions to IPM-relevant functions (direct and indirect)				
	Biological control	Cultural control methods	Resistance management	Reduction in pesticide use	Land use and management
Insect resistance					
Single Lep	++/+	+	-	++	-
Single Col	+	+	-	+	-
Stacked CC/LC	++/+	+	0/-	++	-
Bt	++/+	+	-	++	-
RNAi	+++	+	++	++	?
Herbicide tolerance					
Glyphosate	+/0/-	+	--	--	+/-
Glufosinate	+/0/-	+	--	--	+/-
Stacked	+/0/-	+	0/-	--	+/-
Disease resistance					
Fungal	+	+	+/0	++	0
Viral	0/+	+	+	+	0
Nematode	0/+	+	?	+	0
Stacked traits					
IR+HT	+/-	+	-	0	-
IR+HT+DR	+/-	+	-	0/+	-
IR+HT+DR+NR	+/-	+	-	0/+	-

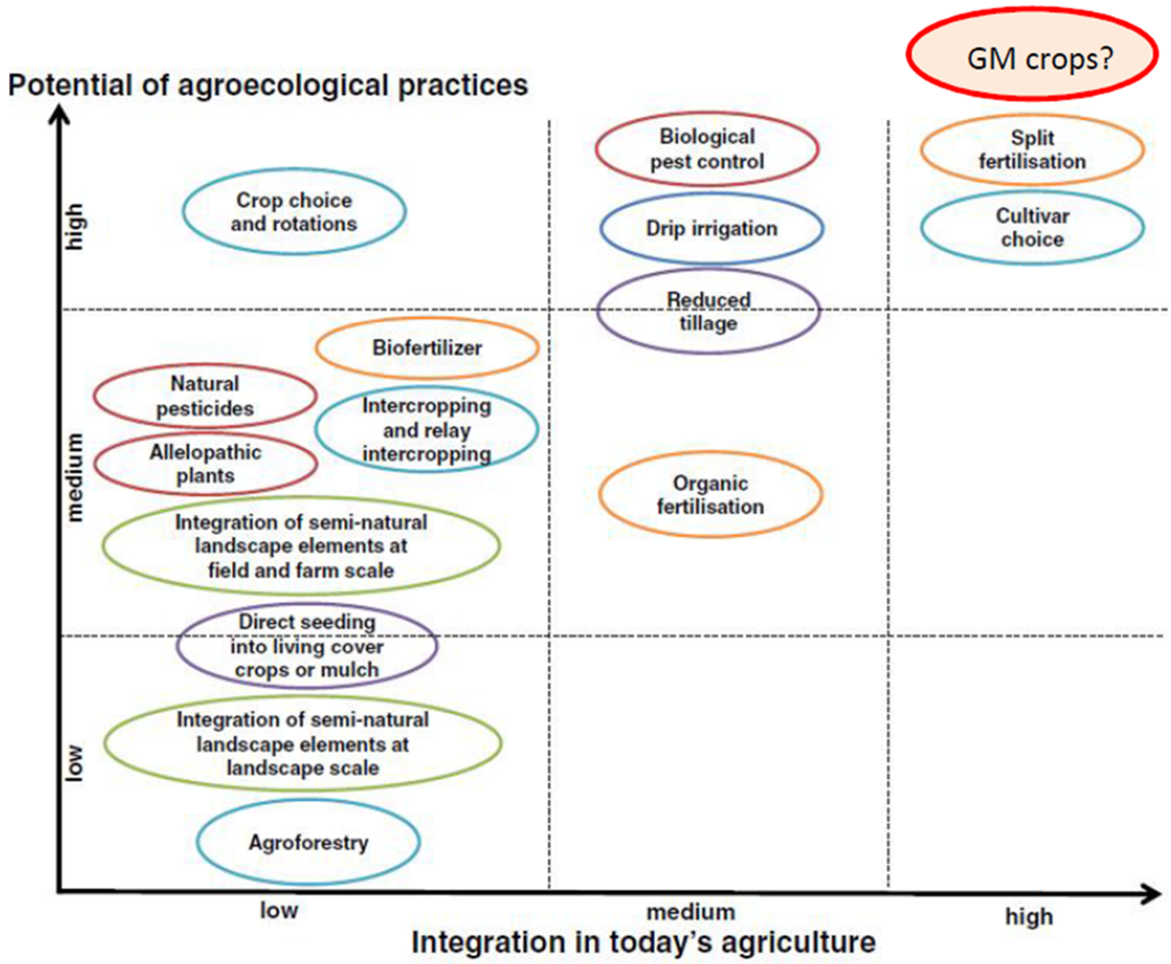

Figure 2. Potential contribution of GM crops to improve agroecological practices, in relation to several other cropping techniques (after Wezel et al. 2013)

Finally, we estimate the potential contribution of GM crops to improve agroecological practices, in relation to several other cropping techniques (Figure 2). GM crops have been extremely rapidly integrated in today's agriculture (where allowed), and they have a high potential to benefit the ecological processes in agricultural ecosystems. Unfortunately, due to the "Reality Gap" (see Figure 1), this opportunity does not seem to be seized, and we remain pessimistic that these potentially valuable techniques actually will be used for the benefit of biological control, nor for becoming integrated in modern IPM systems.

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