Impacts of Genetically Modified Herbicide-Resistant Plants on Biodiversity

1

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Preamble

The key messages below highlight relevant issues regarding environmental impacts of cultivation of herbicide-resistant[1] (HR) genetically modified (GM) plants, in order to ensure adequate protection of the environment in the future.

The signatories of the present position paper recommend to implement the following messages into measures with the intention of improving the scope of the current environmental risk assessment (ERA) of HR GM plants.

This position paper does not present a systematic scientific assessment of HR GM crops. It is based on the technical report[2] published by the German Federal Agency for Nature Conservation BfN, the Austrian Environment Agency EAA, and the Swiss federal Agency for the Environment FOEN.

Key Messages of this Position Paper

Cultivation of HR GM crops together with complementary use of broad-spectrum herbicides has significant impacts on crop management strategies and agricultural practices. Insightful studies revealed that the combined use of HR GM crops and the complementary herbicide, also known as HR technology, comprises risks, which should be taken into account during decision making and authorization of HR GM crops. The current approach to ERA and risk management of HR GM crops largely underestimates the direct and indirect effects of the use of HR GM crops and related herbicides. Moreover, the ERA performed during authorization of herbicide products does neither include studies of impacts on biodiversity (using realistic scenarios of cultivation and herbicide regimes).

Failure to adequately assess environmental effects of combined use of HR GM crops and broad-spectrum herbicides can result in a serious underestimation of their effects on biodiversity.

Cultivation of HR GM crops increases pressure on biodiversity[3].

While issues related to conservation of biodiversity are a priority on the agenda of international agreements since 1992, the loss of biodiversity still goes on at a very high rate. Farmland biodiversity is an important element of total biodiversity and an important characteristic when assessing sustainability of agricultural practices. It has been shown that continuous intensive farming is a key driver for the loss of farmland biodiversity. HR technology further intensifies farming[4] and increases consequently the pressure on biodiversity.

Cultivation of HR GM crops has significant impacts on flora and fauna[5].

There is ample evidence that – compared to conventional farming – weeds are suppressed to a higher level in HR cropping systems (*i.e.* the genetically modified crop and its complementary herbicide) during the first years of their application.
This leads to a further reduction of fauna and flora biodiversity within farmland. The low weed density and diversity negatively impact a range of animals feeding on weeds and the respective predators of such animals.

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[1] The terms "herbicide resistance" is used as defined by the Weed Science Society of America (WSSA 1998)

[2] Tappeser B., Reichenbecher W., Teichmann H. (2014). Agronomic and environmental aspects of the cultivation of genetically modified herbicide-resistant plants. A BfN-FOEN-EAA-Joint paper. BfN-Skripten 362, http://www.bfn.de/fileadmin/MDB/documents/service/skript362.pdf

[3] Foley *et al*. (2011)

[4] Firbank *et al.* (2003)

[5] Brooks *et al*. (2003); Bohan *et al*. (2005)

The adoption of HR GM crops leads to the use of more herbicides[6].

HR GM crops facilitate the wider use of broad-spectrum herbicides such as glyphosate and glufosinate for weed control. HR technology allows the post-emergence application of broad-spectrum herbicides on important staple crops. Based on data from the United States Department of Agriculture (USDA), eight years after the introduction of HR GM crops, more herbicides were applied to HR GM crops than to conventional crops[6].

HR GM crops lead to a steady increase in herbicide-resistant weed species and further results in significant changes of arable weed populations[7].

To prevent the development of resistant weeds, scientists have recommended an integrated weed management approach. However, farmers often simply resort to higher herbicide doses or to the use of herbicide mixtures, thereby selecting for increasingly resistant weeds. In return, companies develop GM crops with stacked herbicide-resistance genes, conferring resistance to additional herbicides products. However, weeds resistant to these have already evolved and infested millions of hectares. Further, HR GM crops facilitate the operation of reduced-tillage/no-tillage agricultural management systems. Long-term experience with reduced tillage indicates that weed populations shift to perennial and grass species, while the abundance of broad leaf plants decreases constantly. Additionally, due to the repeated and increased application of broad-spectrum herbicides for weed control, the more robust species establish and spread, whereas the more sensitive disappear, thus reducing in-field biodiversity even further.

HR traits can spread spatially and temporarily[8].

Crops with characteristics such as shattering and seed persistence, *e.g.* oilseed rape, are very likely to emerge as volunteers. Seed spill can also occur outside the fields along transport routes leading to HR feral plants and resistant volunteers on fields without previous HR GM crop cultivation. Gene flow to wild relatives should be particularly taken into account in the ERA, especially for regions where interfertile and weedy hybrids occur.

The signatories are concerned that the overall effects on the environment due to the use of HR GM crops and the associated herbicides are not fully taken into account. This position paper highlights the responsibility of authorities to critically evaluate the ERA submitted by the applicants in the request for a marketing authorization for HR GM crops cultivation and to address any shortcomings of the submitted ERA. The scientific findings referred to in this position paper should be taken into consideration in addressing the negative impacts on biodiversity in depth. Implementation of the key messages of this positon paper assists in informed and robust decision making, with special emphasis on maintaining farmland biodiversity.

[6] Benbrook (2009); Benbrook (2012)
[7] Egan *et al.* (2011); Reddy & Northworthy (2010)
[8] Knispel *et al.* (2008) ; Schafer *et al.* (2011)

Introduction

Conservation of biodiversity is high on the agenda of international and national environmental policies. The need to protect and stop the loss of biodiversity was acknowledged in the Convention on Biological Diversity (CBD), internationally agreed in 1992, and underscored by relevant further decisions. Furthermore, it is common knowledge that intensive high input farming is one of the main drivers behind the ongoing loss of biodiversity in agricultural landscapes[9]. Indicators for such losses of farmland biodiversity are the level of diversity and abundance of weed flora. Two types of GM crops, resistant to broad-spectrum herbicides have been cultivated commercially since mid-1990s. Since then, a wealth of information has been collected on the way of using and impacts of these HR[10] crops on the environment. This position paper emphasizes the lessons learned from the current experience.

There are great concerns that HR GM crops together with the use of complementary herbicides lead to further intensification of farming and therefore to an increasing pressure on biodiversity[11].

The need to study potential environmental consequences of changes in herbicide use due to HR GM plants has been underlined by the Council (of Environment Ministers) of the European Union (EU)[12].

In 2014, a trilateral literature study that focused on this topic, titled "*Agronomic and environmental aspects of the cultivation of genetically modified herbicide-resistant plants*", was published by the National Environment Agencies in Austria and Switzerland and the Federal Agency for Nature Conservation in Germany. This study[13] highlights relevant findings of cultivation of HR GM crops.

The study was intensively discussed at the annual meetings of the EPA-ENCA interest group on environmental risk assessment and monitoring of GMOs (IG on GMOs). The study together with discussions forms the basis of this position paper. The IG on GMOs was founded in 2008 to strengthen the exchange between environmental experts in this field. It is set up by the Environmental Protection Agencies (EPA) and the European Nature Conservation Agencies (ENCA) (for details see chapter "Regulatory Background"). Some of the group members are directly responsible for the evaluation of the ERA and the post market environmental monitoring (PMEM) plans submitted by the applicants.

The IG on GMOs is concerned because in the ERA too little emphasis is given to eco-toxicological effects on non-target species caused by combined use of HR GM crops and the respective herbicides. With this position paper, the IG on GMOs endeavours to identify critical issues for the ERA of HR GM plants within the GMO legal framework.

The IG on GMOs considers it important to share and spread this position paper among authorities who are responsible for the evaluation of ERA and PMEM plans and/or risk management strategies.

[9] Firbank. *et al.* (2008); Robinson & Sutherland (2002)
[10] Also referred to herbicide tolerant in other context (Weed Science Society of America, WSSA 1998)
[11] Firbank *et al.* (2003)
[12] Council of the European Union (2008)
[13] Tappeser B., Reichenbecher W., Teichmann H. (2014). Agronomic and environmental aspects of the cultivation of genetically modified herbicide-resistant plants. A BfN-FOEN-EAA-Joint paper. BfN-Skripten 362, http://www.bfn.de/fileadmin/MDB/documents/service/skript362.pdf

Regulatory Background

In the European Union, the deliberate release of GMOs is regulated by Directive 2001/18/EC, now amended by the Directive (EU) 2015/412[14] and Regulation (EC) No 1829/2003. Within the authorization process, the applicant has to conduct a detailed ERA. Objectives, principles and methodology of the ERA are further outlined in Commission Decision 2002/623/EC[15]. The scope of the ERA is broad – evaluation of direct or indirect, immediate or delayed risks to human health and the environment, as well as the principle of cumulative long-term effects. The ERA has to be conducted in a scientifically sound and transparent manner, and on a case-by-case basis, depending on the GMP species, the concerned trait(s), their intended use(s) and the characteristics of the receiving environment(s), following a stepwise approach. The steps in the ERA usually include hazard, exposure and risk characterization (risk scenarios), and, when applicable, the hazards following changes in agricultural management.

One of the main areas which should be addressed in the ERA of the cultivation of HR GM crops is the environmental impact of changes in cultivation practices, including the herbicide use.

With the aim of reducing risks to public health and to the environment, the EU established a community framework (Directive 2009/128/EC) for the sustainable use of pesticides which are authorized under the plant protection regulation (Regulation (EC) No 1107/2009). According to this Directive, the EU Member States should develop comprehensive and operational national action plans to reduce risks of pesticide use. Moreover, they may provisionally limit or ban the use or/and placing on the market of a product on their territories in the case of specific and documented risks to human or animal health as well as to the environment.

According to this framework, the ERA of pesticides includes an assessment of impacts on non-target organisms and studies of residual activities in soil and water. But it does not currently include studies of impacts on biodiversity or changes in agricultural management practices. Regarding HR GM crops, the two most common plant protection products used in their cultivation are glyphosate and glufosinate. Glufosinate, due to its reproductive toxicity, is expected to be phased out in the EU in 2017[16], while glyphosate, authorized in 2002, is now under evaluation, and the decision about renewal of authorization is being postponed until at least the end of 2015.

[14] Directive (EU) 2015/412 amending Directive 2001/18/EC as regards the possibility for the Member States to restrict or prohibit the cultivation of genetically modified organisms (GMOs)

[15] Commission Decision of 24 July 2002 establishing guidance notes supplementing Annex II to Directive 2001/18/EC

[16] See Annex I of Commission Implementing Regulation (EU) No 540/2011 as regards the list of approved active substances

Scale of HR GM Crop Cultivation[17]

Resistance to glyphosate and glufosinate allows previously sensitive crops to survive repetitive applications of the herbicide. Until now, many GM glyphosate- and glufosinate-resistant crop species have been globally tested in field experiments. Increasingly (28 % of total acreage), companies develop and sell GM crops with stacked HR traits, which combine glyphosate-resistance with resistance to glufosinate and/or resistance to other herbicides such as 2,4-D, dicamba or ALS[18] inhibitors.

The widely and commercially grown varieties belong to a restricted number of crop species: maize, cotton, canola and soybean. In 2014, GM crops have been grown in 28 countries on more than 181 million hectares (average annual growth rate of 3-4 %).

HR GM crops are by far the most widely planted GM crops and mostly cultivated within North and South America. Out of the 181 million hectares of GM acreage worldwide, about 59 % (100.4 mil. ha) were planted with HR varieties and 15.4 % (26.3 mil. ha) were planted with Bt (*Bacillus thuringiensis*) varieties. A still increasing amount, 25.6 % (43.6 mil. ha) of crops with stacked traits (mainly HR/insect resistance stacks) has been planted. Hence in 2012, 84.6 % of the GM crops carried herbicide-resistance traits.

Direct Impacts of Glyphosate and Glufosinate[19, 20]

The cultivation of HR GM crops has the potential to affect farmland wildlife through the associated use of broad-spectrum herbicides and related management practices. These broad-spectrum herbicides have long been perceived as less hazardous than other herbicides. However, present data indicate that glyphosate- and glufosinate-based herbicides, apart from being toxic to plants, can be also toxic to other life forms. Glyphosate-based herbicides play a significant role in human cell toxicity, acting as endocrine disruptors.

Glyphosate has recently been classified by the International Agency for Research on Cancer (IARC) as a Group 2A carcinogen: glyphosate and insecticides malathion and diazinon were classified as probably carcinogenic to humans[21]. The evidence in humans comes from exposure studies, mostly agricultural, in the USA, Canada, and Sweden, published since 2001. It remains to be seen how the IARC classification of glyphosate will be considered in its reassessment for the renewal of authorization in 2015.

When cultivating HR GM crops, the use of the complementary herbicide further increases the pressure on flora and fauna[22, 23].

Glyphosate-based herbicides have shown to be highly toxic to amphibians and a range of aquatic organisms while glufosinate shows a high reproductive toxicity to mammals. Studies[24] show that the combined effect of the surfactants (used in glyphosate formulations) and the active ingredient significantly increase the

[17] Brief 49: Global Status of Commercialized Biotech/GM Crops (2014) http://www.isaaa.org/resources/publications/briefs/49/
[18] ALS = acetolactate-synthase
[19] Wauchope *et al.* (2002)
[20] Seralini *et al.* (2014); Wagner *et al.* (2013)
[21] World Health Organization WHO: IARC Monographs Volume 112
[22] Buckelew *et al.* (2000); Cakmak *et al.* (2009); Heard *et al.* (2003a), (2003b); Johal & Huber (2009); Kremer & Means (2009)
[23] http://www.biologicaldiversity.org/news/press_releases/2015/pesticides-06-23-2015.html
[24] See for references in Cox & Surgan (2006)

toxicity of glyphosate-based products, in particular for aquatic organisms.

Glufosinate- and glyphosate-based herbicides are reported to lead to shifts in the composition and activity of the soil microflora suggesting that the HR GM cropping systems can affect soil life and health. Also, glyphosate-based herbicides are reported to adversely affect micronutrient uptake of plants and the severity of plant diseases[25]. Glyphosate not only inhibits EPSPS, the key enzyme of the shikimate pathway in plants for the synthesis of aromatic amino acids, and the derived secondary plant compounds. It is also a strong systemic metal chelator and impedes the availability and uptake of micronutrients thereby affecting plant disease resistance and plant growth.

Because of the collected evidence for toxic effects of glyphosate-based herbicides on several life forms within the last years, the signatories of the position paper welcome the US EPA's intention to evaluate the impact of glyphosate on 1500 endangered plants and animals in the USA within the next five years. The last assessment was done in 1993, when less than 5 % of today's amount of glyphosate was applied in the USA.

Current data on long-term (eco-) toxicological profiles and long-term impact assessments of currently used broad-spectrum herbicides show that their impact is more harmful on biodiversity than earlier assumed[26].

Glyphosate and glufosinate use is not unique to herbicide-resistant HR GM cropping systems. But compared to other cropping systems the given herbicides may be used at other application rates, dosages and/or crop life stages. However, not only direct impacts of the applied herbicides, but the overall effects of the herbicide management systems have to be taken into consideration when assessing the impact of HR technology on biodiversity.

Impacts of HR GM Crops on Agriculture and Practices

Like any significant change in crop choice, switching to HR GM crops can have various impacts on agricultural practices and agronomy[27]. Examples include weed control, soil tillage, planting, crop rotation, yield, and net income. An important matter regarding the cultivation of HR GM crops is facilitated weed control. Namely, the extension of the time window for spraying that allows post-emergence application of herbicides instead of the routine pre-emergence application in conventional crops. In addition to the application of glyphosate as a drying or ripening agent, cultivation of HR GM crops allows further changes in its use (agricultural practices).

The long-term cultivation of HR GM crops leads to increased use of herbicides[28].

There is an agreement in the literature that with the introduction of HR GM crops in the US, lower amounts of herbicides (as active ingredient per hectare) were applied during the first years (from 1996 onwards), compared to conventional crops. It is crucial to note that based on the USDA statistics, the trend turned in 2000. Already by 2004, a substantial increase in the number and volume of herbicides used in HR GM crops was reported in comparison to conventional crops. In the following years, the difference increased progressively and led to an estimated amount of 239 million kg of additional herbicides for the period of 1996-2011. It is

[25] Eker *et al.* (2006); Tesfamariam *et al.* (2009); Cakmak *et al*. (2009)
[26] Heard *et al.* (2003a); Heard *et al.* (2003b); Séralini *et al.* (2014)
[27] Prince *et al.* (2012)
[28] Powles (2008); Benbrook (2012)

noteworthy that HR soybean accounts for two thirds of the total increase. In Argentina glyphosate use increased significantly in line with the tendency to cultivate greater surfaces with glyphosate-resistant soybean.

Moreover, mechanical weed control decreased with the introduction of HR varieties. The reason for this is that HR GM crops are well adapted to tillage systems without or with reduced mechanical weed control.

Parallel to the adoption of HR GM crops a trend to monoculture and an increase of HR volunteers is observed[29, 30]**.**

In addition, in regions where HR GM crops are widely adopted, less crop rotation and crop diversification takes place, following a clear trend towards monoculture of HR GM crops. Unfortunately, this trend enhances disease and pest pressure although, in theory, high weed control levels in HR GM cropping systems would allow to include crops with higher weed infestation and to broaden crop rotation.

However, crop rotations in HR systems may have changed due to volunteer problems. Mostly, HR volunteers are plants from previous year's plantings. They survive pre-seeding herbicides preparing the field for the next planting and cause undesirable effects especially in less competitive crops. In consequence, this requires the application of additional herbicides. In particular, crops with characteristics such as shattering and seed persistence, *e.g.* oilseed rape, are likely to emerge as volunteers. Seed spill can also occur outside the fields and along transport routes potentially leading to HR feral plants. Oilseed rape volunteers with resistance to glyphosate and glufosinate have already been detected in fields where HR GM crops have not been planted previously. Oilseed rape plants with multiple herbicide-resistance genes, not commercially sold, have also been found, providing evidence of novel transgene combinations in the wild. The transfer of HR genes to wild relatives should be taken into account and avoided in centres of crop origin and regions where interfertile weedy hybrids and wild relatives occur as well as in high value ecosystems and protected areas.

Changes in Weed Susceptibility

The increased dependence on herbicides for weed control in HR GM crop cultivation leads to a shift in weed species composition. Less sensitive species and populations survive sprayings and subsequently grow and spread, whereas species that are more sensitive disappear.

Although glyphosate was not considered to be a high-risk herbicide with regard to resistance development, at least 31 glyphosate-resistant weed species, comprising more than 242 populations, have been found. Today, they infest millions of hectares of HR GM crops and conventional crops. Some of the resistant weed biotypes are cross-resistant to other herbicides. Glyphosate-resistant weeds can withstand up to 19-fold dose compared to sensitive weeds and exhibit a great diversity of genetic resistance mechanisms. So far, only two weed species resistant to glufosinate have been described.

HR GM crops lead to a steady increase in herbicide-resistant weed species which can cause significant changes in arable weed populations[31]**.**

Weed scientists have recommended for years that farmers should implement an integrated weed management approach.

[29] Belde *et al.* (2000)
[30] Schoenenberger & D'Andrea (2012); Knispel & McLachlan (2009); Knispel *et al.* (2008); Mallory-Smith & Zapiola (2008); Schafer *et al.* (2011)
[31] Heap (2015)

This approach would comprise a combination of a number of weed management methods ranging from crop rotation, herbicide rotation and mechanical weeding to cover crops, intercropping and mulching. Continuous glyphosate-resistant cropping has become common in North and South America. Unfortunately, farmers often simply resort to higher herbicide doses and additional herbicides. Obviously, these high doses or mixture of herbicides have a high impact on the environment. Furthermore, companies increasingly develop and sell GM crops with stacked HR traits, which combine glyphosate-resistance with resistance to glufosinate and/or resistance to other herbicides. However, a number of weeds are already hard to control because they are resistant to synthetic auxins and even more to ALS-inhibitors. In addition, merely rotating herbicides may exacerbate resistance problems by selecting for more general resistance mechanisms in weeds. Finally, combination effects occur when various substances act together in a different way than what they individually do. Additive and synergistic effects are one of the areas upon which further research would be needed.

Effects of Agricultural Intensification and HR GM Crops on Biodiversity

Farmland biodiversity is a highly important factor when assessing sustainability of agricultural practices. The previously highlighted impacts of agricultural practice of HR GM crops have effects on biodiversity.

Biodiversity is negatively affected by the cultivation of HR GM crops[32].

Glyphosate and glufosinate are broad-spectrum herbicides and therefore affect more weed species than other currently used herbicides. Weed suppression is clearly intensified in most crops and regions where HR GM crops are planted, because less effective herbicides and sometimes mechanical weeding have been replaced by these two herbicides. The effects of the HR GM cropping systems on species abundance and diversity were investigated in different studies, namely the Farm Scale Evaluations (FSEs). Differences were found in weed flora and fauna between different weed management regimes. Likewise, studies showed that the diversity, density and biomass of the seed bank in farmland are clearly lower in HR systems compared to conventional management systems.

High pressure of herbicides on non-target organisms in agricultural areas intensifies farmland biodiversity loss[33].

Field margins often harbour rare plant species. Therefore, drift of non-selective herbicides to field margins is a concern to nature conservation and biodiversity of many agricultural areas. The impact of non-selective herbicides on the flora and on the associated fauna is of particular significance. It has been shown that the cover of field margins, the flowering of the plants and the seeding are reduced up to half in HR spring oilseed rape relative to conventional oilseed rape.

Spray drift can also damage hedgerows and trees growing close to arable fields. The indirect effects of such plant suppression and habitat destruction have a major role in invertebrate (and vertebrate) biodiversity. In consequence, animals feeding on weeds and on predators of these animals are endangered. Therefore, the equilibrium of the predator-prey systems becomes even more crucial as well as the impact on beneficial organisms.

[32] Bohan *et al.* (2005); Buckelew *et al.* (2000); Heard *et al.* (2003a); Roy *et al.* (2003)
[33] Brower *et al.* (2012); Schmitz *et al.* (2013); Srandberg *et al.* (2012); Jasinski *et al.* (2004); Roy *et al.* (2003)

Studies in the US found less canopy arthropods and significantly less spiders and green lacewings in HR soybean than in conventional soybean.

A prominent example of indirect effects of HR cultivation is the reduction in the abundance of the monarch butterfly and its host plant. Recent data from the US and Mexico indicate that the size and geographical distribution of the overwintering population of the migratory monarch butterfly[34] has significantly declined within the last decade. This has been linked to three factors, among them the loss of milkweed[35], the feeding host plant of monarch larvae due to the expansion of HR GM crops in the US.

The importance of correct timing of herbicide application was shown to have an impact on biodiversity.

Weed diversity and density were extremely low when glyphosate was applied earlier than recommended. This shows that not only the intensification in agricultural practice and agronomy but also the way herbicides are applied endanger farmland biodiversity.

Conclusion

There is ample scientific evidence that HR GM cropping systems – compared to conventional farming – lead to an increase in herbicide use and to changes in weed management practices. Weed control in HR GM cropping systems is very effective, but has negative consequences on weed diversity and density which further negatively impacts a range of animals feeding on weeds and their respective predators. Due to commercial cultivation HR traits can spread spatially and temporarily, and in certain important crops like oilseed rape result in gene flow to wild relatives.

HR GM crop farming contributes to agricultural intensification, which further reduces farmland biodiversity. This increases the overall pressure on biodiversity. Following the adoption of HR GM cropping systems, less alternative weed control measures are used, enhancing diseases and pest pressure.

Recent scientific evidence shows that the use of broad-spectrum herbicides has direct negative effects (eco-toxicological effects) on several life forms. To reduce the negative effects of HR GM cropping systems on biodiversity, it is essential to take into account the documented evidence regarding direct and indirect negative effects and integrate them in the ERA.

The available scientific evidence regarding negative impacts of HR GM crop cultivation on biodiversity should be acknowledged and addressed within the ERA for HR GM plants under the GMO regulation framework.

This position paper highlights scientific evidence regarding the adverse effects of the combined use of HR GM crops and the complementary herbicides. The messages of this position paper should help competent authorities to critically evaluate the ERA, risk management and PMEM of HR GM crops under the current regulation.

The signatories plead for improving the ERA on a case-by-case principle as allowed within the GMO legal framework while – under the pesticide regulation – the assessment of effects on biodiversity may be restricted to an assessment of direct effects of the herbicide. Thus indirect effects due to changes in herbicide use patterns may be neglected.

[34] *Danaus plexippus*

[35] *Asclepias syriaca*

The key messages of this position paper underline that further efforts are necessary to fully implement the requirement of the EU legal framework on GMOs as well as the internationally agreed policy goals to stop the loss of biodiversity on farmland.

As the scientific knowledge for the assessment of environmental impacts of HR GM crops is still limited, the signatories urge to conduct further targeted research on long-term, additive and synergistic effects of using complementary herbicides together with cultivation of HR GM crops and related weed management practice.

Agricultural intensification and pesticide use are among the main drivers of biodiversity loss. According to the above mentioned information and the present experience in countries adopting HR GM crops, where herbicide use was increased instead of reduced, it is clear that HR GM cropping systems need to be re-evaluated with respect to their sustainability, in order to prevent further adverse impacts on biodiversity in general.

Activities of the EPA ENCA Interest Group on GMOs

Most members of the IG GMO within the EPA- and ENCA networks are involved in the evaluation process of GMOs in the EU and other European countries. Hence, the group consists of agencies responsible for the authorization of GMO releases as well as public institutions that provide scientific support to national administrations in this process. In addition, several IG GMO members are involved in the development of concepts for the risk assessment and the environmental monitoring of GMOs and participate in ongoing research projects at the national and EU level. Because of their responsibilities in environmental protection and nature conservation, the author institutions of this position paper are also involved in various other topics on risk assessment and environmental monitoring. A number of these topics are addressed through joint activities in the working groups of the EPA and ENCA networks.

Such joint activities include the exchange of knowledge and experience between member institutions, the harmonization of existing or newly developed approaches in risk assessment and environmental monitoring, or collaborations to identify key problems and opportunities associated with risk assessment and environmental monitoring.

The author institutions support the current efforts to establish an appropriate framework for the evaluation of environmental risk assessment and monitoring of GMOs in Europe by contributing their competence and their vast experience with environmental monitoring activities in different regulatory fields.

Abbreviations

HR: herbicide-resistant
GM: genetically modified
GMP: genetically modified plant(s)
ERA: environmental risk assessment
ENCA: European Nature Conservation Agencies
EPA: European Protection Agencies

Selection of References

Only a selection of references is included in the present position paper. Further references can be found in the technical paper: Tappeser B., Reichenbecher W., Teichmann H. (2014); *Agronomic and environmental aspects of the cultivation of genetically modified herbicide-resistant plants*. A BfN-FOEN-EAA-Joint paper. BfN-Skripten 362. The BfN-Skripten are not available in book trade but can be downloaded as pdf documents from the internet at: http://www.bfn.de/0502_skripten.html.

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