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POSSIBLE ENVIRONMENTAL RISKS OF INTRODUCTION OF GENETICALLY MODIFIED PLANTS IN ARMENIA AND ASSESSMENT OF THOSE RISKS

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The article focuses on description of general environmental risk of invasion of new habitants, possible non-target effects of Genetically modified plants and potential introgression of transgenes into crop wild relatives' populations and approaches for assessment of those risks suitable for Armenia.

Genetically modified organisms – risk assessment - crop wild relatives

Յոդվածում նկարագրված են գենետիկորեն վերափոխված բույսերի տարածման, ոչ նպատակային օրգանիզմների վրա նրանց ազդեցության և մշակաբույսերի վայրի ցեղակիցների պոպուլյացիաների մեջ տրանսգենների ներմուծման հիմնական էկոլոգիական ռիսկերը և Յայաստանում դրանց գնահատման համար կիրառելի մոտեցումները:

Գենետիկորեն վերափոխված օրգանիզմներ – ռիսկի գնահատում – մշակաբույսերի վայրի ցեղակիցներ

В статье представлены основные экологические риски распространения генетически модифицированных растений, их влияние на нецелевые организмы, интрогрессии трансгенов в популяции диких сородичей культурных растений и применимые в условиях Армении подходы для их оценки.

Генетически модифицированные организмы – оценка риска –дикие сородичи культурных растений

The national and worldwide importance of biosafety in Armenia is conditioned by a number of factors, particularly, due to the diversity of altitudes, climatic zones and landscapes found in Armenia, the country hosts a surprisingly high diversity of plants and animals, including many endemic, relict and rare species. Armenia is considered one of the most important centers for agrobiodiversity in the world, and represents a relatively large area supporting wild relatives of crops and agricultural varieties. For example, the "Erebuni Reserve", located not far from Yerevan City, is the only reserve of wild cereals in the world and is a unique habitat of wild wheat such as Triticum araraticum, T.boeoticum, T.urartu, Secale vavilovii, Hordeum spontaneum and others.

Agricultural species are of particular importance. Armenia is especially rich in apricot, grape, peaches, apples, plums, pears, pomegranates, quinces, figs, walnuts and other fruits. Agroecological conditions also permit the cultivation of many varieties of vegetables, including tomato, pepper, eggplant, cabbage, potato, cucumber, carrot, pumpkin, bean, garden radish, parsley, basil, coriander, mint, fennel, estragon, cress, cauliflower, lettuce, water melon, melon and peas. Winter wheat and spring barley are the dominant cereals. Maize is mainly grown for feed, in mountainous area cultivation of rye and oats is limited. Alfalfa, sainfoin, clover, amaranth, feed beet and vetch are grown as feed crops, while of industrial crops, only a small amount of tobacco is cultivated.

Agriculture is an important factor in many nations' economies because of the jobs and incomes it provides and because it is often an important source of hard currency. In Armenia the system of agricultural food products, which, being one of the most important sectors of the economy, has a crucial role in the improvement of the Armenia's overall social and economic situation and ensuring its food products' safety, also became part of these processes. During the recent years, the agricultural food products system has provided about 35% of the country's gross domestic product, including approximately 25% accounting for agriculture (Haykazyan and Pretty, 2006).

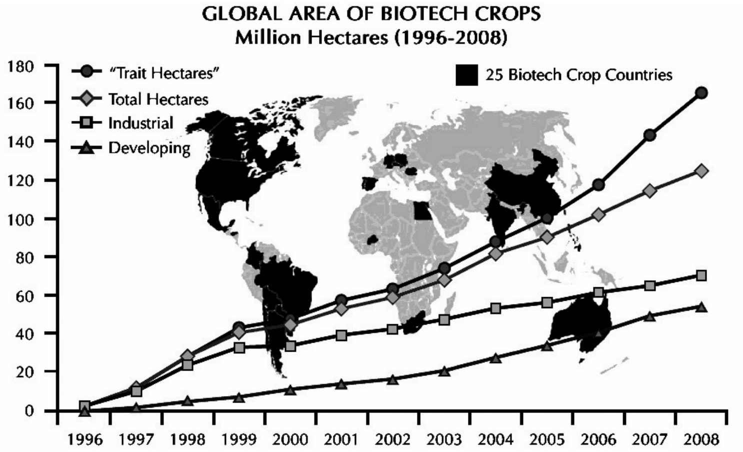
The safe use of biotechnology should be ensured, especially in developing countries where the genetically modified organisms (GMOs) and their products are used sometimes without choice. Now in Armenia we face similar problems. The biosafety-related activities in Armenia started in 1993 when the National Assembly ratified the Convention on Biological Diversity.

Review of the current situation shows that for effective implementtation of biosafety in Armenia there is need to put in place national biosafety regulations and guidelines in accordance with Cartagena protocol. Those regulations and guidelines should emphasize and regulate the safe transfer of GMOs and their products from the country of origin to Armenia, safe handling and use of GMOs and products of the import; safe movement of GMOs through transit. The scientific risk analysis plays an important role for effecttive implementation of described activities.

<u>Current status of GMOs production in the world.</u> GMOs are the organisms that have been altered by using modern biotechnology in a way to either increase or decrease a certain characteristics. It can add a desired or undesired effect to an organism. The first GM plants were commercialized 13 years ago in 1996 in the USA. As a result of the consistent and substantial economic, environmental and welfare benefits offered by biotech crops, millions of small and resource-poor farmers around the world continued to plant more hectares of biotech crops in 2008, the thirteenth year of commercialization (James, 2008). Apparently in 2008, the total global area of biotech crops continued to grow strongly reaching 125 million hectares, up from 114.3 million hectares in 2007.

The biotech soybean continued to be the principal biotech crop in 2008, occupying 65.8 million hectares or 53% of global biotech area, followed by biotech maize (37.3 million hectares or 30%), biotech cotton (15.5 million hectares or 12%) and biotech canola (5.9 million hectares or 5% of the global biotech crop area).

Nowadays great diversity of traits and genetically engineered organisms (plants, animals and micro-organisms) are under development. Most promising in terms of expected profits are pharmaceutical traits (enzymes, vaccines, etc.), industrial products especially Agro-fuels but also other products (e.g. starch from amylopectin producing potatoes, etc.).



An "apparent" increase of 9.4% or 10.7 million hectares between 2007 and 2008, equivalent to a "real" increase of 15% or 22 million "trait hectares"

Source: Clive James, 2008.

Fig.1. The global trend from the first year of production in 1996 up to 2008.

These are very important developments given that biotech crops can contribute to some of the major challenges facing global society, including: food security, high price of food, sustainability, alleviation of poverty and hunger, and help mitigate some of the challenges associated with climate change. However, deliberate or inadvertent releases of GMOs into the environment could have negative ecological effects under certain circum-stances.

Potential environmental effects of introduction of GM plants in Armenia. In spite the fact that Armenia characterised by sufficient scientific and industrial capacity in the field of biotechnology, the biotechnological research that is carried out in the country in the field of agriculture mainly relates to the selection of cultivated plants and their accelerated reproduction, but not in the field of development of genetically modified plants. So, from this point of view Armenia can be classified as only GM crops importing country. For Armenia the main risks can be characterised as environmental and socio-economic in gene-ral. Taking into account that the small territory of Armenia is characterised with rich wild and crop plant biodiversity including endemics, relict plants, crop wild relatives (Triticum, Aegilops, Hordeum, Secale etc.) of economic importance, the assessment of the risk of potential environmental effects of GMOs is of particular significance.

The potential environmental risks of GM crops for Armenia are presented in Fig. 2. All these risks are interlinked directly or indirectly.

Risk assessment has a long tradition in regulating human activities with the aim to minimize or avoid risk to human health and the environment. Examples can be found in the production of medical products, chemistry or nuclear power.

Risk assessment methodology for GMOs has evolved over the last several years. At a conceptual level, the methodology has been adapted from the existing paradigm for environmental risk assessment, which was developed for chemicals and other types of environmental stressors. According to the European regulations, the safety of GMOs has to be assessed prior to releases into the environment and placing on the market. The approach is described in more detail in Directive #2001/18/EC on the deliberate release of GMOs into the environment, which was adopted in April 2001 and repealed Directive #90/220/EEC in October 2002.

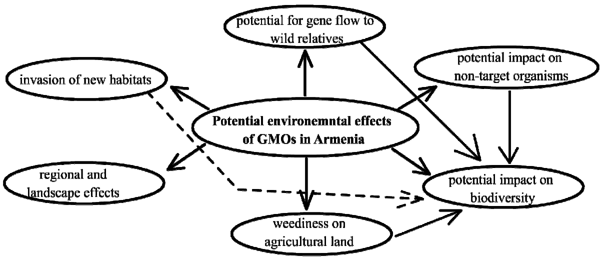


Fig. 2. Potential environmental risks of deliberate release of GMOs in Armenia

Common understanding regarding the conceptual basis for risk assessment is a challenge. There is considerable variation among risk assessment frameworks for GMOs regarding the steps or components of risk assessment. In general, the entire process of risk assessment, combined with risk management and risk communication is referred to risk analysis (Fig. 3).

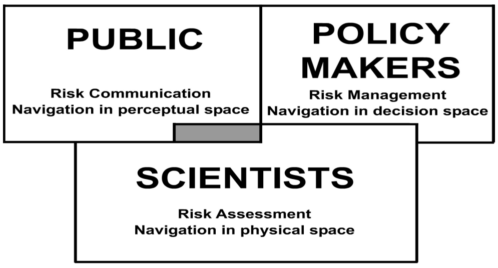


Fig. 3. Risk analysis consists of three interconnected components- risk assessment, risk management and risk communication

Environmental risk assessment is defined by Directive #2001/18/EC as the evaluation of risks to human health and the environment, whether direct or indirect, immediate or delayed, which may pose experimental deliberate release or deliberate release by placing GMOs on the market.

The risk assessment is the science and process of estimating risk. It's implemented my scientists. The objective of environmental risk assessment, according to the European legislation, is to identify and evaluate potential adverse effects of a GMOs and to elucidate if there is a need for risk management and suitable measures to be taken. Risk management is the process of considering alternative courses of action, and selecting the most appropriate option after integrating the results of risk assessment with engineering, social, economic, and political concerns in order to make a decision. Risk communication is the interactive exchange of information and opinions throughout the risk analysis among risk assessors, risk managers, consumers, feed and food businesses, academic community and other interested parties.

Risk assessment traditionally consisting of four steps: hazard identifycation, exposure assessment, effects characterization, and risk characterization (Fig. 4).

Hazard identification is very important process scoping and framing the following risk assessment process. It focuses on identification of stressor and development of an analysis strategy, including risk hypotheses.

Exposure is an important topic and an important term used a lot in risk assessment. It means contact or co-occurrence between the transgenic, transgene product and GMO as a stressor, typically it is considered as a primary stressor and an ecological entity, receptor of that. The risk can be quantified by combining hazard (H) and exposure (E) (Poppy, 2004).

The effects characterization is the characterization of the potential consequences of exposure, if it occurs. The fourth step is the most important step when risk assessor combine knowledge and if it is possible to combine exposure that is given and adverse effects that can happen, than it is possible to talk about the risk, and only than risk assessor can start thinking about risk characterization. The risk can be presented as a characteristic of a situation or action wherein two or more outcomes are possible, the particular outcome that will occur is unknown and at least one of the possibilities is undesired (Covello and Merkhofer, 1993).

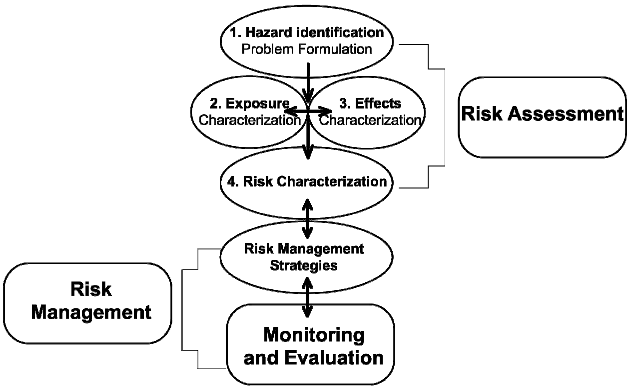


Fig. 4. Key steps of risk assessment of potential environmental effects of GMOs and interconnection between risk assessment and risk management

The principal approach to assess the safety of GMOs is largely accepted. First of all risk assessment should be science-based and carried out to ensure a very high scientific standard. For every GMO the risk assessment is done on a case by case basis and in a stepwise manner. This means that for example each GM plant is tested first in the laboratory then on a small scale in a field trial, followed by a large-scale field trial before authorization for placing on the market can be requested. The following step can only be carried out if the preceding step has shown that the GMO does not pose any risk to the environment.

Approaches for environmental risk assessment suitable for Armenia. Armenia is in the process of initiation of the biosafety-related activities and has not high labour facilities, therefore the risk assessment should be developed appropriately, sound to medium costs requirements.

For assessment of the possible risks of invasion of new habitants and risks of weediness on agricultural lands the ability of GM plant to reproduce under the climatic and environmental conditions in the release area have to be assessed (Fig. 5). It is known that if the GM plant is able to reproduce in the release area, than there is a risk for invasion and its establishment in natural habitats (Kjer et al, 1990; Traxler, 2001).

For risk assessment firstly the information on evolutionary history, morphology, life history traits, and vegetative reproduction is needed. In this case, the assessment should be based on available information. If the literary data and/or results of analysis show that the GM plant has the potential to sexually reproduce or propagate vegetatively, and establish in natural habitats in the region of the release, than the fitness of the plant needs to be tested (Kjer et al, 1990).

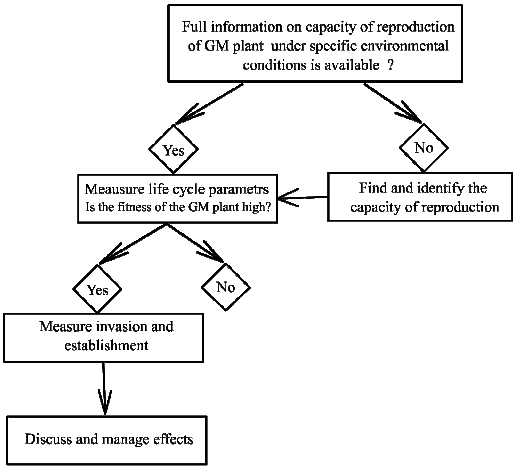


Fig.5. Key steps of risk assessment of possible invasion of new habitants by GMOs

During testing different environmental conditions of the area of release should be tested, including conditions which may have been removed by inserted trait, in order to identify the type of environmental conditions giving "no fitness advantages" to conditions eventually resulting in "improved fitness". The growth stage of GM plant most susceptible to the stressor needs to be found. If fitness of GM plants is improved at a level occurring in any recipient environment then the plant needs to be tested in full-life-cycle experiments under relevant field conditions.

The selection of field localities relevant for the experiments is primarily dependent on the plant species and on the inserted trait. In Armenia it is difficult to carry out full-life-cycle experiments of GM plants, tests of critical stages need to be supplemented by modelling of seed dispersal, habitat invasion and reproductive success using representative data and estimation on life-cycle parameters. The results obtained should be discussed and managed, the conclusion on assessment should be developed and possible adverse effects for small regional level formulated.

To identify possible non-target effects of GM plants the species groups which are likely to be exposed to new plant compounds or altered performance of the transgenic plant should be found (Figure 6). To such groups of organisms the other plant species, pollinators, detrivores, herbivores and predators can be concerned. On Figure 6 the model for risk assessment of GM plants on non-target organisms is presented. This model is called functional model and was developed by the group of scientists from Brazil, Vietnam and East Africa within the project which was financially supported by the Swiss Agency for Development and Cooperation (Nelson K., Banker C., 2007), and which is used in our Laboratory at the Yerevan State University with small modifications.

In dependence of the GM plant species and ecological conditions of the area of release, species, exposure conditions, and end-point have to be chosen. As direct effects of GM plants on non-target organisms, the toxic effects on other plants, herbivores, pollinators, detrivores and microorganisms have to be assessed. The exposure analyses have to be carried out. As indirect effects, the food-chain effects should be assessed in terms removal of food for higher trophic levels. The methodology and types test systems depend on mode of action and expression of the trait and on the distribution and species specificity of toxic compounds.

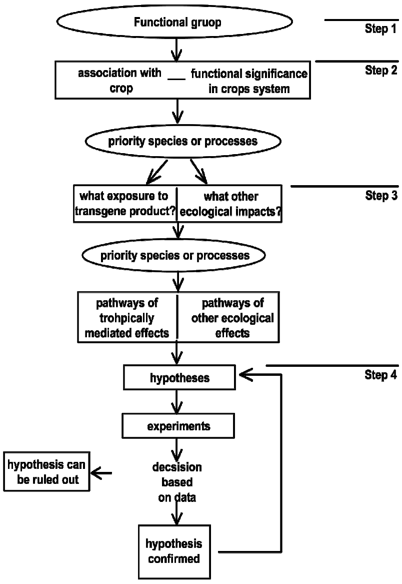


Fig. 6. Key steps of functional model for assessment of possible non-target effects of GMOs

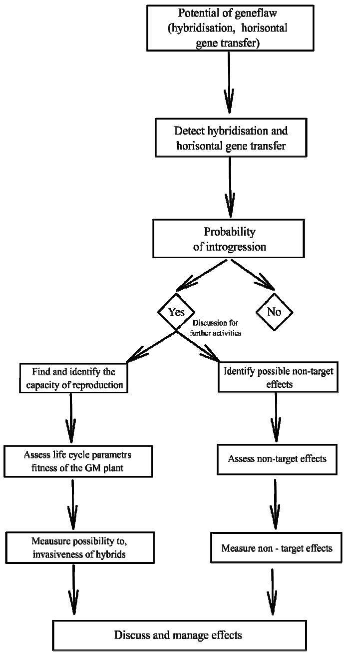


Fig. 7. Key steps of assessment of potential gene flow of GMOs

The test has to be performed for different functional groups of organisms, but also if there are problems with labour and costs, as for Armenia, it should be possible to choose key functional groups of organisms. If any non-target effect of GM plants on specific groups of organisms is identified than the non-target effects in the field have to be measured. For evaluation of non-target effects comparative tests of the population development for those taxa, which have proved sensitive, should be made. The sampling should be adjusted to the species of interest and supplementary also other species of the same functional group. Then the results should be discussed and managed by risk management working group.

For detection of potential introgression of transgenes into wild populations, (i.e. gene flow) the assessment of hybridisation potential with any naturally occurring plant is needed. This can be done by a literature study or, if no data exist, by simple hybridisation experiments with plants from closely related taxa (Figure 7). The measurements of hybridisation rates, assumed selective advantage of inserted gene, and fitness measurements of parent plants, hybrid plants, and plants from the first and second back-cross generations have to be carried out. Prior to these activities, the assessment of gene flaw presence of receptive stigmas of sexually compatible cultivars, traditional cultivars, land races, wild and weedy relatives within the viable pollen transmission range have to be evaluated. The flowering phenology, viable pollen movement distance determined by pollination mechanism and viability of the pollen, pollination mechanism, means of pollination in wild and weedy related species and other parameters have to be assessed.

If hybrids are formed and hybrid plant that has the inserted gene has a fitness advantage over an otherwise similar plant without the inserted gene, than further investigations are needed.

This discussion should include considerations on invasiveness into the new ecosystems and possible effects on other organisms. In order to predict whether the inserted gene will be introgressed into the naturally occurring plants, it is necessary to describe and assess the direction of the selective forces operating on the inserted gene in the natural plant population.

Additionally, it is necessary to take into account whether the transgene can be introgressed into another organism by horizontal gene transfer and the effect of such an introgression. There may be unwanted consequences of horizontal gene transfer to another organism. Such consequences may be assessed verbally if no data are available.

Finally it is very important to compare conventional cropping system and GM cropping systems in some general points: differences (for example herbicide application), ecological effects (wildlife effects, effects on non-target organisms). These could be done by application literary data and public participatory methods. All the results obtained have to reported and discussed, for further development and decision making.

REFERENCES

1. *Covello V. T., Merkhofer M. W.*, Risk Assessment Methods: Approaches for Assessing Health and Environmental Risk, Plenum Press, New York, 1–7, 1993.
2. FAO, The State of Food and Agriculture 2003–2004: Agricultural Biotechnology: Meeting the Needs of the Poor? Rome, 194 p., 2004.
3. *James C.* Global Status of Commercialized Biotech/GM Crops: 2008. ISAAA Brief No. 39. ISAAA: Ithaca, NY. 2008.
4. *Haykazyan Vardan, Pretty Jules*, Sustainability in Armenia: New Challenges for the Agricultural Sector, University of Essex, UK, 31 p., 2006.
5. *Kjer Christian, Damgaard Christian,* Risk Assessment of Genetically Modified Higher Plants (GMHP), NERI Technical Report, n0 303, Denmark, 35 p., 1990.
6. *Nelson Kristen C., Banker Mchael J.* Problem formulation and options assessment handbook. A guide to the PFOA process and how to integrate it into environmental risk assessment (ERA) of genetically modified organisms (GMOs), A publication of ERA project, Minnesota, 252 p., 2007.
7. *Traxler Andreas, Heissenberger Andreas et al.,* Ecological monitoring of genwtically modified organisms, Riegelnik,Austria, 87 p., 2001.
8. *Tollens Eric, Demont Matty, Swennen Rony,* Agrobiotechnology in developing countries, Outlook on Agriculture, 4, 231–238, 2004.

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