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Review paper

GENETICALLY MODIFIED TREES - STATE AND PERSPECTIVES

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Genetically modified trees are the result of modern plant breeding. Its introduction into the environment for experimental purposes or wider cultivation is defined differently from country to country. Public opinion is divided!

Conducted research are part of the activities within the COST Action FP0905 „*Biosafety of forest transgenic trees*", which aims to collect information and define the scientific attitude on genetically modified trees

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as a basis for future European Union (EU) policy in this field. The collected information refer to eight countries: four EU member states (Italy, Slovenia, Romania and Bulgaria) and four countries in the process of pre-accession (Croatia, Montenegro, Serbia and Bosnia and Herzegovina). A comparative analysis involved the state of forest resources (area of forest land and forest cover), forestry legislation, legislation relating to genetically modified organisms and the general public attitude on this issue.

The collected information provide a good basis for understanding this issue in order to define a clear scientific attitude as a recommendation.

Key words: genetically modified trees, forest resources, legislation, public attitudes

INTRODUCTION

The increasing demand for wood as raw material for different purposes, as well as for multiple-use forest functions, make the protection of natural forests the priority task of forestry science and profession (ŠIJAČIĆ-NIKOLIĆ and MILOVANOVIĆ, 2010).

Man has cultivated plants for thousands of years, during which time crop plants have been continually selected for disease resistance, improved yield, growth or other useful characteristics (ATHERTON, 2002). The efficiency of different measures of germplasm conservation of valuable species depends primarily on the degree of information on its genetic variation. During the last fifteen years, the demand for codominant, locus specific and multiallele DNA markers has been considerably increased, because they can be applied to the population genetics research, mapping and marker assisted selection, in the aim of defining the association of genes and favourable phenotypic traits (MILOVANOVIĆ *et al*., 2007).

The history of plant breeding dates since early humans identified seeds from the most productive plants and saved them to plant in the following growing season. The modern plant breeding, whose beginning correlates with the rediscovery of Mendel's work, has led to great success in combining desirable traits in a single plant (PILACINSKI *et al*., 2011). In conventional breeding, the plant breeders have been developing new crop varieties by using the existing genetic variability through crossing diverse genotypes, but genetic modification technology, known as genetic engineering (GE), has made possible the insertion of desired foreign genes - the outcome is a genetically modified (GM) product (GHOSH, 2001). The term „*Genetically Modified Organism*" or GMO has been applied to organism in which techniques of genetic engineering have been used to introduce or remove specific parts of their genome (GLIŠIN, 2005). Genetic modification is usually seen as very controversial use of biotechnology (WALTER and MENZIES, 2010).

In forestry, the definition of biotechnology covers all aspects of tree breeding and plant cloning, gene manipulation and gene transfer (NEALE, 2007; WALTER and MENZIES, 2010). Tree improvement, control of pests, propagation and conservation are some of broad areas of application for biotechnology in forestry (GASTON *et al*., 1995, ŠIJAČIĆ-NIKOLIĆ and MILOVANOVIĆ, 2007; MILOVANOVIĆ and

ŠIJAČIĆ-NIKOLIĆ, 2008). There is interest in the use of fast-growing forest trees, because forests help to maintain biodiversity, mitigate climate changes and increasing CO_2 levels, protect land and water resources, also provide social and environmental benefits (HARFOUCHE *et al*., 2011, MILOVANOVIĆ and ŠIJAČIĆ-NIKOLIĆ, 2006).

Genetic modification technology is still new in forestry, however, some of confined field trials on transgenic forest trees (broadleaved and few species of conifers) have been established worldwide. In some countries there are small experimental field trials of short duration, which, in many cases, must be destroyed before seed production occurs. In other countries, experimentation is restricted to laboratories or greenhouses (WALTER and MENZIES, 2010). There are, almost, no commercial plantations of GM forest trees (only in China GM poplars have been commercialized). Different situation is with annual GE crops (soybean, maize, cotton, papaya, sugar beet, tomato, sweet pepper) which have been commercialized in many countries. In spite of commercial release of these GM agricultural crops and huge world market, there are still some obstacles to testing and deployment of GMTs (TANG and NEWTON, 2003; AHUJA, 2011).

Introduction of GM plants into the environment for experimental purposes, like field testing, as well as commercial use, can find a lot of problems, especially a non-acceptance by the public.

The aim of this paper was to make a comparison between selected countries on the state of forest resources, forestry legislation, legislation related to genetically modified organisms and the general public attitude on this issue, as a basis to create a draft questionnaire for conducting specific survey about transgenic trees.

MATERIALS AND METHODS

This paper presents the results of the *Short Term Scientific Mission* (STSM), which was implemented in the period from 9th to 31st May 2011, in Florence, supported by the COST Action FP0905 „*Biosafety of forest transgenic trees*". The subjects of the research were eight countries: four EU Member States (Italy, Slovenia, Romania and Bulgaria) and four countries in the process of EU pre-accession (Croatia, Montenegro, Serbia, Bosnia and Herzegovina).

First activity was studying the scientific papers and other literature sources published on the subject about GMTs, and collecting information about the implementation of EU directives related to GMTs. Secondly, for each selected country, information were found about GM plants in the past and in the present.

Another activity was to make a comparative analysis between eight countries, which involved forest resources (area of forest land, forest cover), forestry legislation and legislation related to genetically modified organisms. Also, the comparison on general public attitude on this issue was done.

RESULTS AND DISCUSSION

Firstly, comparison was done on forest resources - forest land area (Table 1) and forest cover (Figure 1).

Table 1. Comparison – Forest land area

Country	Forest land area (ha)
Italy	9 857 000
Slovenia	1 185 145
Romania	6 382 200
Bulgaria	3 900 000
Croatia	2 688 687
Montenegro	743 609
Serbia	2 252 400
Bosnia and Herzegovina	2 867 412

Italy has the largest forest land area (9 857 000 ha) and Montenegro has the smallest (743 609 ha). It is interesting that Montenegro is the second of selected countries (after Slovenia) with high percentage of forest cover (54%).

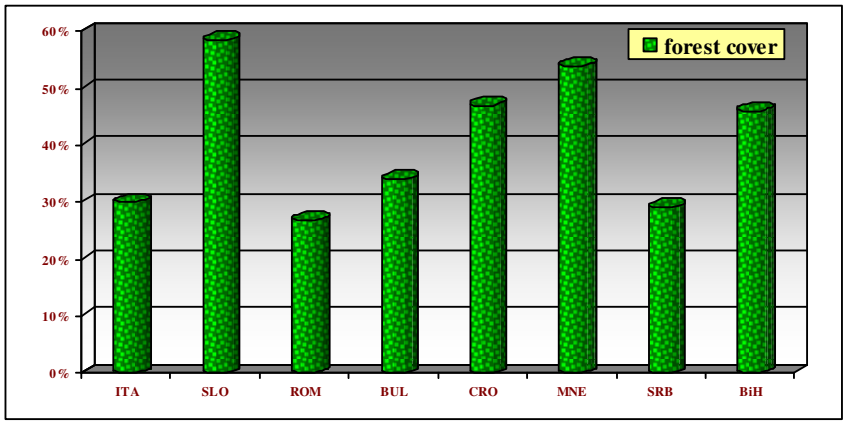

Figure 1. Comparison – Forest cover (Source: www.fao.org)

Figure 1 show that the highest percentage of forest cover has Slovenia (59%), and the lowest percentage has Romania (27%). It was important to make comparison on forest resources because it can be in relationship with a situation on GM trees in these countries. Secondly, comparison was done on the Forestry legislation (Table 2). This table shows that Bulgaria (2011), Montenegro, Bosnia and Herzegovina and Serbia (2010) have the latest Laws on Forests.

Table 2. Comparison – Forestry legislation in selected countries

Country	Forestry legislation
Italy	Law on Forests (2001)
Slovenia	Law on Forests (1993/2002)
Romania	Law on Forests (2008)
Bulgaria	Law on Forests (2011)
Croatia	Law on Forests (2005/2008)
Montenegro	Law on Forests (2010)
Serbia	Law on Forests (2010)
Bosnia and Herzegovina	Draft Law on Forests (2010)

After the state of forestry resources and legislation, the comparison on legislation and public awareness of GMTs was done – firstly, on production or import of GM plants in the past (Table 3).

Table 3. Comparison – Production or Import of GM plants in the past

Production/import of GM plants in the past		
Country	**Yes**	**No**
Italy		√
Slovenia	√	
Romania	√	
Bulgaria	√	
Croatia		√
Montenegro		√
Serbia	√	
Bosnia and Herzegovina		√

This table shows that four of eight countries (50%) have imported GM crops (but no GM trees) or had production of GM crops in past, and other 50% did not. For example, genetically engineered soybeans (known as Roundup Ready - RR), have been grown commercially in Romania and transgenic tobacco plants from Bulgaria were the first genetically modified organisms released in the Balkan region. In Italy, there is no public register regarding the location of cultivated GMO, but Slovenia imported maize seed (in 1999 and 2000) from both USA and Canada. Nowadays, in Slovenia, there are not field trials with GM plants, so, anyone planning a field trial must apply for a permit for the implementation. A new Romanian law on GMO was published in 2006, to harmonize Romanian regulations with those in the European Union. Until 2006, Romania was Europe‘s biggest commercial grower of GM soy, but the Romanian government has decided to ban the growing of RR soybeans from 2007 (when Romania entered the EU). In Croatia there are neither commercially produced biotech crops nor seeds, there are no GM plants under development, and this country does not importing GM plants. Breeders are afraid of

growing genetical modified trees and crops, there is a feeling that biotechnology is something unnatural. Montenegro has relatively strict controls on import and has a policy of keeping its agriculture and forestry free from GMO. Also, Serbia does not produce any GM plants and no biotechnology varietes are permitted for imports to Serbia, but illegal GE soybeans have been found to be increasingly grown in Serbia (in 2002, RR soybeans were discovered to be illegally growing on some 20 ha, and in 2003 on some 1000 ha). Serbia, as Montenegro, has a policy of keeping its forestry free from GM trees. Knowledge about biotechnology in Bosnia and Herzegovina is poor, plant production is more traditionally oriented and the use of pesticides is lower than in Europe. This country does not produce GM plants.

Table 4 shows a comparative analysis on the GM legislation. Bosnia and Herzegovina (2009) and Serbia (2009) have the latest Laws on GMO that is the same situation as forestry legislation, for these two countries. Slovenia has the oldest Law on GMO (2002).

Table 4. Comparison – The legislation on GMO

Country	The legislation
Italy	Law on GMO (2003)
Slovenia	Management of GMO Act (2002)
Romania	Law on GMO (2006/2009)
Bulgaria	Law on GMO (2005)
Croatia	Law on GMO (2005)
Montenegro	Law on GMO (2008)
Serbia	Law on GMO (2009)
Bosnia and Herzegovina	Law on GMO (2009)

The development of GM trees could be hindered by regulatory and social hurdles. Responsible use and development, as well as science-based oversight of GM tree technologies, are essential for regulatory and public acceptance (HARFOUCHE *et al*., 2011). There are differences in the regulation of GMO between countries, with some of the most marked differences occurring between the USA and Europe. In the European Union, the monitoring of commercially cultivated GMO is regulated in the EU-Directive 2001/18/EC. There are two different sets of rules for genetically modified products in the EU: one for the use of GM plants, and the other for food and feed made from them (SCHMELLER and HENLE, 2008).

Most of selected countries have the legislation in accordance with the legal order of the EU (Italy, Slovenia, Romania) and some countries have more restrictive law than EU regulations (e.g. Serbia, Montenegro, Croatia). In the process of EU accession some of selected countries changed politics/law on GMO (e.g. Romania has decided to ban the growing of RR soybeans from 2007, when entered the EU).

In Italy, Slovenia and Romania the legislative and administrative framework of biosafety for the area of GMO is established in accordance with the legal order of the EU. The Bulgarian GMO law is mainly in line with EU legislation,

but it is more stricter for some parts then EU legislation. This Law forbids cultivating GM modified crops as tobacco, vegetables and fruits, cotton, etc.

The Croatian Parliament has adopted several laws regulating GMO, new law is in some aspects stricter than EU law. Serbia and Montenegro was the first country (2001) to establish a regulatory system for controlling GMO in South-East Europe. In 2006, Montenegro declared itself an independent state, and new law, which permits that GMO may be used in closed systems, has adopted in 2008. The new Law on GMO that the BiH Parliament passed in 2009 is in line with EU regulations. In the same year (2009) National Parliament of the Republic of Serbia adopted new Law on GMO that fully prohibits the possibility of commercial growing of live modified organisms and products derived from genetically modified organisms, that is considered more restrictive than EU regulations. The previous Law on GMO (2001) was more liberal in the area of trade with GMOs than the new Law.

Finally, comparison was done on general public attitude on GMO and situation against GMO in these countries (Table 5). Actually, it was about „*GMO Free Regions*“, campaigns and protests against GMO. There are no GMO-free regions in 3 of 4 countries in the process of joining EU, but in other five countries there are „GMO-free“ regions, mostly in Italy.

Table 5. Comparison – The GMO-free regions (www.gmo-free-regions.org)

The GMO-free regions		
Country	**Yes**	**No**
Italy	√	
Slovenia	√	
Romania	√	
Bulgaria	√	
Croatia	√	
Montenegro		√
Bosnia and Herzegovina		√
Serbia		√

The „*GMO Free Region*“ concept refers to a public statement which shows the position of society actors regarding the use of GMO, either for cultivation or for consumption (http://www.gmo-free-regions.org). In Italy 16 out of 20 regions, 41 provinces and 2446 municipalities have declared themselves „GMO-free“. In Slovenia 79 community councils (more than 30% of all Slovenian communities) have declared themselves „GMO-free“. In Romania 50 communities and 4 cities, but in Bulgaria only 5 municipalities were declared „GMO-free“ by the local authorities. On the other hand, there are 14 „GMO-free“counties in Croatia. Different situation is in Montenegro, Serbia, Bosnia and Herzegovina - there are no „GMO-free“zones, yet. Public and scientific concerns have been raised about the environmental safety of GM trees. The main important environmental assessments of GM plants are

effects on biodiversity, putative invasiveness, vertical or horizontal gene flow, etc. There is a need to further scope of risks associated with the massive field deployment of GM plants (BOŠKOVIĆ *et al*., 2005).

The use of genetically modified organisms has sparked significant controversy in many areas, the public has a general awareness of genetic engineering. However, a deeper understanding of transgenic tree product development beyond proof of concept, including the different phases of transgenic tree development and factors that can affect development expenses, is often lacking (HARFOUCHE *et al*., 2011)**.** In the EU public attitudes to the genetic engineering are dominated by fear of the unintended consequences of scientific progress (BRANDT, 2003).

Today, scientists and the biotechnology industry face a growing number of questions and ethical issues relating to the social context in which biotechnology is used, which may mean a growing discrepancy between public and expert views. Successful adoption of genetically engineered trees will depend not only on the soundness of the technology and science, but also on how these trees are perceived by the public (GAMBORG and SANDŘE, 2010).

Opponents of the application of biotechnology in forestry point especially to the potential for environmental damage. At present, GM trees are largely confined to the domain of field trials or laboratories, where risks and benefits can be intensively studied, but more field trials are needed to provide science-based assessment of the value and environmental safety of GM trees (GASTON *et al*., 1995; MEGALOS, 2006; HARFOUCHE *et al*., 2011). Ecologists have been concerned that novel transgenes from GM trees may cause ecological or economic harm, or both. Advances in strategies to avoid that, are very important. The potential environmental and social impacts of the release of GMTs have become an increasingly contentious issue that will require more research, before use these technologies to their full advantage (MERKLE and DEAN, 2000; WOLFENBARGER and PHIFER, 2000; PEÑA and SÉGUIN, 2001; RWIN and JONES, 2006). Commercial GMO cultivation has raised controversial debates on the potential adverse efects and public acceptance is low, even though GM-crops may have some advantages, the potential adverse efects of GMOs on the environment needs to be closely monitored (SCHMELLER and HENLE, 2008).

CONCLUSION

All living organisms, including trees, are part of the ecological food chain, and many species are in contact with transgenic species expressing the foreign gene. Dispersal of pollen or seeds from modified forest plantations may cause detrimental or beneficial ecological impacts on wild or managed ecosystems, insertion of genes designed to prevent reduce dispersal could reduce the risk and extent of undesired (BRUNNER et al., 2007; MACEK *et al*., 2008; FLADUNG *et al.*, 2010).

Genetically modified trees are the major products of the tree breeding that have a great potential in production of phytochemicals and amelioration of polluted soils and improvement of environmental conservation (ISAJEV *et al*., 2005).

Biotechnology has shown great promise for forest tree improvement to compensate for the ever-increasing demand for wood and to reduce pressure on native forests (ŠIJAČIĆ-NIKOLIĆ *et al*., 2009a; ŠIJAČIĆ-NIKOLIĆ *et al.*, 2009b, MILOVANOVIĆ and ŠIJAČIĆ-NIKOLIĆ, 2010; ŠIJAČIĆ-NIKOLIĆ *et al.*, 2011), more wood of higher quality will need to be produced on less land by planting highly productive trees, also wood is one of the major renewable materials (BOERJAN, 2005).

There are diferent benefits of transgenic trees which include tolerance to arid or cooler conditions, also increased wood quality and improved growth, pest resistance GMTs might restore certain tree species that are either critically endangered or have been lost from forests owing to the introduction of pests (HARFOUCHE *et al*., 2011). More research is needed about the potential risks, benefits and ethics associated with GM tree deployment, and that research must focus on the economic, ecological and sociological perspective both in the developed and undeveloped world (MEGALOS, 2006).

This research showed that there are no GM trees in eight selected countres, but there were grown or imported some GM plants (mostly crops) in the past. Most of selected countries have legislation in accordance with the legal order of the EU, but some countries have more restrictive law on GMO than EU regulations. Public opinion is divided, and there is need for specific survay on this issue, in all of these countries.

It is important to develop recommendations for the use of GMTs in forestry and plantations, in accordance to safeguarding the environment. It is necessary to perform socio-economic analyses of the use of GMTs considering the concerns and acceptance by the public, about GMO legislation and environmental impacts of use of GM crops and trees.

Strong linkage between scientific-research and commercial sectors is necessary through project activities with the aim of GMTs socio-economic and environmental impact surveys (MILOVANOVIĆ *et al.*, 2011).

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GENETSKI MODIFIKOVANO DRVEĆE - STANJE I PERSPEKTIVE

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Genetski modifikovano drveće je rezultat savremenog oplemenjivanja biljaka. Njegovo uvođenje u životnu sredinu u eksperimentalne svrhe ili šire gajenje definisano je različito, od zemlje do zemlje. Mišljenje javnosti je podeljeno!
Obavljena istraživanja deo su aktivnosti u okviru COST akcije FP0905 „*Biosafety of forest transgenic trees*", koja ima za cilj prikupljanje informacija i definisanje naučnog stava o genetski modifikovanom drveću, kao osnove za buduću politiku Evropske unije u toj oblasti. Prikupljene informacije odnose se na osam zemalja: četiri zemlje članice Evropske unije (Italija, Slovenija, Rumunija i Bugarska) i četiri zemlje u procesu pridruživanja (Hrvatska, Crna Gora, Srbija i Bosna i Hercegovina). Komparativnom analizom obuhvaćeno je stanje šumskih resursa (površina šumskog zemljišta i šumski pokrivač), zakonodavstva vezano za šumarstvo i za genetski modifikovane organizme i stav šire javnosti o ovom pitanju.
Prikupljene informacije pružaju dobru osnovu za sagledavanje ove problematike u cilju definisanja jasnog naučnog stava kao preporuke.

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