iForest
Biogeosciences and Forestry

Research Article
doi: 10.3832/ifor1441-008
vol. 9, pp. 344-353

Public attitudes towards the use of transgenic forest trees: a cross-country pilot survey

Vassiliki Kazana [(1)], Lambros Tsourgiannis [(2)], Valasia Iakovoglou [(1)], Christos Stamatiou [(1)], Alexander Alexandrov [(3)], Susana Araújo [(4)], Sasa Bogdan [(5)], Gregor Bozic [(6)], Robert Brus [(7)], Gerd Bossinger [(8)], Anastasia Boutsimea [(1)], Nevenka Celepirović [(9)], Helena Cvrčková [(10)], Matthias Fladung [(11)], Mladen Ivankovic [(9)], Angelos Kazaklis [(1)], Paraskevi Koutsona [(1)], Zlata Luthar [(12)], Pavlina Máchová [(10)], Jana Malá [(10)], Kostlend Mara [(13)], Milan Mataruga [(14)], Jana Moravcikova [(15)], Donatella Paffetti [(16-22)], Jorge AP Paiva [(17)], Dimitiros Raptis [(1)], Conchi Sanchez [(18)], Sandra Sharry [(19)], Terezia Salaj [(15)], Mirjana Šijačić-Nikolić [(20)], Noemi Tel-Zur [(21)], Ivaylo Tsvetkov [(3)], Cristina Vettori [(22)], Nieves Vidal [(18)]

Information on public attitudes towards the use of transgenic trees in forest plantations is important in the decision-making process and policy implementation for safe tree development, particularly at the EU level. In Europe, the use of transgenic forest trees is very limited and therefore such information is completely lacking. To address this issue within the FP0905 European COST Action on the Biosafety of Transgenic Forest Trees a pioneer cross-country pilot survey on public attitudes towards the use of transgenic forest trees was conducted using young population as a focus group. This was decided mainly because this focus group represents the future consumers, policy makers or developers. Specifically, the survey aimed to: i) assess the level of young people's knowledge about transgenic forest trees, ii) identify issues of concern to them regarding the cultivation of transgenic forest trees and iii) explore whether they approve or disapprove of the use of transgenic forest trees in plantations. Purposive sampling was performed and university students of different disciplines were included in the research as sampling subjects. In total, 1868 completed questionnaires from 15 European and non-European countries were analyzed. The young educated people that took part in the survey appeared to approve of the use of transgenic forest trees in plantations and would be willing to buy forest transgenic products. The potential loss of biodiversity due to a risk of gene flow between transgenic and wild trees was seen as the safety issue of most concern when considering the commercial release of transgenic forest trees. However, a serious perceived lack of knowledge about potential benefits and risks of the cultivation of transgenic forest trees was recorded in most of the countries. K-means clustering was implemented on respondents' positive responses to identify potential country patterns. No differences in patterns of public attitude towards the acceptance of the commercial growing of transgenic forest trees were observed between European and non-European countries. Extended research on public attitude issues towards the use of transgenic forest trees is strongly recommended as a basis for policy implementation on safe tree development.

Keywords: GM Forest Trees, Public Awareness, Public Acceptance, k-means Clustering, University Students

Introduction

Advances in biotechnology have made feasible the growth of genetically modified (GM) or transgenic forest trees on a commercial scale (Van Frankenhuyzen & Beardmore 2004, Williams 2006, Häggman et al. 2013 – http://www.cost-action-fp0905.eu). Common genetic modifications include alterations of lignin content and composition, insect and disease resistance, herbicide tolerance, abiotic stress tolerance, growth improvement and reproductive development. The use of transgenic forest trees in commercial plantations is expected to contribute to increased forest productivity, improved paper pulp and biofuel production, climate change mitigation, preservation of biodiversity and reduction of use

(1) Eastern Macedonia and Thrace Institute of Technology, Department of Forestry & Natural Environment Management, 1st km Drama-Mikrohori, 66100 Drama (Greece); (2) Region of Eastern Macedonia & Thrace, 67100 Xanthi (Greece); (3) Bulgarian Academy of Sciences, Forest Research Institute, Kliment Ohridski Blvd. 132, Sofia 1756 (Bulgaria); (4) Instituto de Tecnologia Química e Biológica, Universidade Nova de Lisboa, Av. da República, 2780-157 Oeiras, Portugal & Instituto de Investigação Científica Tropical (IICT), Biotrop, Rua da Junqueira, 30, 1349-007 Lisboa (Portugal); (5) University of Zagreb, Faculty of Forestry, Department of Forest, Genetics, Dendrology and Botany,Svetošimunska 25, 10 000 Zagreb (Croatia); (6) Slovenian Forestry Institute, Vecna 2, SI-1000 Ljubljana (Slovenia); (7) Department of Forestry and Renewable Forest Resources, Biotechnical Faculty, University of Ljubljana, Vecna pot 83, SI-1000 Ljubljana (Slovenia); (8) The University of Melbourne, Department of Forest and Ecosystem Science, Creswick, Victoria 3363 (Australia); (9) Croatian Forest Research Institute, Laboratory of molecular-genetic testing, Division of genetics, forest tree breeding and seed science, Cvjetno naselje 41, 10450 Jastrebarsko (Croatia); (10) Forest and Game Management Research Institute, Strnady 136, 25202 Jíloviště (Czech Republic); (11) Thünen Institute of Forest Genetics, D-22927 Grosshansdorf (Germany); (12) Agronomy Department, Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, SI-1000 Ljubljana (Slovenia); (13) Agricultural University of Tirana (Albania); (14) University of Banja Luka (Bosnia and Herzegovina); (15) Institute of Plant Genetics and Biotechnology, Slovak Academy of Sciences, Akademicka 2, PO Box 39A, 95007 Nitra (Slovakia); (16) Department of Agriculture, Food and Environmental Science, Agricultural Genetics Section, University of Florence, P. le delle Cascine 28, 50144, Florence (Italy); (17) iBET, Instituto de Biologia Experimental e Tecnológica, Apartado 12, 2780-901 Oeiras, Portugal & Instituto de Investigação Científica Tropical (IICT), Biotrop, Rua da Junqueira, 30, 1349-007 Lisboa (Portugal); (18) Instituto de Investigaciones Agrobiológicas de Galicia (CSIC), La Coruna (Spain); (19) Universidad Nacional de la Plata, Facultad de Ciencias Agrarias y Forestales, Av.60 y119-c.C. 31, La Plata (Argentina); (20) University of Belgrade, Faculty of Forestry (Serbia); (21) French Associates Institute for Agriculture and Biotechnology of Drylands, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negar, Sede-Boqer Campus, 84990 Midreshet Ben-Gurion (Israel); (22) Institute of Bioscience and Bioresources (IBBR), Division of Florence, v. Madonna del Piano 10, 50019 Sesto Fiorentino, FI (Italy)

@ Vassiliki Kazana (vkazana@gmail.com)

Received: Sep 08, 2014 - Accepted: Jul 04, 2015

Citation: Kazana V, Tsourgiannis L, Iakovoglou V, Stamatiou C, Alexandrov A, Araújo S, Bogdan S, Bozic G, Brus R, Bossinger G, Boutsimea A, Celepirović N, Cvrčková H, Fladung M, Ivankovic M, Kazaklis A, Koutsona P, Luthar Z, Máchová P, Malá J, Mara K, Mataruga M, Moravcikova J, Paffetti D, Paiva JAP, Raptis D, Sanchez C, Sharry S, Salaj T, Šijačić-Nikolić M, Tel-Zur N, Tsvetkov I, Vettori C, Vidal N (2015). Public attitudes towards the use of transgenic forest trees: a cross-country pilot survey. iForest 9: 344-353. - doi: 10.3832/ifor1441-008 [online 2015-11-20]

Communicated by: Cristina Vettori

of energy, pesticides and fertilizers (Sedjo 2006, Chapotin & Wolt 2007, FAO 2008, 2010, Hinchee et al. 2009, Flachowsky et al. 2009, Harfouche et al. 2011). Despite these potential advantages, commercial GM forest tree plantations are not presently grown anywhere in the world, except China. Several issues represent significant obstacles for the commercialization of GM forest trees (Valenzuela et al. 2006, Farnum et al. 2007, Harfouche et al. 2011, Häggman et al. 2012) including technical limitations, restrictive regulation frameworks and socio-economic considerations.

Technical limitations relate to the required scientific advances in biotechnology, particularly solutions to issues related to gene stability, mass propagation, genetic deployment and environmental impacts. Regulation frameworks impose extensive approval processes for the deliberate release of transgenic forest trees. These frameworks require comprehensive safety assessments but risk analyses differ between countries. Within European Union countries the rules for the deliberate releases of GM forest trees, mainly implemented through the 2001/18/EC directive, are very strict and aim at providing high levels of protection for human health and the environment (Aguilera et al. 2013, Häggman et al. 2013). As a result, the approval process for deliberate releases is often time-consuming and expensive (Harfouche et al. 2011). Socio-economic considerations are mainly related to potential markets for products derived from transgenic trees, their public acceptance and the cost of patents. Public acceptance in particular is influenced by political, environmental, public health and socio-cultural concerns, which have been raised mainly by opinion influencing groups. Concerns often focus on potential genetic flow between transgenic and wild trees and consequent implications for the natural environment, increased use of broad spectrum pesticides in pesticide resistant forest trees, negative effects on forest tree fitness, potential higher vulnerability of forest trees to viral and other diseases, increased soil decomposition, adverse effects on bio-trophic processes in host ecosystems, flowering suppression and cultural adaptation to changing biodiversity conditions (El-Lakany 2004, Van Frankenhuyzen & Beardmore 2004, Williams & Davis 2005, Sedjo 2006, Farnum et al. 2007, FAO 2008, 2010).

Information on public attitudes towards the use of transgenic trees in forest plantations is important in the decision-making process and policy implementation for safe tree development, particularly at the EU level. However, in Europe in particular, such information is completely lacking, although relevant information is available for the use of GMOs in agriculture (Ferguson et al. 2002, Hossain et al. 2002, Grice et al. 2003, Cormick 2004, Hoban 2004, Magnusson 2004, Pereira de Abreu et al. 2006, Shehata & Cox 2007, Costa-Font et al. 2008, European Commission 2010, Buah 2011, Wnuk & Kozak 2011, Amin et al. 2014, Maes et al. 2014). To address this lack of information and to explore potential patterns or trends in the public attitudes towards the use of GM forest trees in plantations, a cross country pilot survey was coordinated within the frame of the European COST ACTION FP0905 during 2012 and 2013. Specifically, this survey focused on young people and aimed to: (i) assess the level of their knowledge about transgenic forest trees; (ii) identify issues of concern to them regarding the cultivation of transgenic forest trees; and (iii) explore whether they approve or disapprove of the use of transgenic forest trees in plantations. Since commercial GM forest plantations are not currently grown anywhere in the world (except China), it was decided to focus on young people aged 18 to 35 years, thus representing the future consumers or developers, or even policy makers.

Material and methods

Purposive sampling was conducted in all the countries using university students of three different categories of study fields as subjects. These included students of: (i) forestry; (ii) other environment-related disciplines, such as botany, biology, agriculture, landscape architecture and environmental science; and (iii) economics and related disciplines, such as accounting, business administration, financial management, management science and marketing. This non-probability sampling scheme was used since the primary goal of our survey was the detection of preliminary cross-country information on potential patterns or trends in knowledge, attitudes and perceptions of safety issues related to the cultivation of transgenic forest trees of young adults. University students were selected as subjects because it was considered that they would have the largest potential to establish and advance our understanding of young people's attitudes towards the use of transgenic forest trees in plantations due to their higher educational level. Furthermore, university students have been widely used as subjects of research also in many other studies, particularly in the fields of social psychology, marketing and consumer research (Peterson 2001, Druckman & Kam 2009, Wnuk & Kozak 2011).

The questionnaire for this survey contained questions organized in four sections: (i) socio-demographic questions; (ii) three questions of yes/no-type related to knowledge about transgenic forest trees; (iii) questions concerning issues relevant to public acceptance of the cultivation of transgenic forest trees; and (iv) questions related to the nature of safety concerns about the cultivation of transgenic forest trees. The detailed questions are reported below in the table captions.

Four of the six questions in section three were of yes/no type, while the other two included a number of options with a qualitative rating scale either of acceptance or importance in a country context. In particular, one of the questions in section three prompted the evaluation of different types of potential benefits deriving from the use of transgenic forest crops. For this evaluation, a four-level rating scale was used: "very important", "slightly important", "not important" and "I do not know". Listed potential benefits included a reduced need for chemicals and energy to process cellulose from wood, the harvesting of a smaller number of trees for consumption, a reduced use of insecticides, pesticides and herbicides, the restoration of poison contaminated soils, a reduction in old growth logging, higher pulping efficiency, better timber quality, more efficient biofuel production, stronger timber for construction and the potential for higher tree productivity.

Section four of the questionnaire included two questions about safety concerns. Both questions in this section required the evaluation of options from a list of potential risks related to the release of transgenic forest trees. Options included a potential for lesser fitness of transgenic trees, higher vulnerability to viral diseases, higher rates of soil decomposition, higher pesticide resistance, a potential for extended use of broad-spectrum pesticides, loss of biodiversity due to gene flow between transgenic and wild trees, adverse effects on bio-trophic processes of host ecosystems, increased costs of controlling pest outbreaks and the cultural adaptation to changing biodiversity conditions due to transgene escape. Question one in section four prompted the respondents to select only one safety issue which they regard as being of most concern. In the second question a four-level rating scale was used presenting the following options: "serious hazard, "slight hazard", "no hazard" and "I do not know".

Questionnaires were handed to students, who completed them on site. A total of 1868 questionnaires were received from across 15 countries located in 4 continents: Europe (12 countries), South America (1 country), Australia (1 country) and West Asia (1 country). European participants were weighted towards countries in south-eastern Europe, central Europe and south-western Europe. The distribution of respondents by country of origin is displayed in Fig. 1.

The questionnaires were subjected to statistical analysis using the software package STATISTICA® version 8.0 (StatSoft, Tulsa, OK, USA). ANOVA tests were used to analyze variances between cross-country positive responses regarding knowledge about the cultivation of transgenic forest trees, public approval of growing transgenic forest trees and the public attitude towards the labeling of products from transgenic trees and its legally mandatory process. Different country patterns of positive responses with regard to these variables were determined by using *k*-means clustering.

The k-means clustering approach is a statistical method to group items in *k* groups/clusters, where *k* is a pre-defined number (Murty et al. 1999, Bishop 2006, Jain 2010). This grouping aims to minimize the within-group variance while maximizing the between-group variance, *i.e.*, groups are determined by minimizing the sum of squared (Euclidean) distances between each item and the corresponding centroid, where a centroid may be a mean vector. A flow chart of the relationships between clusters of countries is shown in Fig. 2.

The null hypotheses which were tested were as follows:

- $H_0$1: People from different countries cannot be classified into similar groups according to their knowledge of transgenic forest tree plantations.
- $H_0$2: People from different countries cannot be classified into similar groups according to their attitude regarding acceptance of the approval to grow transgenic forest tree plantations.
- $H_0$3: People from different countries cannot be classified into similar groups according to their attitude regarding agreement to the labeling of transgenic forest tree products and its legally mandatory process.

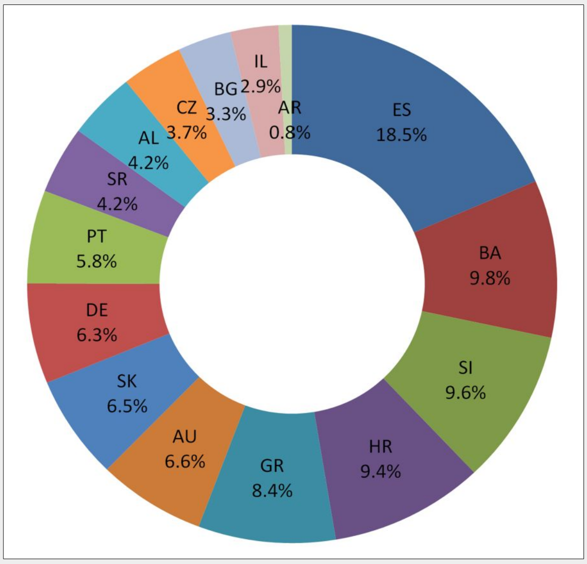

Fig. 1 - Distribution of respondents by country of origin. (AL): Albania; (BA): Bosnia and Herzegovina; (BG): Bulgaria; (HR): Croatia; (GR): Greece; (SI): Slovenia; (SR): Serbia; (CZ): Czech Republic; (DE): Germany; (SK): Slovakia; (PT): Portugal; (ES): Spain; (AR): Argentina; (AU): Australia; (IL): Israel.

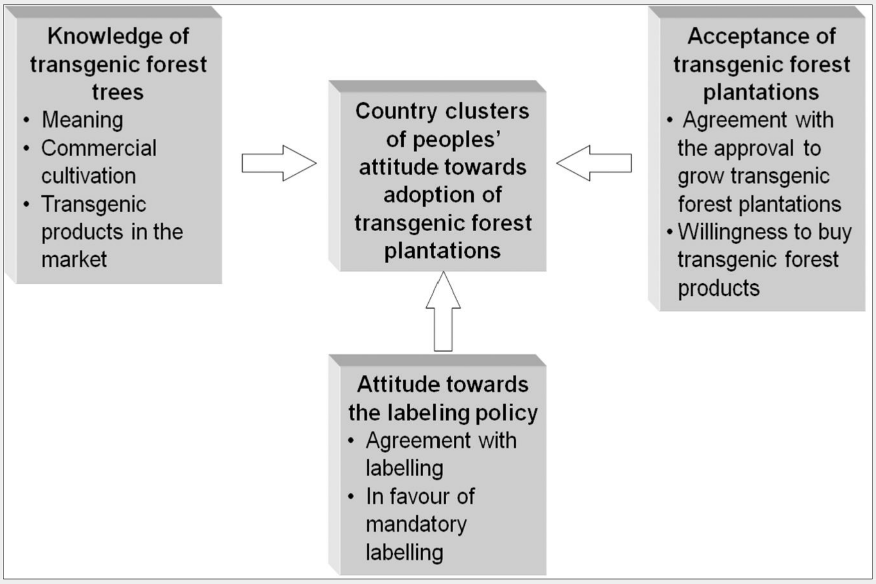

Fig. 2 - Relationships between clusters of countries.

Results and discussion

Respondents' demographic information

The respondents' demographic characteristics, in particular gender and average age by country of origin are displayed in Tab. 1. In general, the average age of respondents by country ranged from 20 to 27 years of age (all were university students) but was somewhat higher in Argentina (31) and Bulgaria (35), because postgraduate students were included in the sample population for these countries.

Respondents' knowledge of transgenic forest plantations

More than 60% of respondents in all countries stated that they knew the meaning of forest transgenic trees, with the exception of Israel where almost 60% stated that they did not know what was meant by this term. The highest percentage of respondents who stated to know what transgenic forest trees are, was recorded in Argentina (100%). A very high percentage of positive responses (95%) were also recorded in Portugal. Overall, the high degree of knowledge of transgenic forest trees might be attributed to the high educational level of the subjects (university students). In contrast, more than half of the respondents across most countries stated that they did not know whether transgenic forest tree crops were grown commercially. The lowest number of positive responses to this question was recorded in Australia (26%) and Israel (22%). In the remaining surveyed countries, the number of positive responses was higher, ranging from 30% to around 50% of the sample population. Furthermore, about 50% or more of the respondents in most countries declared that they did not know whether any final products from transgenic forest tree planta-

Tab. 1 - Respondents' demographic profile.

Countries	Gender		Average Age (Years)
	Males (%)	Females (%)	
Albania	34	66	23
Bosnia and Herzegovina	84	16	22
Bulgaria	44	56	35
Croatia	37	63	20
Greece	46	54	22
Slovenia	37	63	21
Serbia	75	25	20
Czech Republic	39	61	22
Germany	43	57	24
Slovakia	37	63	22
Portugal	29	71	22
Spain	43	57	22
Argentina	47	53	31
Australia	45	55	23
Israel	55	45	27

Tab. 2 - Cross-country comparison of respondents' positive responses about their knowledge of transgenic forest tree plantations. (Q1): "Do you know what a genetically modified forest tree is?"; (Q2): "Do you know if transgenic forest plantations are grown commercially?"; (Q3): "Do you know if final products of transgenic forest plantations are sold in the market?".

Countries	Q1	Q2	Q3
Albania	87	64	65
Bosnia & Herzegovina	80	42	56
Bulgaria	82	40	37
Croatia	71	46	52
Greece	65	46	51
Slovenia	86	30	32
Serbia	82	52	46
Czech Republic	79	56	29
Germany	88	41	36
Slovakia	75	30	40
Portugal	95	32	36
Spain	80	46	65
Argentina	100	73	53
Australia	62	26	30
Israel	42	22	13

tions, such as wood, biofuel, pulp and paper, was sold on the market. The highest number of positive responses with regard to this question was recorded in Spain and Albania (65% in both countries), while the lowest level of awareness was recorded in Israel (13%) and Australia (30%).

Detailed sample results for cross-country comparison of respondents' positive responses about their knowledge of transgenic forest tree plantations for all three questions are provided in Tab. 2.

Analysis of variances between the positive responses with reference to the three questions (Q1, Q2 and Q3) concerning the public knowledge of transgenic forest trees was explored with the ANOVA test. The null hypothesis tested was that the means of positive responses in all countries regarding the three questions Q1, Q2 and Q3 representing the variables for knowledge of transgenic forest trees were all equal. The null hypothesis H_o1 was rejected.

Respondents' attitudes towards adoption of transgenic forest tree plantations

The respondents appeared very positive about the approval of growing transgenic forest trees in plantations, excluding natural forests in all the countries involved in this survey. Even in the countries with the lowest numbers of positive responses to the relevant question (Q4), such as Bulgaria, Croatia, Greece and Serbia, almost 60% of the respondents would agree with permission to be granted for commercial transgenic forest tree plantations. The majority of respondents also appeared willing to buy products from such plantations, such as wood products or pulp and paper. These findings are compatible with the results of a recent study, which attempted to explore consumers' potential buying behavior towards transgenic forest products in Greece (Tsourgiannis et al. 2015).

Over 80% of respondents from all countries stated that they were in favor of using labeling to identify products of transgenic origin. The great majority of those respondents, also over 80% in all countries, argued that labeling should be legally mandated. The distribution of positive responses by country of origin with respect to questions Q4, Q5, Q6 and Q7, which are concerned with public attitudes towards the adoption of transgenic forest tree plantations are reported in Tab. 3.

Analysis of variances (ANOVA test) between the positive responses with reference to the questions Q4 and Q5 (representing acceptance of the use of transgenic forest trees in plantations) and the questions Q6 and Q7 (concerning the labeling policy of transgenic forest tree plantations) were performed. Both the null hypotheses, that tested whether the means of positive responses in all countries regarding the variables Q4 and Q5 (H_o2) and the variables Q6 and Q7 (H_o3) were equal, were rejected.

Country patterns of respondents' positive attitude responses regarding knowledge and adoption of transgenic forest tree plantations

In order to explore possible patterns on the basis of the country of origin, the *k*-means clustering was applied on the respondents' positive responses with respect to the different variables representing their knowledge and acceptance of the use of transgenic forest trees. The country patterns that were recognized appeared to have no correlation to the geographic origin of the countries, either between European countries or between European and non European countries. Specifically, regarding the respondents' positive responses to the variables representing knowledge of transgenic forest trees, four different clusters of countries were recognized based on the distances from each respective cluster center. The first country cluster consisted of two non-European countries, Australia and Israel, and involved positive responses with means ranging from about 50% with regard to variable Q1, which represents knowledge on what transgenic forest trees are, to very low means (~20%) with regard to variables Q2 and Q3 representing knowledge on commercial cultivation of transgenic forest tree plantations and knowledge on market availability of products from transgenic forest trees, respectively. Therefore, respondents in the first country cluster can be characterized as "less informed" with regard to their knowledge of the use of transgenic trees in plantations. The second country cluster consisted of Albania and Argentina and involved very high levels of positive responses. with means of about 95% with respect to Q1 that were followed by high levels of positive responses with

Tab. 3 - Cross-country comparison of public positive responses regarding acceptance of use of transgenic forest tree plantations. (Q4): "Would you agree with transgenic forest crops to be approved for commercial planting in forest tree plantations (not in natural forests)?"; (Q5): "Would you purchase the final products (wood products, pulp, paper etc) produced from transgenic forest plantations?"; (Q6): "Would you agree with the final products produced from transgenic forest plantations to be labeled to indicate that they originate from genetically modified trees?"; (Q7) "If YES, would you agree with the labeling of such products to be legally mandatory?"

Countries	Q4	Q5	Q6	Q7
Albania	74	76	88	83
Bosnia & Herzegovina	80	77	84	90
Bulgaria	56	60	93	93
Croatia	59	67	95	91
Greece	59	63	90	88
Slovenia	81	86	82	80
Serbia	63	36	88	90
Czech Republic	93	94	77	81
Germany	89	89	91	86
Slovakia	82	85	93	90
Portugal	91	92	98	99
Spain	75	75	96	94
Argentina	93	93	80	73
Australia	83	85	97	90
Israel	85	85	94	87

respect to Q2 and Q3 with approximate means of 70% and 60%, respectively. Therefore, the respondents in this second country cluster can be characterized as "very highly informed" with regard to their knowledge of the use of transgenic trees in plantations. The third country cluster consisted of five countries – Bosnia and Herzegovina, Croatia, Greece, Serbia and Spain – with means of positive responses to Q1 of about 80%, low positive responses to Q2 with an approximate mean of 45% and a high mean of positive responses to Q3 of about 60%. Consequently, the respondents in this third country cluster can be characterized as "highly informed" with regard to their knowledge of the use of transgenic trees in plantations. Finally, the fourth country cluster consisted of six countries – Bulgaria, Slovenia, Czech Republic, Germany, Slovakia and Portugal. Countries in this cluster provided positive responses to Q1 with very high means of around 85% and low means of positive responses to Q2 and Q3 of around 40%. Respondents in this fourth country cluster can therefore be characterized as "moderately informed" with regard to their knowledge of the use of transgenic trees in plantations.

In terms of positive responses to variables Q4 and Q5, two different clusters of countries were determined on the basis again of the distances from each respective cluster center. Variables Q4 and Q5 were used to represent the respondents' agreement to approvals of transgenic forest trees for commercial forest tree plantations and their willingness to purchase products of transgenic origin, respectively. The first country cluster consists of six countries – Albania, Bulgaria, Croatia, Greece, Serbia and Spain. It involved positive responses with means of 65% and 67% with regard to Q4 and Q5, respectively. Therefore, the respondents in the first country cluster could be characterized as "favorable" with regard to their agreement on the use of transgenic trees in plantations and their willingness to buy transgenic forest products. The second country cluster consists of the remaining nine countries – Bosnia and Herzegovina, Slovenia, Czech Republic, Germany, Slovakia, Portugal, Argentina, Australia and Israel – all having very high means of positive responses that range between 86% and 88% for Q4 and Q5, respectively. The respondents in this second country cluster could be characterized as "strongly favorable" with regard to their agreement to the use of transgenic trees in plantations and their willingness to buy transgenic forest products.

Regarding the respondents' positive responses to variables Q6 and Q7 two different clusters of countries were identified, also on the basis of distances from each respective cluster center. Variables Q6 and Q7 were used to represent the respondents' agreement with the labeling of transgenic forest products and the requirement for this to be legally mandatory, respectively. The first country cluster consisted of four countries – Albania, Slovenia, Czech Republic and Argentina. It involved positive responses with very high means of about 82% and 79% for Q6 and Q7, respectively. The respondents in this country cluster can be characterized as "strongly favorable" to the labeling of transgenic forest products and the requirement for this to be legally mandatory. The second country cluster consisted of the remaining eleven countries – Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Serbia, Germany, Slovakia, Portugal, Spain, Argentina, Australia and Israel – that revealed very high means of positive responses ranging between 93% and 91% for Q6 and Q7, respectively. The respondents of this second country cluster can be characterized as "very strongly favorable" towards the labeling of transgenic forest products and the requirement for this to be legally mandatory.

The plot of means for each country cluster regarding all the seven questions is shown in Fig. 3, the members of each country clusters are listed in Tab. 4 and the results of the corresponding analysis of variance are reported in Tab. 5.

The potential benefits of transgenic forest tree plantations that were rated as "very important" in at least half of the surveyed countries involved the use of fewer chemicals and energy, and the harvesting of a smaller number of trees for consumption needs, both associated to cellulose isolation by modified low-lignin wood. Also rating as "very important" were the use of fewer insecticides, pesticides and herbicides in forest tree plantations as a consequence of modified traits related to insect, pest and herbicide resistance, the restoration of contaminated soils connected with

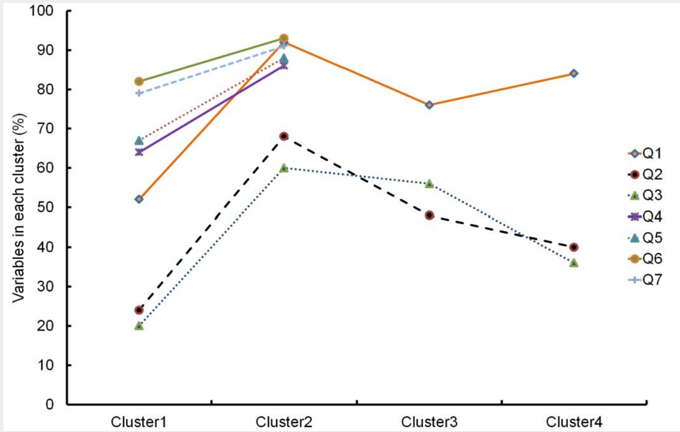

Fig. 3 - Plot of means for each country cluster based on positive responses to the questions about knowledge and acceptance of the use of transgenic forest tree plantations.

Tab. 4 - Country patterns of respondents' positive attitude responses regarding the knowledge of transgenic forest tree plantations and the acceptance of their use. (CDist): distance from the respective cluster center.

No. of country	Country members of clusters	Q1, Q2, Q3		Q4, Q5		Q6, Q7	
		Cluster	CDist	Cluster	CDist	Cluster	CDist
1	Albania	2	5.73	1	9.18	1	5.15
2	Argentina	2	5.73	2	6.19	1	4.59
3	Australia	1	7.66	2	2.88	2	3.13
4	Bosnia & Herzegovina	3	3.77	2	8.56	2	6.13
5	Bulgaria	4	2.00	1	7.84	2	1.63
6	Croatia	3	2.90	1	3.77	2	1.68
7	Czech Republic	4	11.26	2	6.66	1	3.57
8	Germany	4	2.81	2	2.22	2	3.54
9	Greece	3	6.36	1	4.86	2	2.68
10	Israel	1	7.66	2	1.90	2	2.81
11	Portugal	4	7.22	2	4.66	2	6.97
12	Serbia	3	6.74	1	3.21	2	3.32
13	Slovakia	4	7.65	2	3.48	2	0.57
14	Slovenia	4	5.13	2	3.88	1	0.56
15	Spain	3	6.84	1	9.29	2	3.32

Tab. 5 - Analysis of variance of positive responses between the seven questions representing variables for knowledge and acceptance of use of transgenic forest tree plantations.

Variable	Between SS	df	Within SS	df	F	Prob.
Q1	2080.40	3	748.53	11	10.23	0.001633
Q2	2220.40	3	600.53	11	13.56	0.000515
Q3	2424.43	3	494.50	11	17.98	0.000150
Q4	1742.40	1	553.33	13	40.93	0.000024
Q5	1440.00	1	451.33	13	41.47	0.000022
Q6	347.64	1	237.30	13	19.05	0.000767
Q7	386.40	1	186.93	13	26.87	0.000176

increased tree stress/poison tolerance and higher tree productivity attributed to disease resistance and modification of growth factors. The percentages of respondents, who rated each of these potential benefits of GM forest tree plantations as "very important" in each country are presented in Fig. 4 and Fig. 5. In the group of countries consisting of Albania, Serbia, Greece, Bulgaria, Bosnia and Herzegovina, Portugal, Spain, Germany and Australia more than 45% of the respondents stated that these potential benefits would be very important for their countries. On the other hand, in Argentina, Israel, Czech Republic, Croatia, Slovenia and Slovakia a high proportion of the respondents (ranging from one third in Israel up to two thirds in Slovakia) stated that they were not able to rate the importance of these potential benefits of GM plantations due to lack of relevant knowledge on these issues.

With regard to safety concerns, the potential loss of biodiversity due to potential gene flow between transgenic and wild trees was identified by the respondents as the issue of most concern about the adoption of transgenic forest tree plantations in all countries. However, the proportion of respondents identifying the potential loss of biodiversity as the most important safety issue of concern ranged from 30-34% in

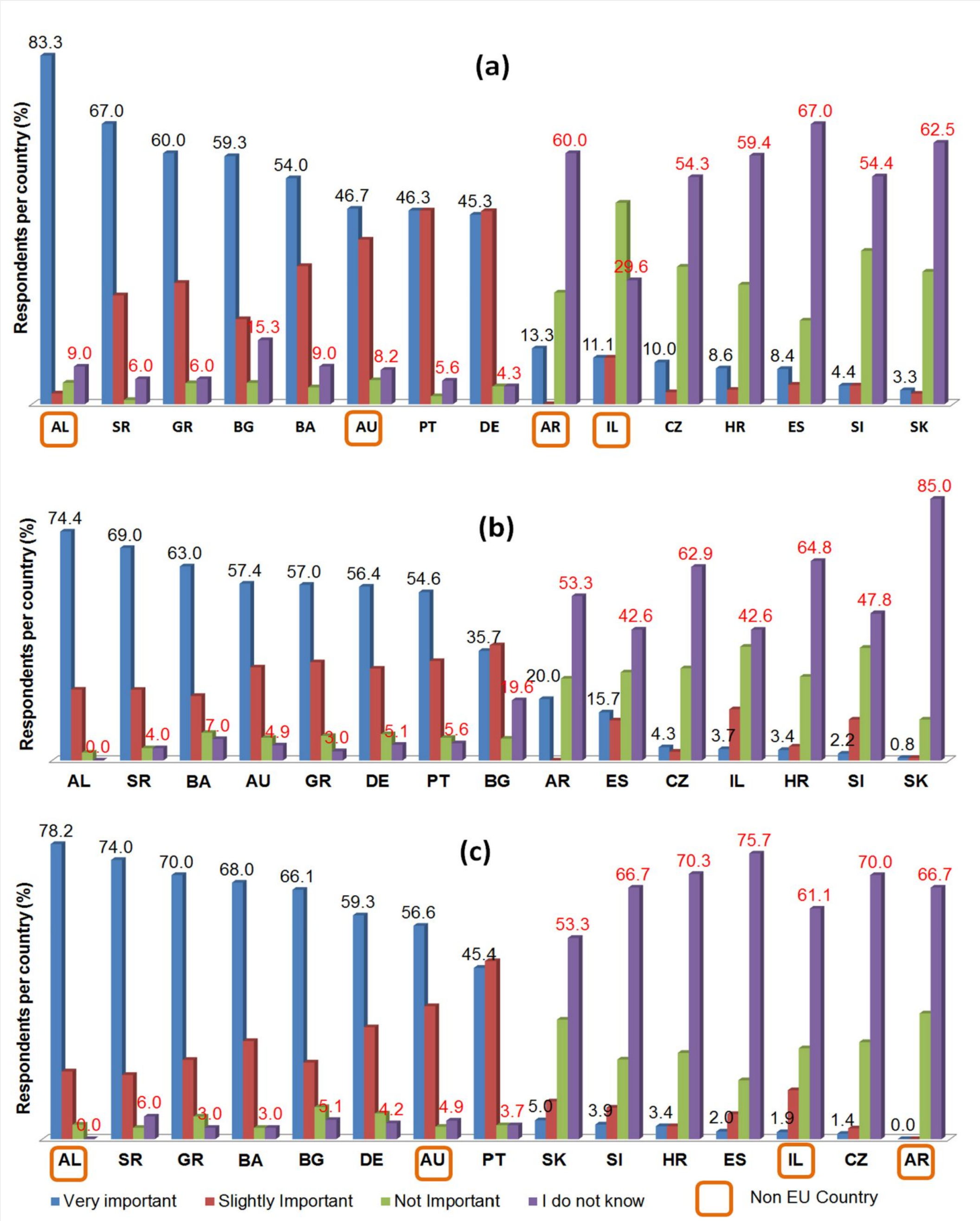

Fig. 4 - Respondents' attitudes about the importance of transgenic forest tree plantations potential benefit related to A) the use of less chemicals and energy to isolate cellulose from wood, B) the harvesting of a smaller number of trees for consumption needs and C) the use of fewer insecticides/pesticides in plantations. (AL): Albania; (BA): Bosnia and Herzegovina; (BG): Bulgaria; (HR): Croatia; (GR): Greece; (SI): Slovenia; (SR): Serbia; (CZ): Czech Republic; (DE): Germany; (SK): Slovakia; (PT): Portugal; (ES): Spain; (AR): Argentina; (AU): Australia; (IL): Israel.

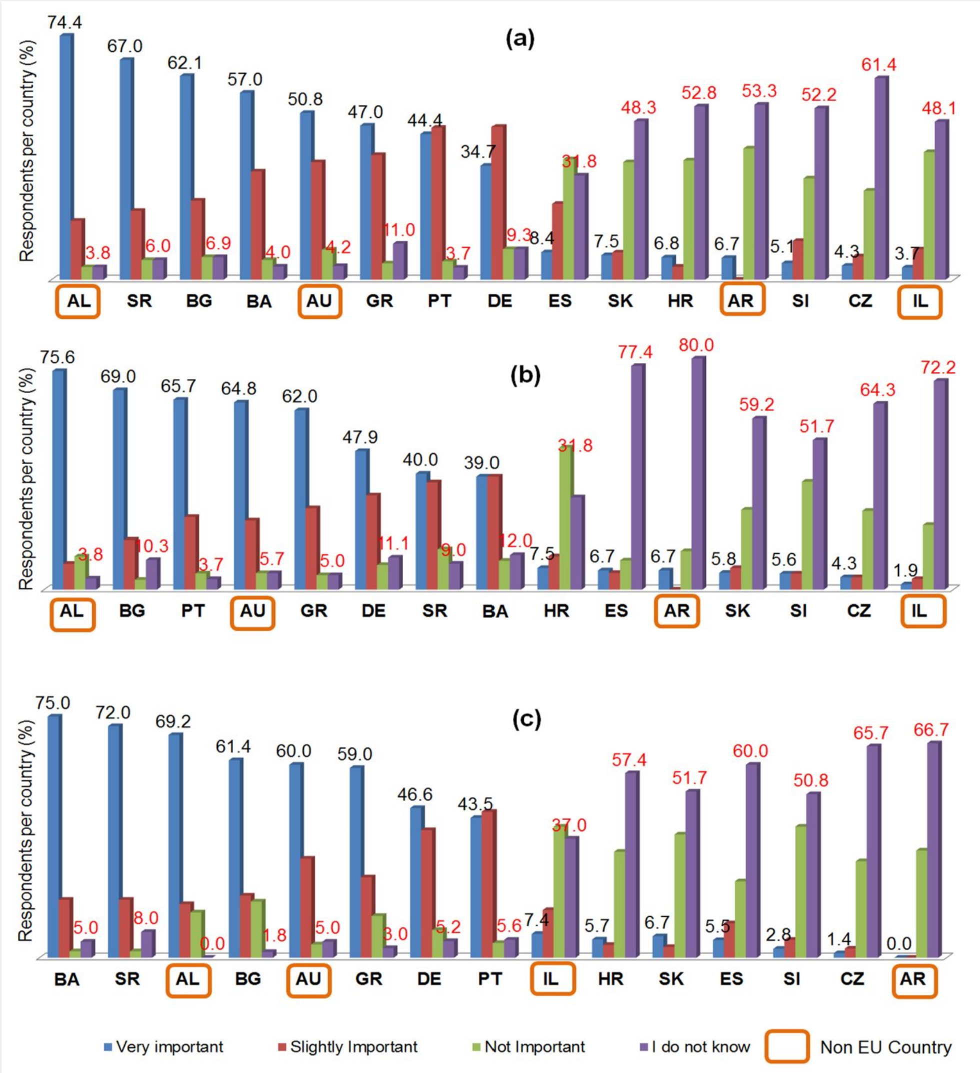

Fig. 5 - Respondents' attitudes about the importance of transgenic forest tree plantations potential benefit related to A) less herbicide treatments of plantations, B) restoration of contaminated soils and C) higher tree productivity. (AL): Albania; (BA): Bosnia and Herzegovina; (BG): Bulgaria; (HR): Croatia; (GR): Greece; (SI): Slovenia; (SR): Serbia; (CZ): Czech Republic; (DE): Germany; (SK): Slovakia; (PT): Portugal; (ES): Spain; (AR): Argentina; (AU): Australia; (IL): Israel.

some countries, such as Slovenia, Bosnia and Herzegovina, Albania and Australia, to 38-43% in Israel, Slovakia, Germany, Serbia, Spain and Greece, up to 46-59% in Bulgaria, Argentina, Portugal and Croatia. The distribution of the respondents' concerns about the potential loss of biodiversity as the most important safety issue of concern is summarized in Fig. 6.

The potential negative impacts associated with transgenic forest tree plantations that were rated as "serious hazards" were a potential for higher vulnerability of forest trees to viral and other diseases due to modification of lignin content, an increased use of broad-spectrum herbicides due to modification to herbicide resistance, potential loss of biodiversity due to gene flow between transgenic and wild trees, adverse effects on bio-trophic processes of host ecosystems if new genetic traits enter these ecosystems and potential cultural adaption to changing biodiversity conditions due to transgene escape. The distribution of respondents' who rated each of these potential hazards of GM forest tree plantations as "serious hazards" in each country is presented in Fig. 7. In the group of countries consisting of Albania, Serbia, Greece, Bulgaria, Bosnia and Herzegovina, Spain and Australia, more than 40% of the respondents in each country stated that these potential risks would constitute a "serious hazard" for their countries. In Portugal, more than 60% of the respondents were of the opinion that these potential risks would be a "slight hazard" for their country. The same trend was observed in Germany for most of these potential risks. On

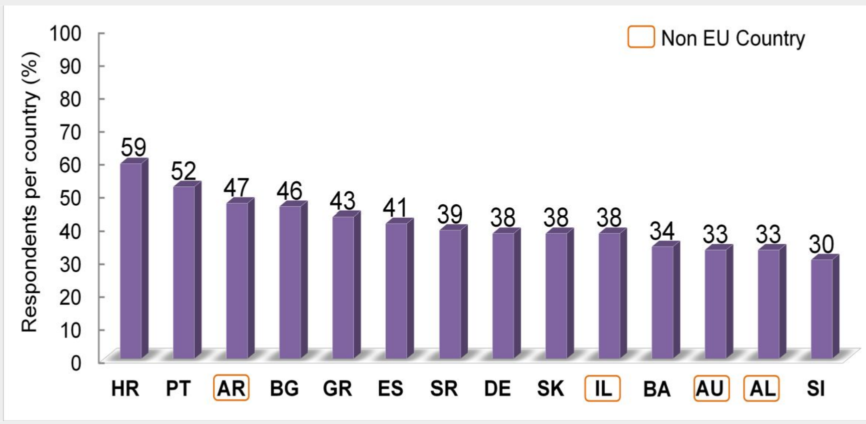

Fig. 6 - Respondents' attitude about potential loss of biodiversity as the most important safety issue of concern regarding the use of transgenic trees in plantations. (AL): Albania; (BA): Bosnia and Herzegovina; (BG): Bulgaria; (HR): Croatia; (GR): Greece; (SI): Slovenia; (SR): Serbia; (CZ): Czech Republic; (DE): Germany; (SK): Slovakia; (PT): Portugal; (ES): Spain; (AR): Argentina; (AU): Australia; (IL): Israel.

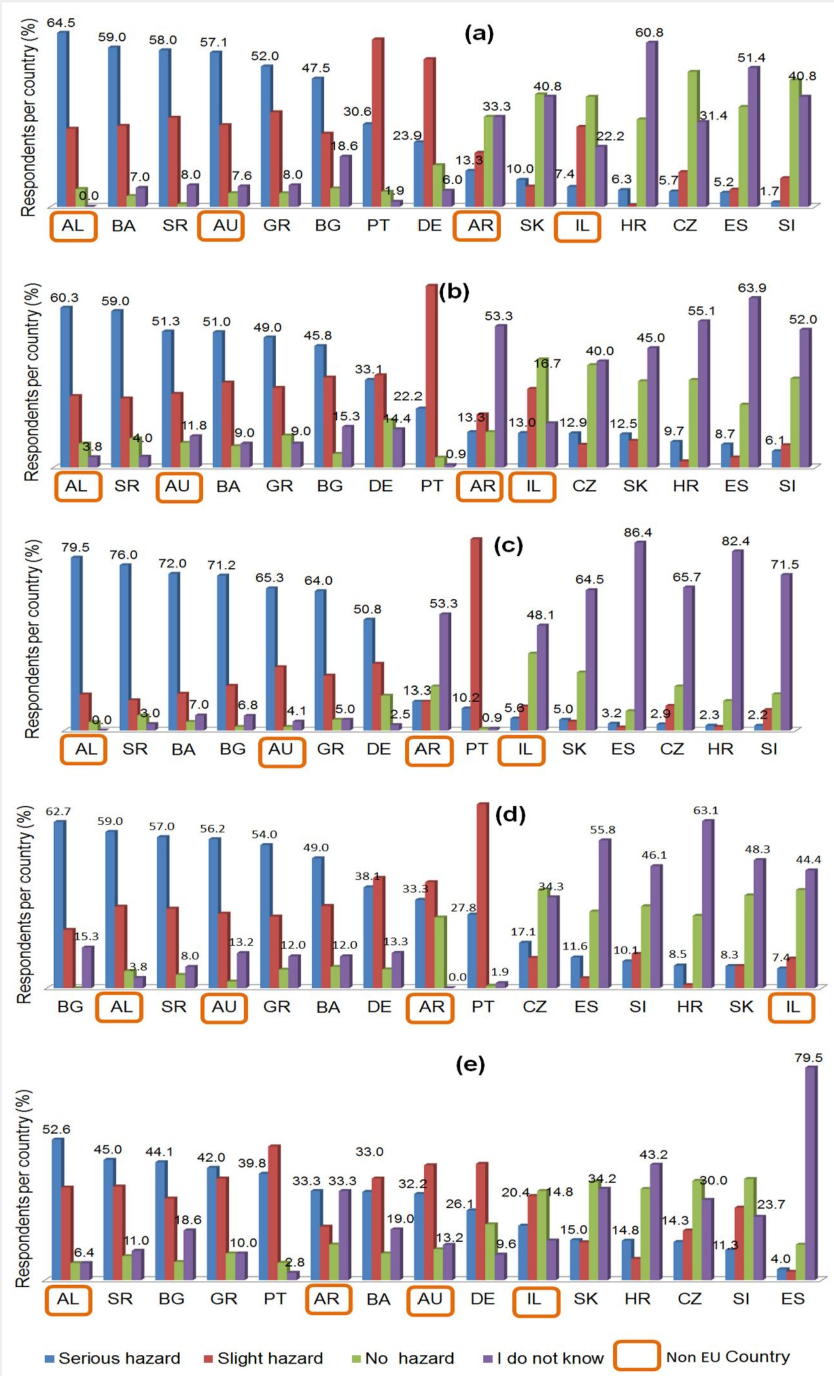

Fig. 7 - Respondents' attitude about the importance of transgenic forest tree plantations potential hazards related to A) higher vulnerability of forest trees to viral or other diseases, B) increased use of broad spectrum herbicides, C) loss of biodiversity, D) adverse effects on bio-trophic processes of host ecosystems, E) cultural adaption to changing biodiversity conditions. (AL): Albania; (BA): Bosnia and Herzegovina; (BG): Bulgaria; (HR): Croatia; (GR): Greece; (SI): Slovenia; (SR): Serbia; (CZ): Czech Republic; (DE): Germany; (SK): Slovakia; (PT): Portugal; (ES): Spain; (AR): Argentina; (AU): Australia; (IL): Israel.

the other hand, in Argentina, Israel, Czech Republic, Croatia, Slovenia and Slovakia a high proportion of the respondents (ranging from one third in Israel up to two thirds in Slovakia) stated that they were not able to rate how serious any of these potential negative impacts of GM forest tree plantations would be due to lack of relevant knowledge on these issues.

The stated lack of knowledge about the potential benefits and risks of transgenic forest tree plantations by the respondents in almost half of the surveyed countries is of particular concern. Clearly, an educational effort is required which should be based on credible scientific information to increase public awareness and to inform the ongoing debate about potential benefits and risks of transgenic forest tree plantations. Such an effort might well contribute to even greater public acceptance and at the same time generate the required market input for the safe, profitable and sustainable cultivation of transgenic forest tree plantations.

Conclusions

In this paper we presented the results of a cross-country pilot survey, which was conducted to gather information and identify patterns in public attitudes towards the use of transgenic forest trees in plantations. The results were based on responses from university students of different fields of study, that is, young, educated people aged 18 to 35 years. Respondents came from fifteen countries including Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Greece, Serbia, Slovakia, Slovenia, Spain and Portugal located in Europe, Argentina located in South America, Israel in West Asia and Australia.

The results presented in this paper provided novel cross-country insights into the attitudes of young people towards the acceptance of cultivation of transgenic forest trees. Several reasons add value to the results of this paper work. First, it is a pioneer, pilot empirical study brought to publicity on issues related to public acceptance and attitudes towards transgenic forest tree cultivation, as most of the published work to date includes general studies on public attitudes towards biotechnology, such as the Eurobarometer studies and agricultural biotechnology in particular. Second, focusing on young people aged 18 to 35 years it is important, because at this stage commercial GM forest plantations are not grown anywhere in the world except China, and therefore this focus group represents the future consumers, policy-makers or developers. Furthermore, the cross-sectional data from European and non-European countries provided the required information to identify patterns regarding the knowledge, perceptions on benefits and risks, as well as acceptance of the use of transgenic forest trees in plantations. The key findings of our cross-country pilot survey can be summarized as follows.

No differences in patterns of public attitude towards the acceptance of the commercial growing of transgenic forest trees were observed between European and non-European countries. Overall, the young educated people that took part in the survey appeared to know the meaning of the transgenic forest trees, but they were not sufficiently informed about the status of commercial cultivation of transgenic forest trees and potential market availability of transgenic forest products. Also, respondents appeared to approve the use of transgenic forest trees in plantations and not in natural forests, and would be willing to buy forest transgenic products. In addition, they would like these products to be labeled, so as to indicate their transgenic origin and would be in favor of a mandatory labeling policy.

However, the potential loss of biodiversity due to a risk of gene flow between transgenic and wild trees was seen as the safety issue of most concern when the commercial release of transgenic forest trees is considered, although the response percentage ranged between 30 and 60% of the sample population in each of the surveyed countries.

The potential benefits of transgenic forest tree plantations that were rated as "very important" in the country context in at least half of the surveyed countries included the use of fewer chemicals and energy to isolate cellulose from wood, the harvesting of a smaller number of trees for consumption needs, the use of fewer insecticides, pesticides and herbicides, the restoration of contaminated soils and higher tree productivity.

Potential higher vulnerability of forest trees to viral and other diseases, an increased use of broad-spectrum herbicides, loss of biodiversity due to gene flow between transgenic and wild trees, adverse effects on bio-trophic processes of host ecosystems if new genetic traits enter these ecosystems and the potential cultural adaption to changing biodiversity conditions due to transgene escape were all seen as serious hazards in a country context.

Last, but not least the serious perceived lack of knowledge about potential benefits and risks of the cultivation of transgenic forest trees in plantations recorded in most of the countries has to be highlighted.

The results of our study contribute to the improvement of the scientific basis that is required for safe tree development and implementation of policy directives, particularly at the EU level. However, certain limitations of our study need to be stated, so as any future efforts to this purpose would provide better insights in the issues under concern. The study is limited in its scope, as it involves a specific focus group of young educated people. Therefore, a more elaborated and larger scale social research is required prior to any generalization of patterns or trends regarding broader public attitudes towards the use of transgenic forest trees in plantations. Our pattern analysis so far has included the geographic origin of the respondents with regard to knowledge, perceptions and acceptance of the growing of transgenic forest trees. Other correlations associated with the different disciplines of the students used as sample population, the year of study, the gender and age or whether field trials exist in the country or not, should be further explored and brought to publicity. The authors have already begun such effort.

In conclusion, the positive attitude of young people towards the cultivation of transgenic forest tree plantations might be seen as a driver for future market adoption of products from transgenic forest trees. Extended research on the issues of public knowledge, perceptions and acceptance of the use of transgenic forest trees should be undertaken in order to provide the scientific knowledge required for policy implementation on safe tree development. The perceived lack of knowledge revealed in our study even among the young educated people indicates that a combined governance and educational effort should be promoted to increase public awareness and disseminate adequately the state-of-the-art scientific knowledge, as this will most likely determine market opportunities for transgenic forest tree products.

Acknowledgements

The authors acknowledge the support of the EU COST Action FP0905 on "Biosafety of forest transgenic trees: improving the scientific basis for safe tree development and implementation of EU policy directives". The authors would like also to thank all the students of the following Universities who participated in the survey: 1. Agricultural University of Tirana, Albania; 2. University Nacional de la Plata, Argentina; 3. University of Melbourne, Australia; 4. University of Banja Luka, Bosnia and Herzegovina; 5. Forestry University of Sofia, Bulgaria; 6. University of Zagreb, Croatia; 7. Czech University of Life Sciences, Prague, Czech Republic; 8. Charles University, Prague, Czech Republic; 9. University of Economics, Prague, Czech Republic; 10. University of Goettingen, Germany; 11. University of Hamburg, Germany; 12. University of Thuenen, Ahrenburg, Germany; 13. University of Berlin, Germany; 14. University of Hannover, Germany; 15. Eastern Macedonia & Thrace Institute of Technology, Greece, 16. Hebrew University, Israel; 17. Ben Gurion University, Israel; 18. Instituto Superior de Agronomia, University of Lisbon, Portugal; 19. University of Algarve, Portugal; 20. Instituto Politecnico de Castelo Branco, Portugal; 21. University of Belgrade, Serbia; 22. University of Singidunum, Serbia; 23. University of Novi Sad, Serbia; 24. Constantine the Phylosopher University in Nitra, Slovakia; 25. Slovak University of Agriculture in Nitra; 26. Comenius University in Bratislava, Slovakia; 27. University of Ljubljana, Slovenia; 28. Universidade de Santiago de Compostela, Spain. Furthermore, the authors thank Leonor Morais and Helena Almeida (ISA-UL), Alfredo Cravador (Univ. Algarve) and Margarida Ataíde (IPCB) for their support in carrying out the survey in Portugal. Finally, Susana Araújo and Jorge A.P. Paiva acknowledge the *Fundação para a Ciência e a Tecnologia* (FCT, Portugal) for the research contract within the frame of the *Programa Ciência* 2008 funded by POPH (QREN) and Gregor Bozic the Slovenian Research Agency for the research contract P4-0107.

References

Aguilera J, Nielsen K, Sweet J (2013). Risk assessment of GM trees in the EU: current regulatory framework and guidance. iForest - Biogeosciences and Forestry 6 (3): 127-131. - doi: 10.3832/ifor0101-006

Amin L, Hassan Z, Ibrahim M, Ibrahim R (2014). Gender effect on awareness and attitude toward genetically modified foods and medicine. Journal of Food, Agriculture and Environment 12 (1): 2-7.

Bishop CM (2006). Pattern recognition and machine learning. Springer-Verlag, New York, USA, pp. 740. [online] URL: http://cds.cern.ch/record/998831/files/9780387310732_TOC.pdf

Buah JN (2011). Public perception of genetically modified food in Ghana. American Journal of Food Technology 6 (7): 541-554. - doi: 10.3923/ajft.2011.685.694

Chapotin SM, Wolt JD (2007). Genetically modified crops for the bioeconomy: meeting public and regulatory expectations. Transgenic Research 16 (6): 675-688. - doi: 10.1007/s11248-007-9122-y

Cormick C (2004). Australian attitudes to GM foods and crops. In: Proceedings of the "14th Australian Weeds Conference" (Sindel BM, Johnson SB eds). Charles Sturt University, Wagga Wagga (New South Wales, Australia) 6-9 Sep 2004, pp. 14-17. [online] URL: http://www.caws.org.au/awc/2004/awc200410141.pdf

Costa-Font M, Gil JM, Traill WB (2008). Consumer acceptance, valuation of and attitudes towards genetically modified food. Review and implications for food policy. Food Policy 33 (2): 99-111. - doi: 10.1016/j.foodpol.2007.07.002

Druckman JN, Kam CD (2009). Students as experimental participants: a defense of the "narrow" data base. Social Science Research Network, Rochester, NY, USA, pp. 34. [online] URL: http://ssrn.com/abstract=1498843

El-Lakany MH (2004). Are genetically modified trees a threat to forests? Unasylva 55 (1): 45-47. [online] URL: http://www.cof.orst.edu/cof/teach/agbio2011/Readings2011/El_LakanyGMTrees Unsylva2004.pdf

European Commission (2010). Europeans and biotechnology in 2010 – winds of change? Publications Office of the European Union, Luxembourg, pp. 172.

FAO (2008). The potential environmental, cultural and socio-economic impacts of genetically modified trees. UNEP/CBD/SBSTTA/13/INF/6, FAO, Rome, Italy, pp. 17.

FAO (2010). Forests and genetically modified trees. FAO, Rome, Italy, pp. 235.

Farnum P, Lucier A, Meilan R (2007). Ecological and population genetics research initiatives for transgenic trees. Tree Genetics and Genomes 3: 119-133. - doi: 10.1007/s11295-006-0063-z

Ferguson CA, Chan-Halbrendt C, Wieczorek A, Wen N (2002). Results from a Hawaii opinion survey on Genetically Modified Organisms. BIO-2, CTAHR, ScholarSpace, University of Hawaii, Honululu, USA, pp. 6. [online] URL: http://hdl.handle.net/10125/3348

Flachowsky H, Hanke M-V, Peil A, Strauss SH, Fladung M (2009). A review on transgenic approaches to accelerate breeding of woody plants. Plant Breeding 128: 217-226. - doi: 10.1111/j.1439-0523.2008.01591.x

Grice J, Wener MK, Romanach LM, Paton S, Bonaventura P, Garrad S (2003). Genetically modified sugarcane: a case for alternate products. AgBioForum 6 (4): 162-168. [online] URL: http://www.agbioforum.org/

Häggman H, Find JM, Pilate G, Gallardo F, Ruohonen-Lehto M, Kazana V, Migliacci F, Ionita L, Sijacic-Nikolic M, Donnarumma F, Harfouche A, Biricolti S, Glandorf B, Tsourgiannis L, Minol K, Paffetti D, Fladung M, Vettori C (2012). Biosafety of genetically modified forest trees (GMTs) – COST Action FP0905 – a common action of European scientists. In: Proceedings of the "2nd International Conference of the IUFRO Working Party 2.09.02". Mendel lectures & Plenary MLP-3, pp. 13.

Häggman H, Raybould A, Borem A, Fox T, Handley L, Hertzberg Lu M M, Macdonald P, Oguchi T, Pasquali G, Pearson L, Peter G, Quemanda H, Seguin A, Tattersall K, Ulian E, Walter C, McLean M (2013). Genetically engineered trees for plantation forests: key considerations for environmental risk assessment. Plant Biotechnology Journal 11 (7): 785-798. - doi: 10.1111/pbi.12100

Hoban TJ (2004). Public attitudes towards agricultural biotechnology. ESA Working Paper No. 04-09, FAO, Rome, Italy, pp. 14. [online] URL: http://www.fao.org/es/esa

Jain AK (2010). Data clustering: 50 years beyond k-means. Pattern Recognition Letters 31:651-666. - doi: 10.1016/j.patrec.2009.09.011

Maes J, Gheysen G, Valcke M (2014). Attitudes of the general public towards genetically modified organisms (GMOs): the paradoxical relationship between knowledge and attitudes. In: Proceedings of the "13th International Public Communication of Science and Technology Conference". Salvador (Brazil) 5-8 May 2014, pp. 11. [online] URL: http://www.pcst-2014.org/pcst_proceedings/artigos/jasmien_maes_godelieve_gheysen_martin_valcke_oral_communication.pdf

Murty MN, Jain AK, Flynn PJ (1999). Data clustering: A review. ACM Computing Surveys 31 (3): 264-323. - doi: 10.1145/331499.331504

Harfouche A, Meilan R, Altman A (2011). Tree genetic engineering and applications to sustainable forestry and biomass production. Trends in Biotechnology 29 (1): 11-17. - doi: 10.1016/j.tibtech.2010.09.003

Hinchee M, RottmanW, Mullinax L, Zhang C, Chang S, Cunningham M, Pearson L, Nehra N (2009). Short-rotation woody crops for bioenergy and biofuels applications. In Vitro Cellular and Developmental Biology - Plant 45 (6): 619-629. - doi: 10.1007/s11627-009-9235-5

Hossain F, Oryango B, Adelaja A, Schilling B, Hallman W (2002). Public perceptions of biotechnology and acceptance of Genetically Modified Food. Food Policy Institute Publication No. WP-0602-002, Rutgers, New Brunswick, NJ, USA, pp. 31. [online] URL: http://core.ac.uk/download/pdf/6553906.pdf

Magnusson M (2004). Consumer perception of organic and genetically modified foods. Acta Universitatis Upsaliensis, Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences 137, Uppsala, Sweden, pp. 71. [online] URL: http://www.diva-portal.org/smash/record.jsf?pid=diva2:164405&dswid=-2653

Pereira de Abreu DA, Rodriguez KV, Schroeder M, Mosqueda MB, Perez E (2006). GMO technology. Venezuelans' consumers perceptions: situation in Caracas. Journal of Technology Management and Innovation 1 (5): 80-86. [online] URL: http://www.jotmi.org/index.php/GT/article/viewArticle/371

Peterson RA (2001). On the use of college students in social science research: insights from a second order meta-analysis. Journal of Consumer Research 28 (3): 450-461. - doi: 10.1086/323732

Sedjo RA (2006). Toward commercialization of genetically engineered forests: economic and social considerations. Resources for the Future, Washington, DC, USA, pp. 46. [online] URL: http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-Rpt-CommercializationGEForests.pdf

Shehata S, Cox LJ (2007). Attitudes of Hawaii consumers toward genetically modified fruit, BIO-7, UH-CTAHR, Apr. 2007, ScholarSpace, University of Hawaii, Honululu, HI, USA, pp. 8. [online] URL: http://hdl.handle.net/10125/12173

Tsourgiannis L, Kazana V, Iakovoglou V (2015). Exploring the potential behavior of consumers towards transgenic forest products: the Greek experience. iForest - Biogeosciences and Forestry 8 (5): 707-713. - doi: 10.3832/ifor1339-007

Valenzuela S, Balocchi C, Rodriguez J (2006). Transgenic trees and forest biosafety, Electronic Journal of Biotechnology 9 (3): 335-339. - doi: 10.2225/vol9-issue3-fulltext-22

Van Frankenhuyzen K, Beardmore T (2004). Current status and environmental impact of transgenic forest trees. Canadian Journal of Forest Research 34 (6): 1163-1180. - doi: 10.1139/x04-024

Williams CG, Davis BH (2005). Rate of transgene spread via long-distance seed dispersal in *Pinus taeda*. Forest Ecology and Management 21: 95-102. - doi: 10.1016/j.foreco.2005.05.052

Williams GC (2006). Opening Pandora's box: governance for genetically modified forests. ISB News Report, January 2006, Wageningen Library, The Netherlands, pp. 4. [online] URL: http://library.wur.nl/WebQuery/file/cogem/cogem_t4513c612_001.pdf

Wnuk A, Kozak M (2011). Knowledge about and attitudes to GMOs among students from various specializations. Outlook on Agriculture 40 (4): 337-342.