Genetically Modified Crops – A Potential Risk for Sustainable Agriculture

Gordana Zdjelar, Zorica Nikolić
Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia
e-mail: gordana.zdjelar@nsseme.com

Abstract

The concept of sustainability applied to agriculture has developed mainly as a result of growing awareness of negative impacts of intensive agriculture production systems on the environment and the quality of life. Intensive agriculture systems are based on genetically uniform crops which can be susceptible to various diseases and insect pests. Genetically modified (GM) crops have been developed in an attempt to expedite the process of crop improvement for food quality and solve some of the problems associated with commercial agriculture, including disease and weed management. The introduction of GM crops into agriculture has opened a great debate about their safety with respect to possible long-term adverse effects on the environment, human health and sustainability of this new agricultural technology. Environmental safety issues focus on the direct or indirect effects of GM crops on non-target organisms and the transfer of GM traits to populations of wild plants via gene flow. Food safety concerns relate to the potential allergenicity of food products. Herbicide tolerant Roundup Ready (RR) soybean is the dominant GM crop occupying 50% of the global biotech area. It is one of seven transgenic soybean lines authorized for the EU market, none of those for cultivation. The most serious problem for farmers who grow RR soybean is the outbreak of glyphosate-resistant weeds, or "superweeds" which can lead to overuse of selective broad-leaf herbicides or herbicide mixtures.

Key words: soybean, herbicide resistance, superweeds

Introduction

Sustainable agriculture. Lewandowski et al. (1999) defined sustainable agriculture as "the management and utilization of the agricultural ecosystem in a way that maintains its biological diversity, productivity, regeneration capacity, vitality, and ability to function, so that it can fulfil – today and in the future – significant ecological, economic and social functions at the local, national and global levels and does not harm other ecosystems". Sustainable development means that economic growth should be promoted but guided in ways to improve the total quality of life both now and in the future, in a manner that maintains the ecological processes upon which life depends (Grice and Lawrence, 2004).

The concept of sustainability applied to agriculture has developed mainly as a result of growing awareness of negative impacts of intensive agriculture production systems on the environment and the quality of life in European rural areas. Intensive agriculture systems are based on genetically uniform crops which can be susceptible to various diseases and insect pests, whereas the extensive agriculture systems are based on crops with wide genetic variation for pest and disease resistance. New varieties require adequate soil moisture, protection against weeds, and protection against pests. Those are provided through the use of chemical fertilizers, irrigation where necessary, and the application of herbicides and pesticides which can cause polluted air, water, soil and decreased food quality. Intensification and wide use of hybrids also result in homogenization and destruction of traditional landscape elements and, consequently, loss of habitats. Marginal areas, on the other hand, are threatened with cessation of agricultural practices and land abandonment. All these factors also lead, directly or indirectly, to the loss of biodiversity.

Awareness is growing that many modern agricultural practices are unsustainable and that alternative ways of ensuring food security must be found. There is a global need to move towards the sustainable production of the food, feed, fuel and fiber for an expanding population on limited and degrading land resources (Nickson, 2005). In recent years, introduction of genetic engineering technologies into agriculture has raised a great debate among scientists, consumers and policy makers with regards to their potential consequences upon the environment, health, and the sustainable development. It is necessary to further examine the issue of GM crops in order to decide whether their cultivation can be considered sustainable and responsible.

Genetically modified crops. The global area in which genetically modified (GM) crops are grown is increasing. In 2011, 29 countries planted commercialized GM crops; eight out of those are members of the European Union (EU). Some of the countries in the EU have authorized the contained cultivation of GM crops but not the commercial cultivation. The largest producers of GM crops are the USA, Brazil, Argentina, India and Canada. Between 1996 and 2011, the global area of GM crops increased from 1.7 million hectares in 1996 to 160 million hectares in 2011. Thus, year-on-year growth measured either in absolute hectares or by percent, was higher in developing countries than industrial countries (James, 2011).

The first genetically modified plant was introduced into commercial production in the USA in 1994. That was Flavr Savr, tomato with delayed ripening (Holst-Jensen, 2009). According to Brookes and Barfoot (2005), 1996 was the first year in which a significant area was planted with crops containing GM traits. Since then, GM plants have become an integral part of agricultural production and there are more and more GM plant species that are commercially available. GM soybean continues to be the dominant GM crop occupying almost 50% of the global biotech area. The second most dominant GM crop is maize (30%), followed by cotton (14%) and canola (5%), while rice, potato, sugar beet, tomato, wheat, tobacco, cucumber, melon, alfalfa, lettuce and sunflower are grown in less than 1% of the area under GM crops (James, 2011).

Genetically modified plants are developed by introducing a gene or genes from related or unrelated species using methods of genetic engineering. This process is known as genetic transformation. A transformation method should ensure stable integration of the foreign DNA into the host genome without structural alterations, as well as stability of the new phenotype over several generations (Niederhauser et al., 1996). Genetic engineering techniques allow scientists to manipulate genetic material more precisely and to expand the scope of breeding new varieties. The main advantage of genetic modification is that crop improvement can be achieved in shorter time and more efficiently compared to conventional breeding methods. Numerous transformation methods have been developed: microprojectile bombardment, microinjection, direct transformation (electroporation, microinjecting, ballistic method and chemical stimulation of endocytosis), *Agrobacterium* species - mediated transformation etc. Each of these methods has advantages and limitations and is used in specific situations. Currently, there is no single technique that is suitable for all species. The most commonly used method includes introduction of DNA into genomic DNA using a bacterial species (e.g. transferring DNA into plant cell via mobile Ti plasmid from *Agrobacterium tumefaciens*) to deliver the gene of interest into the host plant. This method has been successfully used in dicots (i.e. broadleaf plants, such as soybeans, tomatoes etc.). The disadvantage of *Agrobacterium*-mediated transformation method is the impossibility to transform all plant species. Monocots (cereals) are not naturally susceptible to *Agrobacterium* and until relatively recently it have been comparatively difficult to transform them by *Agrobacterium*. However, successful transformations have been reported in the last few years (Mehrotra and Goyal, 2012). The second method widely used for genetic transformation is direct transformation, especially useful in transforming monocot species like maize and rice.

Genetically modified crops have been developed in an attempt to improve food quality and solve some of the problems associated with commercial agriculture, including disease and weed management (Milošević et al., 2008). The first generation of GM crops currently available contains input-traits with agronomic benefits to farmers (e.g. reducing the use of pesticides) and that only indirectly concern the consumers. Those GM crops have herbicide (glyphosate, gluphosinate and oxinyl) tolerance, insect tolerance and resistance (various forms of *Bacillus thuringiensis* Cry proteins) and viral and fungal resistance (Alstad and Andow, 1995). The second generation of GM crops involves health and nutritional properties (e.g. trans-fatty acid reach soybean and rapeseed oil, increased amylase content in maize for alcohol production) directly. Cereals and vegetables with varied nutritional values and organoleptic properties have already offered positive features also for the consumers. Varieties with tolerance to unfavourable agricultural circumstances (drought, cold and salt tolerance) are also a new generation development. The third generation plants are developed not specifically for food industry purposes but rather to produce organic molecules and active ingredients (production of "nutraceuticals" and pharmaceuticals) (Smyth et al., 2002).

At present, only a few food crops are permitted for food use and traded on the international food and feed markets, including herbicide-resistant soybean, herbicide- and insect-resistant maize and oilseed rape, and insect- and herbicide-resistant cotton (primarily a fiber crop, although refined cottonseed oil is used as food), in addition to several varieties of papaya, potato, rice, squash, sugar beet, and tomato approved for food use and environmental release in some countries (Ponti, 2005).

New technologies often raise new concerns and the use of genetic modification to improve food crops is no exception. Thus, the potential benefits of genetically modified crops have to be balanced by concerns over the potential risks to human health and the environment as well as the sustainability of this technology.

Potential risk of genetically modified crops. The introduction of GM crops into agriculture has opened a great debate about the safety of GM crops with respect to possible long-term adverse effects on the environment, human health and also on the sustainability of this new agricultural technology. These issues have been extensively reviewed and investigated (Dale et al., 2002; Ellstrand, 2003; Ervin et al., 2003; Snow et al., 2005; Brookes and Barfoot, 2010; Zdjelar et al., 2011).

Environmental safety issues focus on the direct or indirect effects of GM crops on non-target organisms and introgression of GM traits into populations of wild plants via pollen transfer. Over the long term, transgenic crops modified to be resistant to a particular pest or disease may have a negative effect on non-target species that are harmless or beneficial (O´Callaghan et al., 2005). For example, Bt maize pollen may be toxic to Monarch butterfly (Sears et al., 2001). Although Monarch butterfly is native to Mexico, the USA and Canada it is possible that other butterfly species in Europe can be affected in similar way. The conditions required to grow herbicide tolerant GM plants may also affect local wildlife populations because farmers can use a different herbicide regime to that used on conventional crops (e.g. usage of non-selective herbicide Roundup). Gene flow is the movement of genes between two genetically different populations of the same species (King et al., 2006). There are three ways for gene flow to be mediated: by pollen, seed or vegetative propagule. For example in rapeseed, transgenes can be transferred between cultivars and from cultivars to certain wild relatives, volunteers and feral plants (Devos et al., 2004). If GM plants pass their new traits (pest resistance, herbicide tolerance, drought tolerance, etc.) on to wild relatives, that could enhance the fitness of wild relatives through the expression of a favourable trait. Transgene will quickly be spread in the population through introgression. Individuals with that trait could out-compete individuals without transgene under natural selection. Final result of the previously mentioned, possible environmental consequence of GM crops could be the loss of biodiversity.

Food safety concerns relate to the potential allergenicity (Goodman et al., 2005; Prescott et al., 2005; Mishra et al., 2010) of food products expressing genes that confer resistance to insect, fungal and viral pathogens or provide herbicide tolerance, as well as reduced quality of those products. Since the inserted genes usually come from other organisms such as bacteria, the proteins they produce are often new to animal or human diet. The production of protein may also involve a new biochemical pathway in the plant or affect an existing one, which can mean the production of other novel protein or biochemical by-products, some of which could be allergenic or toxic. This explains why GMOs have been associated with allergic reactions (Pryme and Lembcke, 2003; Prescott et al., 2005).

Agronomic safety issues relate to the potential impact on the agricultural environment by transferring of pest resistance and herbicide tolerance traits from GM crops to weedy species, the persistence of feral crop plants carrying these traits and cross-pollination with non-GM crops in the field (Ervin et al., 2003). The most serious problem for farmers is the outbreak of herbicide resistant weeds so called "superweeds". The incorporation of the herbicide tolerance traits in recipient plants may increase the fitness of these plants, making them more abundant and persistent. Herbicide treatments are commonly used by farmers to control weeds, including volunteers and certain wild relatives. The presence of herbicide tolerant plants limits the effectiveness of herbicides used for controlling weed infestation (Devos et al., 2004). Herbicide tolerant weeds may cause problems to farmers or seed producers if they switch to agricultural practices with low herbicide usage. It is well documented that when a single herbicide is used repeatedly on a crop, the chances of herbicide resistance developing in weed populations greatly increase (Holt et al., 1993). One of the most mentioned concerns regarding the commercial growing of GM plants are possible transfers of transgenic pollen into neighbouring fields with similar crops. If a non-GM crop is fertilized with GM pollen, some percentage of the collected seed product will contain GM. The main sources for GM contamination of non-GM crops at the farm level are: seed impurities, pollen dispersal between fields, seed dispersal with machinery, dispersal of pollen and seeds from volunteer plants, and mixing of crops after harvest (Devos et al., 2004).

Herbicide tolerant soybean. Herbicide tolerance (HT) is the dominant trait in GM crops, followed by insect resistance and stacked genes for the two traits. Herbicide tolerant Roundup Ready (RR) soybean (GTS 40-3-2) is the most common transgenic line of soybean. It is one of seven transgenic soybean lines authorized for the EU market, none of those for cultivation (James, 2011).

Each year, the EU imports approximately 18 million tons of soybeans and 20 million tons of soybean meal from Brazil, the USA, and Argentina. Soybean, as major GM crop, represents the staple constituent of many foods. There are many different kinds of soya-derived products (protein additives, meat analogues, diet foods, milk products analogues, lecithin for desserts, baked goods, etc.) which are common ingredients in many processed foods. It is estimated that as much as 60% of the processed food inventory of a typical supermarket contains material from soya (Nikolić et al., 2009a). The demands of consumers for healthier and safer products have promoted the use of soybean proteins in processed meat products as fat replacers (Castro-Rubio et al., 2005).

Roundup Ready soybean is engineered for tolerance to glyphosate herbicide, commonly sold under the trade name Roundup. Glyphosate is water-soluble, broad-spectrum, non-selective herbicide that is absorbed by the leaves and transported to all parts of the plant, including the roots. It is capable of completely killing even deep-rooted plants. Glyphosate binds manganese, making it unavailable to the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). Because manganese is essential for EPSPS to work, inhibiting it in this way glyphosate subsequently affects an essential biochemical pathway in plants, the shikimate pathway, leading to a shortage of aromatic amino acids for building proteins (Johal and Huber, 2009). As a result, plants treated with glyphosate have lower levels of manganese and other nutrients, reduced shoot and root growth and the end result is the plant's death (Gaines et al., 2011). Several bacterial species show tolerance to glyphosate. The soil bacterium *Agrobacterium* sp. strain CP4 was isolated and introduced into the genome of soybean cultivars using a transformation method called ballistic method. The enzyme EPSPS is present in all plants, fungi and bacteria but not found in animals. It is assumed that glyphosate is relatively harmless to mammals, insects, fish and birds because they do not make their own aromatic amino acids but receive them from plant, microbial or animal-derived foods (Kleter et al., 2005).

The commercialization of GM crops resistant to glyphosate herbicide revolutionized weed management in agriculture. Earlier, in order to control weeds, farmers had to carefully select among a wide range of herbicide active ingredients, carefully manage the timing of herbicide application and combine them with mechanical methods. Herbicide tolerance now offers farmers a management tool to control weeds by allowing crops to be sprayed with herbicides. Glyphosate is an essential element in the GM RR soy farming system. The most serious problem for farmers who grow RR soybean is the outbreak of glyphosate-resistant weeds, or "superweeds". Worldwide, there are 21 weed species with glyphosate resistant strains. Among those are the most problematic agronomic weeds, such as horseweed (*Conyza canadensis*), Palmer amaranth (*Amaranthus palmeri*), Velvetleaf (*Abutilon theophrasti*) and Johnsongrass (*Sorghum halepense*) (Heap, 2011). The most serious outbreaks have occurred in regions where glyphosate-resistant crops have facilitated the continued overuse of this herbicide (Mortensen et al., 2012). Increased herbicide resistance as a result may increase application of selective broad-leaf herbicides or herbicide mixtures. As herbicides are known to accumulate in fruits and tubers as they suffer little metabolic degradation in plant, with this overuse of herbicides questions about food safety also arise (Altieri, 2000). Application of long residual herbicides that are mobile in surface water or penetrate into groundwater could lead to additional water quality concerns. The toxicity of glyphosate is strongly increased by the adjuvants (added ingredients) and surfactants that it is mixed with. Adjuvants facilitate adhesion of herbicides to foliage and penetrate into plant cells, allowing it then to be transported to all parts of the plant. In addition, glyphosate breaks down in the natural environment to form aminomethylphosphonic acid (AMPA), which is very similar in chemical structure to glyphosate. There is evidence that AMPA can also have impacts on animal and human health, and the environment (Abouziena et al., 2009).

Monitoring of genetically modified organisms. Although GM crops are considered to be equivalent to their conventional counterparts and there has been no documented evidence of risk to human health or the environment according to Paarlberg (2010), there are concerns on the potential adverse effects of genetic modification on human health and the environment (Falck-Zepeda, 2009). In addition to this, there is a concern that the trade in GM grain may result in the spread of GMOs to countries where they have not been approved (Clapp, 2008). Consumer concerns about GM foods have affected food regulation policies worldwide and led to the development or changes in GM food labelling legislation in many countries in order to allow consumer choice.

The European Union continues to be a region where the commercial cultivation of genetically modified crops is very limited. Regulation 1829/2003 on genetically modified food and feed and Regulation 1830/2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms have been in force since April 2004. The labelling threshold for GMO content in food has been lowered from 1% to 0.9%. The same threshold is applied for feed (Regulations (EC) No. 1829/2003, 1830/2003). Until then there was no specific regulation on approval or labelling of GM feed. In organic farming, the regulations do not allow the use of genetic engineering in the grain production system partly in order to guarantee GM-free products to the consumers. The proportion of seeds containing GMO may not exceed a critical detection level, e.g. 0.1%, if the crop is to be classified and sold as an organic crop. This includes all sources of transgenic contamination during production and distribution, which is generally low in organic crops because of separate distribution lines (Damgaard and Kjellsson, 2005).

Given that Serbia's own resources are insufficient to respond to the needs of animal nutrition, there is a need to import certain quantities of animal feed and supplements for compound feeding stuffs (enzymes, additives etc.). In this way a number of GM events could illegally enter Serbia mostly as a raw material to be used directly as feed or in feed/food industry. In order to prevent uncontrolled import of GMOs in Serbia new Law on GMO was adopted in May 2009. According to this Law, Serbia strictly prohibits all import, production and commercial growing of GMO crops or products containing GMO (Official Gazette of RS 2009). However, in the agricultural products of plant origin the contamination of 0.9% and 0.1% for seed is permitted. All shipments of soybeans, maize, rice, sugar beet and rapeseed and their products entering Serbia must be tested for GMO content, and are allowed to be imported only if they are GMO-free. Laboratory for Seed Testing, as a part of Institute of Fields and Vegetable Crops Novi Sad, is one of four accredited laboratories which deal with the detection of GMOs in commercially available raw and processed food and feed. In Serbia, over the past ten years, several studies have dealt with the detection of GMOs (Nikolić et al., 2008; Taški-Ajduković et al., 2009; Nikolić et al., 2010; Nikolić and Vujaković, 2011; Zdjelar et al., 2012).

Although the cultivation of GM plants has not yet been approved in Serbia, their import is expected to increase, and their unforeseen, intended or accidental cultivation may eventually occur as has been revealed for Roundup Ready soybean (Nikolić et al., 2009a). As a result of this it has become important to monitor the food chain for the presence of unapproved illegal GMOs as well as to ensure the enforcement of GM labelling (Nikolić et al., 2009b; Park et al., 2010).

Conclusions

Although the global area in which GM crops are grown is increasing, this new agricultural biotechnology still encounters considerable resistance in the European Union. This is mainly due to concerns about possible long-term adverse effects on the environment and human health, but also due to doubts with regard to the sustainability of these transgenic crops. The risk assessment of GM crops focuses especially on potential consequences on the stability and diversity of ecosystems, including putative invasiveness of GM crops, effects on biodiversity, gene flow, impacts on non-target organisms and the impact of presence of transgenic material in food.

Widespread adoption of genetically modified crops carries a potential risk of reducing the level of inter-crop diversity and promotes the cultivation of monocultures on a larger scale. It could affect its stability and cause a loss in the expected welfare of farmers.

Market concentration and monopoly power in the seed industry, reducing choice and control for farmers, who will pay ever higher prices for seed at the end. However, the most serious problem for farmers who grow herbicide tolerant crops, especially RR soybean, is the development of weed populations that are resistant to glyphosate, so called "superweeds". Their appearance can lead to increased usage of selective broad-leaf herbicides or herbicide mixtures that could increase the cost of spraying. Further, increased amount of herbicides can accumulate in fruits and tubers or penetrate into groundwater affecting invertebrates and humans who use them.

Rising consumer concerns about GM foods have affected food regulation policies worldwide and led to the introduction of GM food labelling in many countries in order to allow consumer choice. With GM crops being produced in secrecy and labelling regulation not always in place effectively, the public's right to choice is not always being adequately respected. Consequently it has become important to monitor the food chain for the presence of genetic modification as well as to ensure the application of GM labelling.

It should be noted that it is practically impossible to quantify or predict the long-term consequences arising from the widespread use of GM crops. However from the present literature review, at this point in time, genetically modified crops are not a suitable tool for sustainable agriculture due to specific environmental, economic, and socioeconomic reasons.

References

Abouziena HFH, Sharma SD, Singh M (2009). Impact of adjuvants on bentazon efficacy on selected broadleaf weeds. Crop Prot. 28: 1081–1085.

Alstad DN, Andow DA (1995). Managing the evolution of insect resistance to transgenic plants. Science 268: 1894-1896.

Altieri M (2000). The ecological impacts of transgenic crops on agroecosystem health. Ecosyst. Health 6(1): 13-23.

Belloque J, Garcia MC, Torre M, Marina ML (2002). Analysis of soybean proteins in meat products: A review. Crit. Rev. Food Sci. Nutr. 42: 507–532.

Brookes G, Barfoot P (2005). GM crops: The global socio-economic and environmental impact - The first nine years 1996–2004. UK: PG Economics Ltd.

Brookes G, Barfoot P (2010). Global impact of biotech crops: Environmental effects, 1996–2008. AgBioForum 13(1): 76-94.

Castro-Rubio F, Garcia MC, Rodriguez R, Marina ML (2005). Simple and inexpensive method for the reliable determination of additions of soybean proteins in heat-processed meat products: An alternative to the AOAC official method. J. Agric. Food Chem. 53: 220–226.

Clapp J (2008). Illegal GMO releases and corporate responsibility: Questioning the effectiveness of voluntary measures. Ecol. Econ. 66:348–358.

Dale PJ, Clarke B, Fontes EMG (2002). Potential for the environmental impact of transgenic crops. Nat. Biotechnol. 20: 567-574.

Damgaard C, Kjellsson G (2005). Gene flow of oil seed rape (*Brassica napus*) according to isolation distance and buffer zone. Agric. Ecosyst. Environ. 108: 291-301.

Devos Y, Reheul D, De Schrijver A, Cors F, Moens W (2004). Management of herbicide-tolerant oilseed rape in Europe: a case study on minimizing vertical gene flow. Environ. Biosafety Res. 3: 35-148.

Ellstrand NC (2003). Current knowledge of gene flow in plants: implications for transgene flow. Philos. Trans. R. Soc. B-Biol. Sci. 358: 1163-1170.

Ervin DE, Welsh R, Batie S, Line CC (2003). Towards an ecological systems approach in public research for environmental regulation of transgenic crops. Agric. Ecosyst. Environ. 99: 1-14.

European Commission (2003). Regulation (EC) No. 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed. Official Journal of the European Union, L. 268, 1–23.

European Commission (2003). Regulation (EC) No. 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability of food and feed products produced from genetically modified organisms and amending directive 2001/18/EC. Official Journal of the European Union, L. 268, 24–48.

Falck-Zepeda JB (2009). Socio-economic considerations, Article 26.1 of the Cartagena protocol on Biosafety: What are the issues and what is at stake? AgBioForum 12(1): 90-107.

Gaines TA, Shaner DL, Ward SM, Leach JE, Preston C, Westra P (2011). Mechanism of Resistance of Evolved Glyphosate-Resistant Palmer Amaranth (Amaranthus palmeri). J. Agric. Food Chem. 59: 5886–5889.

Grice J, Lawrence G (2004). Biotechnology and Sustainable Agriculture in Central Queensland. Austral. J. Emerg. Technol. Soc. 2(2): 66-81

Goodman RE, Hefle SL, Taylor SL, van Ree R (2005). Assessing genetically modified crops to minimize the risk of increased food allergy: a review. Int. Arch. Allergy Immunol. 137: 153-166.

Heap I (2011). International Survey of Herbicide Resistant Weeds. Weed-Science.org. (12 October 2011; www.weedscience.org)

Holst-Jensen A (2009). Testing for genetically modified organisms (GMOs): Past, present and future perspectives. Biotechnol. Adv. 27: 1071-1082.

Holt JS, Powles SB, Holtum JAM (1993). Mechanisms and agronomic aspects of herbicide resistance. Ann. Rev. Plant. Physiol. Plant Mol. Biol. 44: 203-229.

James C (2011). Global Status of Commercialized Biotech/GM Crops: 2011. ISAAA Brief No.43. ISAAA: Ithaca, NY

Johal GS, Huber DM (2009). Glyphosate effect on plant diseases. Eur. J. Agron. 31: 144-152.

King RC, Stansfield WD, Mulligan PK (2006). A Dictionary of Genetics. 7th Ed. Oxf. Univ. Press.

Kleter GA, Peijnenburg AACM, Aarts HJM (1995). Health Considerations Regarding Horizontal Transfer of Microbial Transgenes Present in Genetically Modified Crops. J. Biomed. Biotechnol. 4: 326-352.

Law on Genetically Modified Organisms (Official Gazette of RS. No. 41/2009).

Lewandowski I, Härdtlein M, Kaltschmitt M (1999). Sustainable crop production: definition and methodological approach for assessing and implementing sustainability. Crop Sci. 39: 184–193.

Mehrotra S, Goyal V (2012). *Agrobacterium*-Mediated Gene Transfer in Plants and Biosafety Considerations. Appl. Biochem. Biotechnol. Published online.

Milošević M, Nikolić Z, Vujaković M, Taški-Ajduković K, Ignjatov M, Petrović D (2008). GMO-general view. The Second Joint PSU-UNS International Conference on Bioscience: Food, Agriculture and Environment, June 22-24, Novi Sad, Serbia, Proceedings 12-17.

Mishra A, Sharma P, Goel C, Singh BP, Arora N (2010). Allergenicity assessment of genetically modified foods. Int. J. Integr. Biol. 10(1): 1-8.

Mortensen DA, Egan JF, Maxwell BD, Ryan MR, Smith RG (2012). Navigating a Critical Juncture for Sustainable Weed Management. BioSci. 62(1): 75-84.

Nickson TE (2005). Crop biotechnology – the state of play. In: Poppy GM and Wilkinson MJ (eds) Gene flow from GM plants, Blackwell, Oxford, UK, 12-42.

Niederhauser C, Gilgen M, Meyer R (1996). Gentechnologisch veränderte pflanzliche Lebensmittel: Stand der anwendungsorientierten Forschung und potentielle Nachweismöglichkeiten mit molekularbiologischen Methoden. Mitt. Gebiete Lebensm. Hyg. 87: 307-367.

Nikolić Z, Milošević M, Vujaković M, Marinković D, Jevtić A, Balešević-Tubić S (2008). Qualitative Triplex PCR for the Detection of Genetically Modified Soybeand and Maize. Biotechnol. Biotechnol. Eq. 22: 801-803.

Nikolić Z, Taški-Ajduković K, Jevtić A, Marinković D (2009a). Detection of GM soybean in food products by simultaneous employment of three pairs of PCR primers. Food Res. Int. 42: 349-352.

Nikolić Z, Taški-Ajduković K, Tatić M, Balešević-Tubić S (2009b). Monitoring of the Roundup Ready soybean in the Vojvodina province in Serbia. Ind. Crop. Prod. 29: 638–641.

Nikolić Z, Vujaković M, Marjanović-Jeromela A, Jovičić D (2010). Implementation of monitoring for genetically modified rapeseed in Serbia. Electron. J. Biotechnol. 13(5): 1-8.

Nikolić Z, Vujaković M (2011). Monitoring the Occurrence of Genetically Modified Maize in Serbia from 2006 to 2008. Cereal. Res. Commu. 39(2): 267-272.

O´Callaghan M, Glare TR, Burgess EPJ, Malone LA (2005). Effects of plants genetically modified for insect resistance on non-target organisms. Annu. Rev. Entomol. 50: 271-292.

Paarlberg R (2010). GMO foods and crops: Africa`s choice. New Biotechnol. 27(5): 609-613.

Park KW, Lee B, Kim C, Park J, Ko E, Jeong S, Choi K, Yoon WK, Kim HM (2010). Monitoring the occurrence of genetically modified maize at a grain receiving port and along transportation routes in the Republic of Korea. Food Contr. 21: 46-461.

Ponti L (2005). Transgenic Crops and Sustainable Agriculture in the European Context. Bull. Sci. Technol. Soci. 25(4): 289-305.

Prescott VE, Campbell PM, Moore A, Mattes J, Rothenberg ME, Foster PS, Higgins TJ, Hogan SP (2005). Transgenic expression of bean alpha-amylase inhibitor in peas results in altered structure and immunogenicity. J. Agric. Food Chem. 53: 9023-9030.

Pryme IF, Lembcke R (2003). In vivo studies on possible health consequences of genetically modified food and feed – with particular regard to ingredients consisting of genetically modified plant materials. Nutr. Health 17: 1-8.

Smyth S, Phillips PWB (2002). Production differentiation alternatives: Identity preservation, segregation, and traceability. AgBioForum 5: 30-42.

Snow AA, Andow DA, Gepts P, Hallerman EM, Power A, Tiedje JM, Wolfenbarger LL (2005). Genetically engineered organisms and the environment: current status and recommendations. Ecol. Appl. 15: 377-404.

Sears MK, Hellmich RL, Stanley-Horn DE, Oberhauser KS, Pleasants JM, Mattila HR, Siegfriedi BD, Dively GP (2001). Impact of Bt corn pollen on monarch butterfly populations: A risk assessment. PNAS 98(21): 11937-11942.

Taški-Ajduković K, Nikolić Z, Vujaković M, Milošević M, Ignjatov M, Petrović D (2009). Detection of genetically modified organisms in processed meat products n the Serbian food market. Meat Sci. 81: 230-232.

Zdjelar GR, Nikolić ZT, Marjanović Jeromela AM, Jovičić DD, Ignjatov MV, Petrović DN (2011). Environmental and agronomic impact of the herbicide tolerant GM rapeseed. J. Agric. Sci. 56(1): 65-73

Zdjelar G, Nikolić Z, Vasiljević I, Bajić B, Jovičić D, Ignjatov M, Milošević D (2012). Detection of genetically modified soya, maize and rice in vegetarian and healthy food products in Serbia. Czech J. Food Sci. *In press*.