UDC 575:631
DOI: 0.2298/GENSR1003585M
Original scientific paper

THE IMPORTANCE AND IMPLICATION OF GENETIC RESOURCES IN AGRICULTURE

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Milošević M., M. Miloradov, S. Dragin and M. Stegić (2010): *The importance and implication of genetic resources in agriculture* - Genetika, Vol 42, No. 3, 585-598.

The maintenance and preservation of biodiversity is going through the processes of conservation and restoration of disturbed ecosystems and habitats, as well as the preservation and recovery of species. Genetic diversity means the variety and total number of genes contained in plant and animal species and microorganisms. Genetic diversity is the basic unit of diversity, which is responsible for differences between individuals, populations and species.

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Genetic diversity is very important for the preservation of biodiversity and can be saved in several ways. Part of the germplasm is maintained through breeding programs as they evaluate germplasm stored and used as a source of needed diversity.

The Convention on Biological Diversity is one of the most important international agreements to protect nature and conserve genetic resources. International treaties governing the use of genetic resources for food and agriculture are a way to ensure the conservation and sustainable use of plant resources for food and agriculture, and to regulate the rights of farmers.

Key words: biodiversity, conservation of genetic resources, farmer rights, genetic diversity

INTRODUCTION

The maintenance and preservation of biodiversity is going through the processes of conservation and restoration of disturbed ecosystems and habitats, as well as the preservation and recovery of species. Sustainable use of biological diversity does not cause disruption of biodiversity, it is rather the rational use of natural resources and maintenance of biodiversity potential that matches the needs and aspirations and ambitions of present and future generations (MILOŠEVIĆ *et al.,* 2009).

There are three basic forms of biodiversity:

1. Genetic diversity or diversity within a single species, which includes a variety and total number of genes contained in a plant, animal and microbial species;
2. Biodiversity of species which represent the total diversity of species on Earth;
3. Ecosystem biodiversity, which refers to the overall diversity of ecosystems (habitat and living communities), or biotopes and biocoenosis (COLLECTIVE OF AUTHORS, 2003, ĆOSOVIĆ, 2008).

Genetic diversity imply the variability of the species on Earth as well as the specific genetic information of all types of plants, animals, fungi and microorganisms which was created during evolution and cannot be repeated in other species. Genetic diversity includes the variety and total number of genes contained in plants, animals and microorganisms. The diversity of species includes the total number of organic species in all ecosystems on Earth, from pre-beginning of her life. According to some data, between 5 and 80 million plant and animal species inhabits the Earth, only 1,5 million of which are described. There are millions of small invertebrates (mostly insects) which make up 73% of the overall wildlife (ECOFORUM, 2009).

The diversity of ecosystem includes the total diversity of habitats (inanimate nature components) and biocenosis (living component of nature), as well as ecological processes that connect them (biogeochemical cycles, energy flow, trophic relation, succession, etc.) on the basis of which is the uniqueness and functionality of ecosystems as the basic unit of biosphere realized (COLLECTIVE OF AUTHORS, 2003).

The aforementioned multi-layer concept has been used in the early stages of defining the biological diversity. International Organization for Conservation (International Board for Genetic Resources Plant - IBPGR) used this terms and definitions during sixties. Today, a valid definition of biodiversity is: "Biodiversity is the variation of life at all levels of biological organization" (IPGRI, 2004).

If genes are the basic unit of natural selection, according to WILSON (1992), the real biodiversity is actually genetic diversity. For geneticists, biodiversity is the diversity of genes and organisms. They have studied the process of mutation, gene changes, and the dynamics of the genome until they reach the level of DNA. Knowing this, and previously mentioned definition, *WILCOX* (1984) states that genes are the ultimate source of biological organization at all levels of biological systems.

Genetic diversity in agriculture

Genetic diversity is the basic unit of diversity, which is responsible for differences between individuals, populations and species (http://www.fmoit.gov.ba/bh_chm/17%20%20Geneticka%20raznolikost.pdf).

Genetic diversity among organisms exists at the following levels:

1. Within a single individual;
2. Between individuals of the same population;
3. Between different populations of the same species (population diversity) between different species (species diversity) (http://www.fmoit.gov.ba/bh_chm/17%20-%20Geneticka%20raznolikost.pdf).

Structural, functional and spatial aspect of genetic diversity can vary in time which means that there is a time component in the analysis of biodiversity. For example, there can be daily, seasonal or annual changes in the number of species and individuals present in an ecosystem. Some ecosystems are changing in structure or size over time (e.g. forest ecosystems may change in size and structure as a result of natural fires). Space is also a considerable component of biodiversity (*MILOŠEVIĆ et al.*, 2010).

The efficient establishing of genetic diversity implies exact determination of endangered plant species with their location, identification of strategies that will help to preserve species and occasional assuring weather the strategy is working. First of these steps, determination of endangered species, is complicated because of the exceptional plant variety (diversity) which is the result of genetic diversity (http://www.fmoit.gov.ba/bh_chm/5%20-%20Diverzitet%20vrsta.pdf).

The process of collection and preservation of genetic diversity in plants is lasting for nearly a century. Bank of genes which represent live seed collection serve as a source of genes for improving agricultural production characteristics (LAZIC *et al.*, 2009). Today, there are between 300.000 and 500.000 species of cormophytes, 250.000 of which have been identified and described (WILSON, 1988). About 30,000 species are edible, and some 7,000 are used in the system of agricultural production or they are collected as a food source *(*United Nations Environment Programme -

UNEP) (UNEP, 1995). Several thousands of plant species can be called a source of safety for human consumption. Among the plant genetic resources, about 30 plant species are singled out as „important plants“that „feed the world“since they provide 95% of energy (calories) or protein in the diet. Only wheat, rice and maize provide more than half of the energy in the diet of the world population. In these three plant species has been invested the most in terms of conservation and preservation of genetic resources. Sorghum, millet, potato, sweet potato, soybean, sugar beet and cane provide much of the energy needs. Vegetables, fruit and other plant species, including those that are collected and used in the diet, contribute to the quality and variety of food (MYERS, 1990).

Grown plants can be conditionally divided into "modern varieties" and "old varieties." "Modern cultivars" are the product of planned breeding on scientific basis conducted by research institutes, public and private. Newly created varieties must have high uniformity, since that is a condition in a process of recognition and protection of species in the majority of National regulations (MILOŠEVIĆ and MALEŠEVIĆ, 2004). In particular, the requirements are expressed by the international standards prescribed by the Organization for Economic Co-operation and Development - OECD Seed Scheme (OECD, 2007) and the International Union for Protection of New Varieties of Plants – UPOV.

“Old varieties”, known as populations or traditional varieties are result of “breeding” on agricultural lands, committed by farmers, mainly selecting plants which yield more seeds. Selection process, and therefore the changes of genetic diversity, has lasted for generations. Varieties are created with the desire to be uniform and contain high levels of genetic diversity. Often there is a problem to determine these varieties for they are not a result of traditional breeding methods, nor they meet statutory norms, but they can be distinguished by morphological features. Farmers give them names, which need not be unique, as required by the official plant catalog. They are very well adapted to local growing conditions, soil, time of sowing, ripening time, nutrient requirements, etc.

Populations are due to their genetic diversity, often subjected to conservation. Significant variations between the "old varieties” or populations are particularly large in dioecious (crossbreeding, interbreeding) plant species (maize and millet). Inbred species (wheat, barley) or species that reproduce vegetative (potato), have less individual variability, but the number of varieties that have been created is significantly higher (PIMBERT and PRISTLEY, 1986).

It is hard to find a wide genetic diversity in Europe today, as it existed a hundred years ago. Standardization requirements demand application of modern breeding methods which prevent cultivation of many varieties, thus reducing the genetic distance between them (VELLVE, 1993).

Genetic diversity, very important for the preservation of biodiversity, can be saved in several ways. Part of the germplasm is maintained through breeding programs as they evaluate germplasm stored and used as a source of needed diversity. Genetic diversity present within the existing diversity can improve the quality of cultivated plants (http://www.fao.org/ag/AGP/AGPS/GpaEN/gpatoc.htm).

Genetic diversity depends upon the plant species, or on plant genomes, which is one of the most complex living systems. It is composed of three interactive genomes. In addition to nuclear genome, the rest of the genetic system is located in the plastid and mitochondrion. These organelles are semiautonomous and have their own organizational and functional units, but they cannot independently synthesize all of its proteins. Nuclear genome plays an important role in biogenesis of organelles.

The study of genetic diversity today is based upon the analysis of chromosomal location of genes, namely the genes for increasing the yield and other complex features that are significant for agriculture. Chromosome locations are analyzed using “linkage maps”, special maps of related genes. These maps provide the frequency of recombination between genes on chromosomes and thus make possible testing location of genes that determine the characteristics of plants important to agriculture (note that the recombination frequency is the frequency of merged loci on chromosomes and genes during meiosis) (MILOŠEVIĆ *et al.*, 2009).

The techniques of molecular cloning and sequencing deoxyribonucleic acid (DNA) have enabled the study of the structure of genes at the level of nucleotides. Knowledge of the structure, organization and expression properties of the plant genome was achieved by using recombinant DNA techniques. This method has enabled the isolation and characterization of specific parts of DNA by cloning DNA sequences in bacterial cells where they can be multiplied to the required quantity so that desired analysis can be made (http://www.molecular-plant-biotechnology.info/nuclear-genome/plant-genome.htm). Genome analysis offers the final understanding of genetic potential of cultivated plants and their wild relatives, so they can be used for research or breeding.

Characterization of germplasm implies the use of DNA "fingerprinting" technique for the precise establishing, identification and quantitative determination of genetic diversity. These tests are important due to the decline in genetic diversity in response to climate change, changes in pathogen populations and agricultural practices. In the analysis of 105 varieties of Argentine wheat (*Triticum aestivum* L.) cultivated from 1932 until 1995 characterization of samples was carried out using SSR (Simple Sequence Repeat) and AFLP (Amplified Fragment Length Polymorphism) markers. The data of molecular tests has been used to establish the genetic diversity of species that were used in breeding programs, and to prove that during this time period, part of genetic diversity was lost compared to the one previously used in breeding programs (genetic erosion). Differences were found in the results obtained in both applied techniques, including breeding programs with large differences in the number of varieties applied. Differences in genetic diversity were not found between varieties created in the sixties and those created three decades later. Each representative sample contained the full diversity of the Argentine germplasm (MANIFESTO *et al.*, 2001).

Breeding work and genetic resources

Breeders use variety of sources for their work, most commonly their own collections. There are such collections of wheat and sunflower in the Institute of

Field and Vegetable Crops in Novi Sad, as well as a collection of corn genotypes in the Maize Research Institute in Zemun Polje. Gene banks are used to preserve the overall genetic variability within the species on scientific grounds. They are concerned about genetic resources of the research fields from which they collect samples, collection technique, and maintenance the samples until it is used to exchange information and samples.

In order to make a collection, the Institute of Field and Vegetable Crops in Novi Sad carried out characterization of seven populations of native beans from Stepanovicevo. Method of protein markers was applied, with two enzymatic systems: malik enzyme and malate dehydrogenase, because the variability at the protein level is well documented in beans (*Phaseolus vulgaris* L.) (KOENIN and GEPTS,1989). The method of 1D SDS-PAGE electrophoresis was applied. As zimogram shows, differences between genotypes were clearly visible, and their inventory easily feasible (NIKOLIĆ *et al.*, 2007).

Violation of genetic resources

Genetic resources have an irreplaceable role in food production and preservation of biodiversity. Erosion of genetic resources is becoming more and more evident and that is the reason why it has become a fundamental element of national strategies for their preservation and use (LAZIĆ *et al.*, 2009).

Violation of genetic resources can be defined as a situation where plants that are grown on large areas become susceptible to the harmful organisms or adverse external conditions, as a result of changes in genetic constitution, resulting in large losses. One of the reasons for genetic vulnerability is the replacement of varieties that had a genetic diversity with modern cultivars with high plant uniformity.

There are two main factors in establishing the causes of genetic vulnerabilities:

1. Relative area under susceptible varieties,
2. The degree of uniformity between the varieties.

Often, data on sowing some varieties are not available, or complete, and the planted area cannot be determined. The actual degree of its uniformity is difficult to determine because the origin is not always available, even for well-known varieties. The system of varieties protection (breeder's rights) in some countries requires the submission of the genealogy as a condition for protection; in other countries they are protected as confidential information (DRAGIN *et al.*, 2009).

In the Netherlands, for example, three major varieties of potatoes, of nine in total, cover from 81% to 99% of the land. A variety of spring barley occupies 94% area. In the U.S. at 1972 and 1991 was found that nine varieties of eight significant plant species total cover between 50% and 75% of the land. In Ireland, it was stated that six varieties of wheat makes 90% of the total planted areas.

MILOŠEVIĆ *et al.*, (1996) state that new sources of genetic variability may introduce alternative or additional complex of genes that contribute to the new and improved features and ecological adaptation. Indirect benefits of population with a wide genetic basis are increased genetic variability and tolerance of newly varieties or lines. Even when the breeders use populations based on wide genetic basis with similar origin, population structure is changing from program to program. Diversity of cultivars or lines from these populations would have significant value as the prevention of mass occurrence of diseases and insects.

Plant diversity is also needed to help of restoring the system when some of the economically important plant species are affected by disease. Even when varieties carry different names, the degree of genetic diversity may not be large. In Europe, resistance to mildew in barley is based on one gene and one fungicide (WOLFE, 1992).

The rapid turnover of germplasm and other genetic material in the world intended for breeding, preservation in gene banks, or for other purposes, created a significant international threat of increased spread of harmful weeds, insects, pathogens, mites and other harmful organisms. Precautions are therefore indispensable in preventing the introduction and spread of harmful organisms, which represent a major threat to world agriculture (MILOŠEVIĆ, 2001). Pathogens in new conditions may be significantly more aggressive and the biodiversity in a much greater extent subjected to change.

Mutations in pathogen organisms can lead to loss of resistance in some plant species, in a single evolutionary step, because it is very common for most varieties to have the same genetic basis. All F1 rice hybrids which cover 15 million hectares in China (1990) have the same gene for male sterility. The same applies to sunflower. All varieties of rice have the same gene for the growth of short trunks (HARGROVE *et al*, 1985). Uniformity itself is not dangerous, even more, in some plant species it contributes to stability. What is important is the ability to recognize problems that might arise from the uniformity, such as susceptibility to certain diseases, and to overcome it. The best known example is *Phytophthora infestans* in potatoes which caused infection (1845 - 1848) and destroyed potatoes in Europe and North America. One and a half million of people in Ireland, whose diet depended on that plant species, died of starvation. Potato grown in Europe in that period was genetically uniform, since only two or four varieties, native to Latin America, were cultivated. Traces of the disaster are still felt. *Phytophthora infestans* is now widespread in all parts of the world where potatoes are grown. It occurs every year in varying intensity, depending on weather conditions. Losses due to the appearance of the disease are between 5% and 30% per annum despite the regular use of fungicides (MILOŠEVIĆ *et al,* 1996a). The appearance of a new breed of potato downy (A2) in 1980 was noted in Europe, Asia, Latin America, Mexico, for which no resistant varieties (known resistance genes) or effective fungicides are known (FRY *et al.*, 1993).

Conservation of genetic resources

The conservation of genetic resources is impossible to provide due to lack of funds. For this reason, attention is given to commercially important plant species. Genetic variability of these plant species, as well as of those that are not subjected to conservation, depend on their distribution, status in the ecosystem and the presence of the pollen distribution vectors. Because of that, there is an analogy in predicting the population structure of many plant species on the basis of which can be designed state of genetic resources in a given time.

Global plant conservation policy

In April 2002 The United Nations and the Convention on Biological Diversity (*United Nations - Convention of Biological Diversity*, *UN-CBD*) adopted the proposal of the Global Plan for the Conservation of plants that should be implemented by 2010. The Action Plan for biodiversity (*Biodiversity Action Plan - BAP*) is an internationally recognized program focused on specific plant species and the environment, meant to protect and reconstruct biological diversity. The basis for this plan was the Convention on Biological Diversity (adopted 1992). By 2009, 191 countries have ratified the Convention, but only some of them have ratified the Action Plan on Biodiversity.

Basics of the Action Plan on biodiversity include:

1. Preparation and inventory of biological information for selected plants or habitats
2. Connecting the conservation status with specific types of ecosystem
3. Creation of conservation and restoration program for targeted plant species
4. Establishing the budget, time and program for the implementation of institutional connections BAP (UN-CBD, 2002).

The Convention on Biological Diversity
(Convention on Biological Diversity - CBD)

The Convention on Biological Diversity (http://www.cbd.int/convention) is one of the most important international agreements in order to protect nature. It provides a framework of global environmental protection and biological diversity. The Convention on Biological diversity is an international agreement adopted in Rio de Janeiro in 1992. Its main goals are:

1. Conservation of biological diversity and sustainable use of components of biological diversity
2. Correct distribution of benefits from the genetic resources.

The aim of the Convention is the development of national strategies for conservation and sustainable use of biological diversity. The Convention, for the first time, recognizes international agreement related to the conservation of biological diversity which represents a "common concern for the welfare of mankind" and part of the development process. The Contract covers the areas of ecosystems, species and genetic resources connecting the traditional goals of conservation with sustainable use of biological resources. The Convention sets a set of principles for the fair and uniform distribution of profit that comes from the use of genetic resources. It covers the rapidly expanding biotechnology through the application of Cartagena Protocol on Biological Security, addressed to technological development

and biological security measures. The Convention sets a number of tasks before the international community related to the conservation of biodiversity.
Some of them are:

1. Measures and initiatives for the conservation and sustainable use of biological diversity;
2. Regulated access to genetic resources and traditional knowledge;
3. The division of the research results, in an appropriate way, development, and increase of commercial profit from genetic resources;
4. Access to technologies and their transfer, including biotechnology, to government and local communities, that support traditional knowledge and / or sources of biodiversity;
5. Technical and scientific cooperation;
6. Impact assessment;
7. Education and public opinion;
8. Finding financial resources;
9. Writing national reports in an effort to establish contractual relations.

Agreement on Biological Diversity was ratified by the Parliament of Serbia and Montenegro on 05.11.2001 and came into force on 01.06.2002.

International agreements on the use of genetic resources for food and agriculture

There is another way that can provide conservation and sustainable use of plant genetic resources for food and agriculture, and, also, the fair use of profit made from genetic resources in accordance with the Convention on Biological Diversity. These are International treaties governing the use of genetic resources for food and agriculture. By means of these agreements, countries establish effective and transparent multilateral system to promote access to genetic resources for food and agriculture, as well as distribution of profit to the appropriate, correct way. In addition, this Agreement guarantees food security through the conservation and sustainable use of changes of genetic resources at the international level. The system is now applied to 64 plant species. Representatives of governments that ratify the Agreement, determine the conditions for the use of the profit in the International Agreement for the use of genetic resources for food and agriculture. The contract recognizes the economic contribution of farmers and their communities in conservation and use of plant genetic resources. This is the basis for the realization of farmer rights, which include the protection of traditional knowledge and rights to participate in profit sharing and decision making at the national level in relation to genetic resources. The responsibility of the Government is to implement these rights. Contracts entered into force in 2004. Governments that have ratified this Agreement make a governmental body. At the first meeting, the level, form and manner of payment and commercialization in the “material (financial) transmission contract" for plant genetic resources were discussed, as well as the mechanism of implementation of the Agreement and its strategy (www.molecular-plant-biotechnology.info). Each country that ratifies the Convention has the obligation to draft the appropriate legislation for its implementation.

Farmer rights

The realization of the farmer rights is a key for implementation of the International Agreement on the use of plant genetic resources for food and agriculture. At the same time they are a prerequisite for the conservation and sustainable use of vital resources *in situ* and on farms. The contract recognizes the large proportion of farmers throughout the world in conservation and development of plant genetic resources. That share is based on the farmer rights (http://www.farmersrights.org/about/fr_in_itpgrfa.html).

According to the Annex of the International Agreement on the use of plant genetic resources for food and agriculture, farmers' rights are defined as "rights arising from past, present and future participation of farmers in conservation, improvement, and utilization of plant genetic resources, particularly those in centers of origin of diversity". The purpose of these rights is to "ensure the full contribution to farmers and to maintain the continuity of their contribution" (http://www.fao.org/DOCREP/x0255e/x0255e03.htm).

Model for the expected payment compensation by farmer rights

Typically, the royalty for intellectual property is made in the market. Farmers' rights are expressed through the willingness of users to pay for the use of intellectual property, while the recipients of benefits give back part of that value, as a percentage of the resource value in the market. For the realization of farmer rights related to the population as a genetic resource, a simple model for the realization of insured income has been developed, if the payments are based on royalty.

1. $Y_i = A_g * S * P * R * D_i - E_i + O_i$ where:

Y_i - Income benefits for the population as a genetic resource collected in the country;

A_g - Area sown with seed populations which is the genetic resources of the country

S - Quantity of seed per area unit

P - Seed price

R - Fee established for the use of population

D_i - Share the population has in the countries diversity

E_i - Transaction costs of ownership rights to the population as a genetic resource

O_i - Profit from the use of population as a genetic resource that is used to improve other plant species in the country.

This model uses a market approach in order to achieve benefits for achieving the corresponding part of profit obtained from genetic resources, as a farmer right. This model provides that payment performed by user goes to the country of origin threw the percentage of the seed cost. Income depends on the amount of sold seeds originating from a specific genetic resource, seed price and the balance cost of seed and paid compensation. Countries will not only be "exporting" population as genetic resources to be used anywhere in the world, but countries will be "importing" population for their own needs. Even if countries have a sufficient amount of genetic resources, self supply is not always advisable. It was found, for example, that the antracknosis, one of the economically significant diseases of beans in Mexico, entered beans in two centers of diversity. Mexican strain of pathogen may infect Mexican germplasm, but the Andean germplasm is resistant to mentioned pathogen. This means that most countries would be "exporting" germplasm in the extent enough to maintain the level of genetic diversity, while the "export" part of the germplasm is in proportion to the surface on which is a particular plant species cultivated.

On this basis, net income achieved by a country through a system of profit charges available from the population will be:

2. $B_i = Y_i - C_i$, where:
3. $C_i = A_i * S * P * R*(1-D_i)$

B_i - Net income for the country and the fees for the use of populations as genetic resource;

C_i - Payments realized from the land and for use of population as a genetic resource

A_i - Area planted with genetic resource population.

This model will be used for the simulation that allows the acceptable limit for the maximum benefits that can be achieved by country as a compensation in the development and conservation of genetic resources, based on the concept of farmers' rights (PACHIC, 2001). With the introduction of biotechnology and increased intensity of intellectual property protection of genetic material, profit distribution obtained from genetic resources becomes more important. Farmer’s right is a concept that may, in a satisfactory manner provide compensation to farmers for their contribution to the improvement of genetic resources and their conservation.

Received, April 24th,2010

Accepted, December 6th,2010

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ZNAČAJ I KORIŠĆENJE GENETIČKIH RESURSA U POLJOPRIVREDI

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Očuvanje biodiverziteta prolazi kroz procese konzervacije i obnavljanja ekosistema i spoljne sredine, kao i očuvanje i oporavak vrsta. Genetički diverzitet predstavlja ukupan broj koje sadrže biljne i životinjske vrste i mikroorganizmi. Ovaj diverzitet je osnovna jedinica ukupnog diverziteta koji je odgovoran za razlike između jedinki, populacija i vrsta. Genetički diverzitet, koji je vrlo značajan za očuvanje biodiverziteta može da se očuva na nekoliko načina. Deo germplazme se održava kroz programe oplemenjivanja jer se u okviru njihove realizacije vrši evaluacija uskladištene germplazme, kao i njeno korišćenje kao izvora potrebnog diverziteta.

Primljeno, 29.IV. 2010.
Odobreno, 06.XII. 2010.