UTILIZATION AND TRANSFER OF FOREST GENETIC RESOURCES BY INTRODUCTION OF ALIEN SPECIES

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ABSTRACT

Emerging needs for wood, non-wood forest products, different ecosystem services and research programs in the last two centuries have affected the transfer of forest genetic resources within and outside of their natural distribution area. The transfer of species to the new habitats outside their range of distribution involves the well-known risks - reduced growth and (or) dieback as a result of the low adaptive potential of the introduced species to the new environmental conditions. The methods of close and distant - intraspecific and interspecific hybridization have been applied together with the establishment and analysis of the provenance tests throughout the 20th century in Serbia in order to provide a reliable assessment of the adaptive, productive and reproductive potential of the introduced species. The extensive establishment of the plantations for the production of timber for mechanical and chemical wood processing has been one of the main reasons for the introduction of alien species, especially conifers of *Pinus*, *Picea*, *Pseudotsuga* genera and the species of *Populus* and *Salix* genera. This paper deals with the attitude of the human population towards the introduction of alien species, their effects on native habitats and indirect influence on the progress of woody plant improvement.

Keywords: Alien species, forest genetic resources

INTRODUCTION

Genetic resources of forest trees have been used and transferred by humans for millennia. For instance, the ancient Greeks and Romans played a significant role in spreading *Castanea sativa* and its cultivation from the Eastern Mediterranean region (including Anatolia and the Caucasus) to other parts of Europe (CONEDERA *et al*., 2004). Over the last 200 years, genetic resources of forest trees have been increasingly transferred, within and outside of species' native distribution ranges, for forestry and for research and development. Transferred germplasm has been used to grow trees for numerous purposes, ranging from the production of wood and non-wood products to the provision of ecosystem services such as the restoration of forests for biodiversity conservation. International provenance trials have been essential for selecting seed sources for reforestation and for improving tree germplasm through breeding. Many tree breeding programmers were initiated in the 1950s, but as one round of testing and selection typically takes decades, the most advanced of them are only in their third cycle. Recent advances in forest genomics have increased the understanding of the genetic basis of different traits, but it is unlikely that molecular marker-assisted approaches will quickly replace traditional tree breeding methods. Transfers of tree germplasm involve some risks of spreading pests and diseases, introducing invasive tree species and polluting the genetic make-up of already present tree populations. Many of these risks have been underestimated in the past, but they are now better understood and managed. Relatively few tree species used for forestry have become invasive, and the risk of spreading pests and diseases while transferring seed is considerably lower than when moving live plants. This paper attempts to unravel the relationships between humans and woody plants by looking at the importance of introduction of woody plant species for different human activities and especially for forest trees improvement (ISAJEV *et al*., 1986, 2017).

Transfer of forest genetic resources: an historical overview

The history of woody plant introduction is closely linked with that of transportation and European exploration of the planet (16^{th}–19^{th} centuries), (CROSBY, 1986). The transport of a species from one biogeographical region to another was carried out with a particular purpose. Once introduced to a new region, many of these species have been spread un-intentionally by humans within the new biotic regions. Each colonial power established major botanical gardens and experimental stations in various parts of the world, first in the home country and on tropical islands, later in coastal areas and finally in more inland locations.

Ornamentals have been widely introduced in every part of the world. In the past, botanic gardens and individuals were responsible for these introductions. Botanic gardens in all parts of the world have been responsible for the introduction of a large number of species and in every case, species have started to spread into the surrounding vegetation. Erosion control has been a common reason for the introduction of plant species in many parts of the world. Species providing a rapid and thorough cover such as *Lonicera japonica* and *Pueraria lobata* have been favored but these have become major pests (WILLIAMS, 1994). *Elaeagnus angustifolia* was commonly planted as a windbreak and *Lonicera japonica* was planted by game managers for wild deer (BLAISDELL, 1967). In countries such as Britain shrub species such as *Symphoricarpos albus*, were introduced to provide ground cover for game birds (GILBERT, 1995).

The location of introduction was identified, in full or in part, for 388 of the 458 forestry tree species known to occur outside their native range (85 %). Figure 1 shows the number of forestry species that were recorded as introduced, intentionally or by accident, into each of seven geographic regions (Europe, Africa, Australasia, North America, South America, Pacific and Asia). Introductions of forestry species were recorded for all regions.

By 1850, deforestation had reduced average forest cover in Europe to an estimated 20% of land (KAPLAN *et al.*, 2009). Already in the late 18th century, several European countries had started largescale reforestation efforts to stop this forest decline and the continent's forest cover subsequently started to increase during the 19th and 20th centuries (MATHER, 2001). By the 20th century, the purpose of introductions shifted from food plants to timber and other species yielding non-agricultural products. Finally, during the latter part of the 20th century the importance of ornamental species increased dramatically, especially to the more developed and wealthier regions.

The transition from deforestation to reforestation created a strong demand for forest tree seed. In many countries, however, the remaining forests could not meet the high demand and seed had to be sourced from other nations. As a result, large quantities of *L. decidua, P. abies, P. sylvestris* and *Quercus spp*. seed were transferred across Western and Central Europe throughout the 19th century and into the early 20th century (TULSTRUP, 1959). The use of tree species introduced into Europe has also played an important role in these historical reforestation efforts (KJAER *et al.*, 2014).

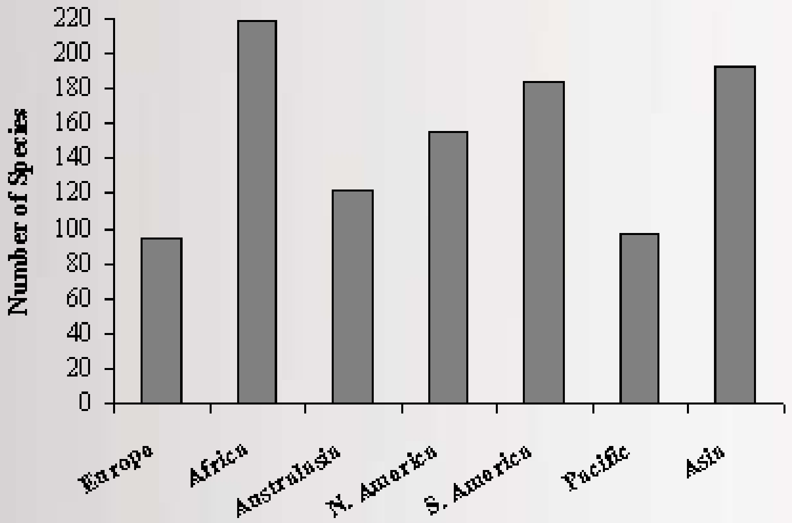

Figure 1. Number of forestry species encountered that having been introduced into each of seven geographic regions, HAYSOM and MURPHY, 2003.

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The environmental risks associated with genetic pollution were largely ignored in the past and it is important not to overstate them now. Strong barriers to hybridization exist between some related species, such as differences in flowering time or the poor fitness of hybrids, which reduce the risks. One approach to reduce the potentially negative impacts of cultivated-wild tree hybridization is to deliberately isolate cultivated material or to plant exotic rather than indigenous trees around natural forests and woodlands (POTTS *et al*., 2001). More research is required on the magnitude of outbreeding depression in tree species, as it remains a relatively understudied phenomenon, with evidence limited mostly to interspecific hybrid segregants (ELLSTRAND, 2003; EDMANDS, 2007). The topic is discussed further in other papers of this special issue (WICKNESWARI *et al*., 2014; THOMAS *et al*., 2014).

Utilization of forest genetic resources research and development

With a few exceptions, forest genetic resources have been utilized extensively in systematic research and development only for about 100 years. The oldest form of research and development is the testing of tree species and their provenances for different uses and under different environmental conditions. The main purpose of provenance research has been, and still is, the identification of well-growing and sufficiently adapted tree populations to serve as seed sources for reforestation (KONIG, 2005). Such research has shown that most tree species have a high degree of phenotypic plasticity (i.e., large variation in phenotype under different environmental conditions (e.g., REHFELDT *et al*., 2002) and that this varies between provenances (e.g., AITKEN *et al*., 2008). Since the 1990s, provenance trials have also demonstrated their value for studying the impacts of climate change on tree growth (e.g., MATYAS, 1994, 1996). Many old provenance trials still exist and continue to provide valuable information for research and development. Due to the long timeframe (often in decades) to reach recommendations, however, it has been challenging for many countries and research organizations to maintain trials and to continue measuring them.

Experience with some conifer exotics in Europe

Tree species, particularly conifers, have been introduced from all over the northern hemisphere into Europe, and this is an unsurpassed region in which to obtain information on the behavior of exotics. It is notable that, after more two centuries of experience, the majority of foresters in Western Europe are inclined to be pessimistic regarding exotics, because they have not yet found a completely successful introduced tree, even though certain species showed great initial promise. The native European trees grow slowly, so there has been a search for faster growing species. Eastern white pine (*Pinus strobus* L.) grows more rapidly than the native European conifers with which it has been associated. In northern Germany near Eberswalde, the writer has seen 45-year-old Douglas fir (*Pseudotsuga taxifolia* (Lam.) Br.) of the same size as 100-year-old Scots pine. Near Tharandt, 55-year-old Douglas firs were from 14 to 20 inches (36 to 51 cm.) in diameter at breast height, exactly twice the size of Norway spruce (*Picea abies* Karst.) of the same age mixed with them. In southern Germany, near Munich, 45-year-old planted Douglas fir was the same height as 77-year-old naturally reproduced silver fir (*Abies alba* Mill.).

Overview of domestication and conservation approaches of poplar (Populus L.) and willows (Salix L.)

The natural range of *Populus* and *Salix* spans impressive ecological amplitude, primarily across the North American, European and Asian land masses – from the subtropics to the boreal forests and arctic tundra, riparian to montane ecosystems and the man-made environment of modern agriculture. As a consequence, poplar and willow geneticists – those responsible for conserving and domesticating germplasm of *Populus* and *Salix* – have an especially broad mandate: to study the genetic diversity of natural populations and be familiar with all the modern tools for genetic improvement in order to serve specific social needs (KUZOVKINA and QUIGLEY, 2005; KUZOVKINA *et al*., 2008; KUZOVKINA and VOLK, 2009; STANTON *et al*., 2010).

Populus domestication has a history of nearly 100 years, beginning with Henry's work-1914, at the Royal Botanic Gardens, Kew, in the UK, and the work of STOUT and SCHREINER, 1933 and STOUT *et al*. 1927 at the New York Botanical Garden in the USA. Other early domestication efforts include those of WETTSTEIN-WESTERSHEIM 1933 in Germany, AL'BENSKII and DELITSINA (1934) in Russia, HEIMBURGER (1936) in Canada, and HOUTZAGERS (1952) in the Netherlands. *Salix* domestication traces to the hybridization studies of Heribert-Nilsson in Sweden, (HERIBERT-NILSSON, 1918), along with Nilsson and Hakansson's cytological work in the 1930s, (NILSSON, 1931; HAKANSSON, 1933, 1938). In the UK, H.P. Hutchinson began work in willow conservation and breeding in the 1920s at the Long Ashton Research Station that was continued by K.G. Stott for the following 30 years (NEWSHOLME, 1992; STOTT, 1992). Most of this work involves 12 species in the genus *Populus* that are noteworthy for their commercial and ecological values. They are the North American species *P. balsamifera*, *P. deltoides*, *P. trichocarpa* and *P. tremuloides* and the Eurasian species *P. alba*, *P. cathayana*, *P. ciliata*, *P. euphratica*, *P. maximowiczii*, *P. nigra*, *P. simonii* and *P. tremula* (STANTON *et al*., 2014).

Within the genus *Salix*, 10 species − *S. caprea*, *S. dasyclados*, *S. eriocephala*, *S. koriyanagi*, *S. miyabeana*, *S. purpurea*, *S. udensis*, *S. schwerinii*, *S. triandra* and *S. viminalis* − are being utilized in developing the world's renewable energy industry, while three others − *S. alba*, *S. babylonica* (synonym *S. matsudana*) and *S. nigra* − are favored for timber products (STANTON *et al*., 2014).

Experience with black locust (Robinia pseudoacacia L.)

The North American black locust has been widely introduced throughout Europe as a source of high quality timber and for erosion control. Some now regard it as a permanent member of the flora (GAMS, 1967). The main uses of *R. pseudoacacia* have been somewhat variable in different parts of Europe and have changed over time. In parts of France and Switzerland the young coppice wood was extensively used in vineyards to support the vines (MONNIER, 1992), but in recent decades it has been replaced by metal posts and wire, and now the species is hardly used. Although the tree produces a highly durable timber, it is disliked by German foresters because the wrong strain, a shrubby variety, was introduced to that country. In Hungary the tree has remained a key timber and is the main source of honey (KERESZTESI, 1977).

Testing and evaluating of introduced exotic species

Introduction of exotic tree species has been the single most important aspect of forest tree improvement for some areas. On the other hand, some regions have such excellent native species or such harsh growing conditions that trees from other lands have proved of little value. There are various intermediate regions in which tree introduction is on of several improvement methods which should be considered.

The procedures and designs used to test exotics are the same as used in the study of individual tree inheritance and racial variation. Exotic testing should be done in two or three stages (WRIGHT, 1993). The first preliminary test should include several scattered plantations on different soil types and with different climates, with few blocks per plantation and small plots. These first tests may well include a few hundred seedlots of several different species or even genera. They may be established over a period of years, with separate plantations for species with different growth rates and growth habits. The second-stage test should concentrate on those races or species that grew best in the first-stage tests. There should be more replication and perhaps larger plots at each test site, and increased attention can be given to individual tree variation. The second-stage trails may often be considered as semi-commercial, designed for the production of wood, as well as data. The third-stage trails can consist commercial plantations designed primarily for wood production.

When working with exotic species for the first time there are lacks the background information of site adaptability, pest problems and silviculturals management that is usually available for a native species. This is the reason for suggesting preliminary testing of variety of site conditions and moderate-scale second-stage testing.

Identification and monitoring of introduced species should be particularly supported in those areas where currently is a lack of documentation. A number of case studies should be conducted in collaboration with countries that have a high degree of dependence on forestry. Such case studies should cover a range of forestry situations (commercial, developmental and environmental) and include the development and promotion of tools for ecological and economic impact assessments. These could also be incorporated into more general decision support systems that include socio-economic factors, as well as biological risk.

CONCLUSIONS

Advances in research and development work in the forestry sector in different parts of the world have shifted germplasm demand toward species and provenances expected to perform well at specific sites for particular functions, bringing significant productivity benefits.

There is a need for further research and monitoring that will provide information on the management processes in planted systems and take account of the scale (i.e. land area) of plantings and of the area occupied by introduced species.

- Introductions should only be considered if clear and well-defined benefits to man or natural communities can be foreseen and demonstrated.

- Introductions should only be considered if no native species are suitable for the purpose for which the introduction is being made.

- Introductions should not be made into pristine natural or semi-natural habitats, reserves of any kind or their buffer zones and, in most cases, oceanic islands.

- The taxonomic identification of the proposed introduction needs to be confirmed.

Only if these first four conditions are met should further assessment be undertaken. Generally, it may be accepted conclusion, that introduced species can fulfill a gradually increasing role in certain ecological or industrial niches but will probably not replace natives over large areas (WRIGHT, 1993).

The continued need for germplasm transfers for research is well recognized by scientists and research institutes who are pressing their governments to minimize the bureaucracy and costs related to the implementation of the Nagoya Protocol.

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