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Gene conservation and breeding programmes for *Picea abies* in Lithuania: present-day achievements

Abstract: At present, Norway spruce stands occupy 22% of the total forest area in Lithuania. Most of them are located in the northeastern highland (Žemaitija) and the central part of the country. 25% of the spruce-dominated stands are pure, the rest are mixed. Natural calamities like storms, droughts, and pests cause substantial damage and occur quite frequently. About 40 thousand ha of stands are cut after each storm. The mean wood yield of the spruce stands is $304 \text{ m}^3 \text{ ha}^{-1}$, and the current annual increment is $6.2 \text{ m}^3 \text{ ha}^{-1}$. The climatic conditions of Lithuania are variable enough to cause differentiation of habitats. For Norway spruce, 6 provenance regions have been established. The national gene conservation programme is based on (a) *in situ* genetic reserves, seed collection stands, and selected genotypes, and (b) *ex situ* clonal archives, seed orchards, experimental plantations, and gene bank collections. The present-day breeding of Norway spruce comprises family tests of populations for individual and population selection, and plans for inter-population hybrids. A strategy for Norway spruce breeding has been approved for the years 2004–2013. There is a genetically diverse material for future breeding: long-distance provenance tests, and population and family tests. Assessments of two provenance tests (aged 9 and 17 years) in central Lithuania revealed superior performance of central and northeastern Polish provenances: superior height, good stem quality, and late bud-burst in spring. This may be attributed to the favourable effect of transfer: avoidance of spring frosts (late bud-burst and good stem quality), and utilisation of the later part of the growing period for growth (late bud-set and superior height). Norway spruce is a climax species with different domestic and Darwinian fitness. Therefore, we suggest that the domestic fitness of local genotypes may be improved by introducing a few Polish clones in Lithuanian breeding populations.

Additional key words: Norway spruce, genetic resources, forestry resources, provenance

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Introduction

Lithuanian Norway spruce populations originate from the “northern” post-glacial refugium. Every 10–20 years, they suffer periodical damage from drought and storm. In 1993, a major part of Norway spruce stands (63% of all spruce stands; 280 thousand ha) were damaged by storms. During 1993–1996, the windfalls were followed by dry sum-

mers and mild winters, which resulted in extensive pest damage to one fifth of all spruce stands in the country. Most of the damaged stands are artificially regenerated, and there always is a need for regeneration material with a high breeding value. At rotation age, Norway spruce produces 300 m^3 of wood per ha, on average. The best stands (in Punia, Birzai, Prienai, and Rietavas forests) yield $600 \text{ m}^3 \text{ ha}^{-1}$. Among the forest tree species in Lithuania, Norway spruce ranks

second according to wood yield, and third according to area.

As shown by the Lithuanian forest survey (Lithuanian Forest Statistics 2006), Norway spruce stands occupy now 22% of the total forest area, compared to 34% a hundred years ago. This reduction in area was caused not only by storms but also by forestry practice. According to calculations, the optimum area of spruce stands in the country should be within the range of 22–34% of the total forest area. (Kenstavičius and Brukas 1984; Kenstavičius 1989). Pure stands make up 25% of all Norway spruce stands. Spruce stands with an admixture of Scots pine have the greatest stability. However, most of the Lithuanian spruce-dominated stands are mixed with softwood deciduous species. The stands of Norway spruce are mainly concentrated in the northwestern highland (Žemaitija), northeastern, and central parts of the country.

The current issues concerning Norway spruce stands in Lithuania are the following:

1. Securing efficient conservation of valuable genetic resources.
2. Afforesting abandoned land with spruce.
3. Establishing seed supply units with a high genetic value.
4. Establishing an efficient long-term breeding programme.

The first breeding cycle of Norway spruce produced a large area of phenotypically selected seed orchards and progeny tests. Presently, the second-generation seed orchards are established. Some first-generation seed orchards were given the status of gene conservation units. Clonal archives consisting of grafted

plus-trees representing the local population were established. In each climatic zone, gene conservation stands and seed collection stands were selected.

The objective of this paper is to review the past and present of the Norway spruce breeding and gene conservation programme in Lithuania.

Present state of Norway spruce in Lithuania

The Norway spruce stands in Lithuania are scattered all over the country, but their largest concentration is found in the northwestern highland and the central Kaunas-Onuškis region. In each of 6 seed zones, one base population of Norway spruce has been selected. Young stands make almost half of the Norway spruce stands, while pre-mature stands account only for 13% (Table 1). This indicates that the resources of commercial spruce timber will be reduced in the near future. Due to the stir damage, the wood yield of mature stands is similar to that of pre-mature ones (Table 1).

A relatively greater part of good-quality spruce stands are located in the south, whereas more plus-trees have been selected in the west of the country (Table 2). Though Lithuania is quite a small country, the Norway spruce populations from various seed zones differ significantly in adaptation traits (Danusevičius et al. 1999).

Since the same standard criteria for plus-tree selection were applied in all seed zones, the number of the plus-trees selected may be an indicator of the breeding value of stands in a particular zone (Table 2). In Lithuania, most of the plus-trees of Norway spruce

Table 1. Distribution of Norway spruce stands according to age class

Age class	Area		Volume (m ³ ha ⁻¹)	Increment (m ³ ha ⁻¹)
	thou. ha	%		
Young (age 1–40 years)	193.3	49	72	3.6
Middle-aged (age 41–60 years)	70.3	18	282	5.6
Pre-mature (age 61–80 years)	49.6	13	304	4.3
Mature (age over 81 years)	79.5	20	306	3.4
Total	392.7	100	186	–

Table 2. Estimates of the genetic quality of Norway spruce stands from different seed zones

Seed zone	Area of spruce stands (thou. ha)	% of spruce stands of 1st breeding category	Ratio: area of spruce stands to number of plus-trees (thou. ha)
Northwestern highland	110.3	2.5	55.1
Midland lowland	121.0	2.6	8.1
Northeastern highland	49.1	1.8	0.9
Sea-side lowland	59.8	5.0	19.9
Central part (Sūduva)	60.1	11.6	4.6
Southern Lithuania	33.9	6.2	0.5
	Total: 434.2	Average: 4.4	Average: 2.9

Table 3. Mean annual increment of Norway spruce plus-trees

Seed zone	Height		Diameter	
	cm	% of country mean	mm	% of country mean
Northwestern highland	43	109	6.0	105
Midland lowland	38	96	5.3	93
Northeastern highland	43	109	5.8	102
Sea-side lowland	34	86	5.5	96
Central part (Sūduva)	36	91	5.6	98
Southern Lithuania	43	109	5.9	103
Average	39	100	5.7	100

have been selected in the northwestern Žemaitija highland (however, the number of such trees standing *in situ* was there reduced by storms), north-eastern Aukštaitija highland, and in southern part of the country (Dzukija). The plus-trees from different seed zones significantly differ in wood yield and crown characteristics. Those from the Prienai population (central seed zone) possess the best phenotypic parameters; their progeny also show superior growth (Table 3). The tallest Norway spruce tree in the country grows near Prienai and has a height of 44 m and a diameter of 63 cm at age 80 years. Progeny testing started in 1974; further tests with variable sets of populations and plus-trees were established in 1983, 1985, 1987, 1990, and 2001.

As shown by the research into the morphological traits of spruce, trees in natural stands significantly differ in phenology, branching type, bark type, and the morphological traits of strobili (Gabrilavičius and Danusevičius 2003). Late-flushing adult trees produce a higher wood yield and have a better stem quality: on average, 77% of good-quality trees in the stand are late flushing, and only 17% are early flushing (Kairiūkštis 1962). The population transfer tests within the country revealed a significant transfer effect: populations moved to a milder seed zone start growth early and are prone to damage by spring frost.

Operational breeding and gene conservation programmes

In 2000, a programme was approved for the breeding and conservation of the forest genetic resources in Lithuania for the years 2000–2010 (Lithuanian Forest Research Institute 2000). The methodological part of the programme includes the following:

1. Strategy for gene conservation and breeding.
2. Establishment of sustainable forest stands.
3. Conservation of genetic diversity.
4. Development of breeding for multiple traits.
5. Increase in adaptation on certain site types.
6. Use of population hybrids in breeding.
7. Increase in resistance to biotic (pest) damage.
8. Establishment of seed collection units from genetically-improved material.

The principle underlying the present breeding programme for Norway spruce is shown in Fig. 1. An important consideration is also the function to be performed by the forest (protective, commercial, short rotation). The gene conservation programme covers the dynamic *in situ* genetic reserves, seed collection stands, and plus-trees, as well as the *ex situ* clonal archives, experimental plantations, seed orchards, and seed samples in the gene bank. The area of the seed collection units was estimated on the basis of the seed demand for reforestation purposes. A summary of the programme is presented in Table 4.

Assessments of two provenance tests in central Lithuania (9 and 17 years old) provided evidence to suggest that central and northeastern Polish provenances performed best (Danusevičius and Gabrilavičius 2001): they exhibited superior height, good stem quality, and late bud-burst in spring (Fig. 2). This was probably caused by the favourable transfer effect making it possible to avoid spring frosts (late bud-burst and good stem quality) and to use the later part of the growing period for growth (late bud-set and superior height). Norway spruce is a climax species whose domestic fitness differs from Darwinian fitness. We suggest that the domestic fitness of local

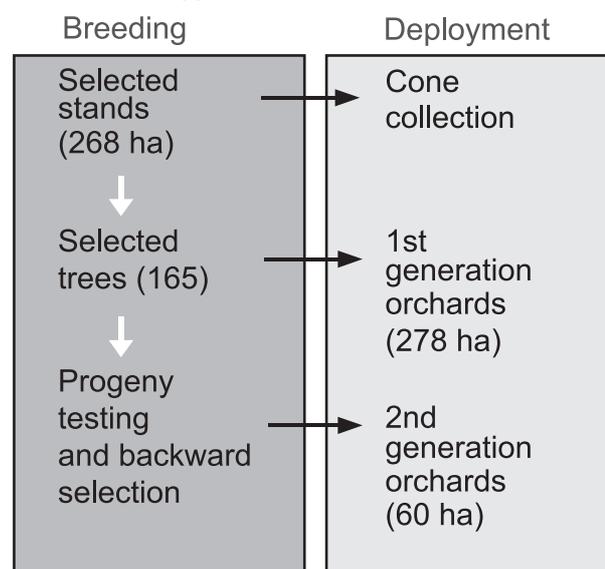


Fig. 1. Principle of presently operational Norway spruce breeding programme in Lithuania

Table 4. Summary of the programme for Norway spruce breeding and gene conservation until 2010

No.	Means	Units	Planned	Implemented 01.01. 2007	%
1. Gene conservation					
1.1.	Selection of genetic reserves	ha	1800	493	62
1.2.	Selection of plus-trees	trees	340	150	44
1.3.	Establishment of multiple-population experimental plantations	families/ha	150/30	120/20	80/67
1.4.	Establishment of clonal archives	clones	654	412	63
1.5.	Selection of seed orchards which can serve for gene conservation	clones/ha	100/18.5	100/18.5	100
1.6.	Seed samples to gene bank	sample	340	298	88
2. Breeding					
2.1.	Progeny testing	family	675	118	17
2.2.	Population transfer tests	population	34	34	100
2.3.	Full-sib progeny testing	family	85	50	59
3. Seed collection					
3.1.	Selection of seed-collection stands	ha	695	311	45
3.2.	Establishment of seed orchards:				
	a) 1st generation	ha	45	278	618
	b) 2nd generation	ha	158	60	38

genotypes would be improved by introducing a few Polish clones into our breeding populations.

Concluding remarks

Considering the fact that the *in situ* conservation of the genetic resources of Norway spruce is problematic, the *ex situ* clonal archive and gene bank collections should be given more attention. The combination with breeding and including seed orchards as gene conservation units seems especially effective.



Fig. 2. Positive effects of transfer of northeastern Polish provenances for 2–3 degrees of latitude towards the North: later start and cessation of growth, which results in less spring frost damage and taller trees. Northern Lithuanian provenance (left) and northeastern Polish provenance (right) planted in a trial in western Lithuania at age 7 years

Long-term planning in the breeding of Norway spruce is urgently needed to effectively utilise the results of the first cycle which started from the natural selections in the forest.

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