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ANALYSIS OF THE FOREST SEED PRODUCTION BASE OF *ACER PLATANOIDES* L. IN BULGARIA

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Abstract

The research considers all Norway maple seed sources included in the National Register of Forestry Seed Production Base in Bulgaria. Also, all forest stands and plantations where Norway maple shares more than 50 % of the composition were selected from the National Data Base of Forest Territories in Bulgaria. The age, mean height and diameter at breast height (DBH) were determined. For the plantations, where the initial planting design was known, the percentage of survival was calculated. For estimation of growing indicators, Tables for High Beech Stands were used, according to the accepted Equivalency List of Tables for Tree Species and Used Abbreviations. The site index, height rates, density (DS), basal area (G_{ba}) and volume (V) per 1 ha, mean annual diameter increment (Z_d) and mean annual height increment (Z_h) were calculated. The selection category of the stands was defined according to the height, in the tables for growth and productivity for High-stemmed beech stands, I-st site index. For determining the selection structure of the stands, the categorization of trees, accepted in the method for analysis of forest plantations was used. The altitude of the forest stands, where the Norway maple predominates, varies from 100 to 1000 m with mean value of 400 m. Both natural stands and plantations are located in habitats, categorized as moderately-rich to rich. The moisture level of the soils is relatively good – from fresh to humid. The terrain expositions of the stands are heterogeneous i.e. 61 % of them are located on shady and 39 % on sunny expositions. The analysis of silvicultural and dendrometric characteristics of the investigated objects shows that Norway maple could have predominantly participation in both forest plantations and natural forest stands. The intensive height growth of the species was registered in both the sub-belt of plane-hills Oak forests and the sub-belt of low-mountain forests of Sessile oak, Common beech and Common fir. This fact shows its pliability to the habitats within the altitudes from 150 to 900 m. The mean diameter at 1.3 m, in the 44–54 years old stands varies from 18 cm to 30 cm. In the category “absolute plus” fall the stands in SFS Berkovica, Vidin, Byala and Gurkovo. However, the results show that the number of stands valuable from the breeding point of view with predominant participation of *Acer platanoides*, is limited, especially in South Bulgaria. Meanwhile, the presence of valuable phenotypes requires their conservation and wider use for production of seedlings for forestry and urban planting.

Key words: distribution, growth, Norway maple, plantations, seed sources, selection, stands.

Introduction

Providing sowing materials with good, proved genetic and germination qualities is a main scientific and practical aim in the production of the forest (Milev et al. 1999) and ornamental plants (Aleksandrov 2007).

Nowadays in Bulgaria there is a constantly growing interest in broadleaves, either for forest planting (EFA 2012), or for the purposes of landscaping. The role of the native species is more and more valued, considering biodiversity conservation (MAF 2011, EFA 2011) and the fact that about one-third of the country's territory is included within the framework of NATURA 2000.

In Bulgaria there are still unused opportunities in investigating and using of species of genus *Acer* for the above mentioned purposes. Norway maple is considered as one of the most valued representative of the genus from forestry point of view (Pandeva 2004) and is reported to show good adaptive behavior in urban environment (Dirr 1998). It tolerates wide range of soils, from sandy to clay and from acidic to alkaline soils (Dirr 1998), but could not bear dry and damp growth conditions (Suszka et al. 1996). It endures air pollution, particularly ozone and sulfur dioxide (Dirr 1998). Also, it is popular with its diversity of ornamental cultivars (Artushenko et al. 1958, Santamour 1976, Krüssmann G. 1984, Dirr 1998, Coombes 1992, Zasada and Strong 2008).

Acer platanoides distribution includes almost the whole Europe, Caucasus, Turkey and Iran. North it spreads to Norway and Finland. In South Europe it reaches altitude of 1000 m and rarely 1200 m. Norway maple has scattered distribution and does not form pure stands, but takes part in groups, in the mixed broadleaved forests (Artushenko et al. 1958, Pandeva 2004, Schmucker 1942, Krüssmann 1984). In Bulgaria it spreads at altitude from 500 to 1500 m, almost in the whole country, apart from Pirin and Slavyanka mountains (Assyov et al. 2012, Milev et al. 2004, Pandeva 2004). Wide distribution is suggesting that different populations are not genetically homogenous. Despite of that, its seed production resources in the country are briefly investigated.

The aim of this study is to propose suggestions for updating the Norway maple forestry seed production data base in Bulgaria by analyzing the condition of the Norway maple stands included in the National forestry seed production register and by searching for additional stands with good qualities.

Objects

The research includes all Norway maple seed sources listed in the National Register of Forestry Seed Production Base in Bulgaria (NSFSPBB, Tables 1 and 6).

All forest stands in which Norway maple presents more than half of the composition were selected from the National Data Base of Forestry Territories in Bulgaria (NDBFTB, EFA 2012). These are 29 stands spread in 12 State forestry services (SFS). Furthermore are selected those ones, which are in good phytosanitary condition and are older than 20 years (Tables 2 and 6). The stands in SFS General Toshevo, which are field protection forestry belts, are removed from the preliminary list by terrain assessment.

A forest stand in SFS Gurkovo, which does not belong to either of the above mentioned registers was identified in the process of field work and was added to the study.

Methods of Study

The information about conditions of the habitats in the investigated Norway maple stands was taken from the forest management plans of the respective SFS.

Table 1. Habitat conditions of the seed production stands taken from the National forestry seed production register.

State forestry service	Forest stand	Area, ha	Altitude, m	Exposition	Slope, degrees	Habitat Site type	Relief form	Soil type	Soil texture	Soil stoniness	Soil density	Basal rock	Soil richness
Botevgrad	246d	15.1	900	N	27	M-NBG-II-1/ C_2(30)	Slope upper part	Eutric Cambisols	Moderete loam	Slightly stony	Optimum	Quartzite	Medium
Balchik	39m (part)	0.5	150	–	0	M-DCH-I-2/ D_1(12)	Flat	Haplic Kastanozems	Moderete loam	Slightly stony	Compacted	Loess	High
Kotel	3p	4.1	900	N	32	T-ESP-II-1/ C_2(71)	Slope upper part	Eutric Cambisols	Loamy sand	Stony	Optimum	Limestone marl	Medium
Tzonevo	80a	15.8	350	NW	17	T-ESP-I-2/ $СД_{23}$(60)	Slope lower part	Grey Luvisols	Moderete loam	Slightly stony	Optimum	Quartz sandstone	Medium to high
Borima	92s	5.6	650	NW	22	M-NBG-II-1/ C_2(27)	Slope upper part	Grey Luvisols	Moderete loam	Slightly stony	Compacted	Limestone marl	Medium
Aitos	160b	17.7	350	W	22	T-ESP-I-2/ C_{12}(56)	Slope lower part	Haplic Chromic Luvisols	Moderete loam	Slightly stony	Compacted	–	Medium
Byala	39g	23.7	300	NW	12	M-NBG-I-2/ C_2(14)	Slope upper part	Carbonic Kastanozems	Moderete loam	Stony	Compacted	Limestone	Medium to high
Tran	148g	21.4	1100	E	27	M-KI-II-2/ C_2(36)	Slope upper part	Eutric Cambisols	Loamy sand	Stony	Optimum	Sandstone	Medium
Smyadovo	11d	20.7	450	NE	19	T-ESP-I-2/ $CD_{2,3}$(60)	Slope upper part	Grey Luvisols	Moderete loam	Slightly stony	Optimum	Sandstone	Medium to high

The code characterizing the site type is haccording to the requirements of The Classification Scheme for the Types of Forest Habitats in Bulgaria (CSTFHB) (Executive Forestry Agency 2011).

The age of stands is taken from the current management plans of the SFSs and updated in the process of our investigation.

Diameters at breast height (DBH) of all trees within the stands less than 5 dka, were measured with 1 cm accuracy. In the larger stands we established temporary experimental plots of 1.5 dka. For the plantations, where the initial planting design is known, survival rate was calculated. The mean diameter was calculated according to the mean basal area. The mean height was calculated from the height of three trees, one with a mean diameter and two with the next closest diameters above and below the mean value.

For estimation of growing indicators, Tables for High-stemmed Beech Stands were used, according to the accepted by Krastanov and Raykov (2004), Equivalency List of Tables for Tree Species and Used Abbreviations.

The site index was defined according to the Tables for High Beech Stands (Nedyalkov 1960). For the height rates the tables of Duhovnikov (1963) were used. The density (DS), basal area (G_{ba}) and volume (V) per 1 ha, mean annual diameter increment (Z_d) and mean annual height increment (Z_h) were calculated. The volume was calculated according to the Volume and Assortment Tables for High-stemmed Beech Stands by Duhovnikov (1963), and the density – ac-

cording to volume of the stands with the Tables for Growth and Productivity (Nedyalkov 1960).

The selection category of the stands was defined according to the height, in the tables for growth and productivity for high-stemmed beech stands, I-st site index (Nedyalkov 1960).

For determining the quality structure of the stands, the category scale of trees, described in the method for analysis of forest plantations was used (Milev 2013).

Results and Discussion

Stands, from the date base of the National Forestry Agency, subject of assessment

According to the data from Executive Forest Agency (EFA), the number of forestry stands where Norway maple represents 50 % or more of the stand composition, is 29. Twenty-one of them are located in Northern Bulgaria (Fig. 1, Table 6), and are spread on the territory of 10 SFS. The other 8 are located in Southern Bulgaria and are on the territory of SFS Gurkovo and Haskovo. The ratio of natural forest stands to plantations is 15/14 (Fig. 1). The plantations were established at the territory of the following SFSs: Silistra, Kipilovo, Byala, Vratza, Haskovo and General Toshevo. The altitude of the forest stands, where the Norway maple predominates, varies from 100 to 1000 m with mean value of 400 m.

Both natural stands and plantations are located in habitats, categorized as mid-rich to rich. The moisture level of the soils is relatively good – from fresh to humid. The terrain expositions of the stands are heterogeneous i.e. they are located on shady (18), as well as sunny (11) expositions (Tables 1 and 2).

Registered stands for seed production

Norway maple stands, registered for seed production, are located at altitude between 150 and 1100 m on total area of 155.5 ha. The results of the terrain investigation

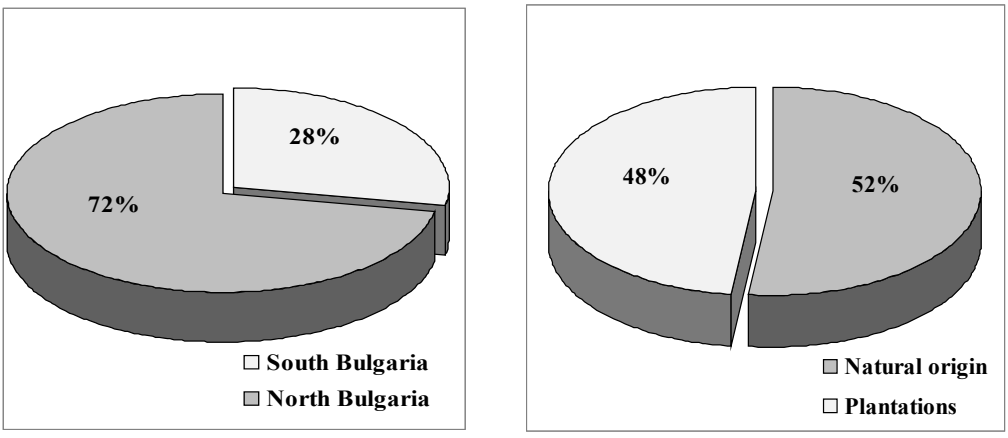

Fig. 1. Distribution of the forest stands with predominant participation of Norway maple by origin and geographic location.

showed that most of them do not posses the necessary characteristics to be used as source of reproduction material.

The stand in SFS Botevgrad was damaged by ice in 2007 and after sanitary felling in 2009 and 2010 Norway maple was removed and does not exist anymore.

In SFS Borima the participation of the species is presented by 19 individuals. Most of them are characterized by forked stems and for this reason are not good as breeding material.

Similar process of transformation in the composition of stands, with dropping out of Norway maple was registered in SFSs Kotel, Tzonevo, Tran and Aitos, and only single trees were ascertained. With age from 130 to 165 years in these forest stands (Table 1), Norway maple drops out of the composition and is being replaced by species with higher longevity like Common beech and Pedunculate oak.

In the stands at SFS Byala and SFS Smyadovo, Norway maple is also presented only by single trees, and it is not mentioned at all in the management plans.

These facts show that only the plantation in SFS Balchik could be a subject of interest from tree breeding and seed production point of view.

Observations in all experimental stands showed that in the natural mixed forest, Norway maple grows mostly with Sycamore (*Acer pseudoplatanus* L.), Common ash (*Fraxinus excelsior* L.), Common beech (*Fagus sylvatica* L.) and Turkish hazel (*Corylus colurna* L.) (Table 3).

The plantations have been established mostly in the lower forest belt, in the subbelt of Oak and mixed deciduous forests (Tables 1, 2, and 6). The planting design varies substantially, from 1×1 m (SFS Balchik) to 4×4 m (SFS Byala) (Table 3).

The survival of Norway maple in the studied plantations is 10–11 % at the age of 50 (SFS Byala and SFS Balchik) (Table 3).

The analysis of silvicultural and dendrometric characteristics of the investigated stands shows that Norway maple could have predominant participation in both forest plantations (SFS Balchik) and natural forest stands (SFS Vidin) (Table 3). According to the NDBFTB the participation of *Acer platanoides* in stand 30 g (SFS Gurkovo) is limited to single trees. In reality though, in the territory of 23.8 ha there is an area of 0.6 ha, in which the participation of Norway maple is 60 % of the composition and it must be taken in to consideration, because of the limited stands with predominant participation of the species.

The height of *Acer platanoides* at age from 44 to 54 years varies from 18.5 m (SFS Balchik) to 27 m (SFS Berkovitza) and at the age of 120 years it reaches 30.5 m (SFS Gurkovo), which is considered as the limit height of the species (Milev et al. 2004, Suszka et al. 1996). The stands in SFS Berkovitza are an example showing the possibility of Norway maple to reach the maximum height at age around 50 years. According to the registered heights, all stands can be classified in the 1st site index category (Table 3).

The comparison between the measured heights and the heights in the tables for growth and productivity of Common beech for the respective age reveals that mean height of the stands in SFS Berkovitza and SFS Vidin are higher than the ones in the table while opposite trend was found in SFS Balchik and SFS Byala. Our investigations indicate that the habitats in the middle forest belt are better for Nor-

Table 2. Habitat conditions of the investigated stands, chosen from the data base of the National Forestry agency.

State forestry service	Forest stand	Area, ha	Altitude, m	Exposition	Slope, degrees	Habitat Site type	Relief form	Soil type	Soil texture	Soil stoniness	Soil density	Basal rock	Soil richness
Berkovitza	204 sh_2	0.3	700	W	12	M-NBG-II-1/ $CD_{2,3}$ (29)	Slope upper part	Eutric Cambisols	Loamy sand	Slightly stony	Optimum	Granite	Medium to high
Vidin	390b, 391b	33	870	NE, SE	16	M-NBG-II-1/ C_2(30)	Slope upper part	Eutric Cambisols	Loamy sand	Slightly stony	Optimum	Diabase	Medium
Byala	243v	1.9	250	N	3	M-NBG-I-2/ D_2(12)	Flat	Grey Luvisols, Mollic	Moderete loam	Slightly stony	Compacted	Limestone	High
Gurkovo	30g (part)	0.6	900	E	29	T-GT-II-1/C_2(71)	Slope upper part	Eutric Cambisols	Moderete loam	Slightly stony	Optimum	Marl	Medium

Table 3. Silvicultural and dendrometric characteristics of the investigated stands.

State forestry service	Forest stand	Origin	Participation ratio	Structure	Scheme, m/m	Number of trees, ha^{-1}	Survival, %	Age, years	H, m	$D_{1.3}$, cm	Site index of *Ap*	Basal area of *Ap*, m^2/ha	Basal area of all species, m^2/ha	Mean height increment of *Ap*, cm/yr	Mean diameter increment of *Ap*, cm/yr	Mean volume increment, m^3/ha.yr	Volume of *Ap*, m^3/ha	Volume of all species, m^3/ha	Stand density
Berkovitza	204 sh_2	Natural	*Ap*3, *Aps*6, *Fs*1	uneven	–	473		54	27	25	I	7.15	23.6	50	0.45	5.03	83	272	0.59
Vidin	390b, 391b	Natural	*Ap*5, *Fe*2, *Fs*2, *Aps*1	uneven	–	410		44	20	19	I	5.94	12	45	0.43	2.58	56	113.5	0.33
Balchik	39m (part)	Plantation	*Ap*10	even	1/1	1100	11	50	18.5	18	I	26.8	26.8	37	0.36	4.66	233	233	0.5
Byala	243v	Plantation	*Fe*6, *Ap*4	even	4/4	62	10	50	19	30	I	1.6	5.1	38	0.60	0.94	13	46.8	0.1
Gurkovo	30g (part)	Natural	*Ap*6, *Aps*2, *Cc*2, *Fs*	uneven	-	247		120	30.5	46	I	24.5	40.7	25	0.38	4.58	333	549	0.6

Note: *Ap* – *Acer platanoides*, *Aps* – *Acer pseudoplatanus*, *Fs* – *Fagus sylvatica*, *Fe* – *Fraxinus excelsior*, *Cc* – *Corylus colurna*.

way maple than the habitats in the lower forest belt.

Fast height growth of the species was registered in both the sub-belt of plane-hills Oak forests and the sub-belt of low-mountain forests of Sessile oak, Common beech and Silver fir. This fact shows its tolerance to the habitats within the altitudinal range from 150 to 900 m. No light dependence was detected, and the growth intensity was related mostly to the soil richness and moisture. Our results concord to the opinion of Dirr (1998) and Suszka et al. (1996) for the wide range of ecological pliability of the species to the soil conditions.

Mean annual height increment of the investigated stands varies from 37 cm (SFS Balchik) to 50 cm (SFS Berkovitza) and in 120 years of age it decreases to 25 cm (SFS Gurkovo), which is explained by reaching the limits of life span of the species (Table 3).

Mean diameter in the 44–54 years old stands varies from 18 cm (SFS Balchik) to 30 cm (SFS Byala), and at the age of 120 years it is 46 cm (SFS Gurkovo) (Table 3).

Mean annual diameter increment in all stands is higher than the values in the growth and productivity tables. Since diameter growth is a function of growing space, i.e. stand density, it is important to note that in all the investigated stands the density is by far less than the value in the growth and productivity tables. It means that Norway maple stands cannot grow at high density typical for Common beech. Mean annual diameter increment varies from 0.36 (SFS Balchik) to 0.60 cm (SFS Byala) (Table 3).

The volume in the 1st site index stands varies from 113.5 (SFS Vidin) to 272 $m^3 \cdot ha^{-1}$ (SFS Berkovitza), with annual volume growth from 2.58 to 5.03 $m^3 \cdot ha^{-1}$. The plantation in SFS Byala is excluded because of the very low density, which makes it not typical forest stand. All the objects show that in age around 50 years the volume is still strongly affected by the stand density (Table 3). At the stage of maturity (SFS Gurkovo) the volume is 549 $m^3 \cdot ha^{-1}$, and mean annual volume increment is 4.58 $m^3 \cdot ha^{-1}$ (Table 3).

The analysis of phenotypic structure shows that the stands in SFS Berkovitza, Vidin and Byala could be classified in “plus” category for height, while those in Balchik and Gurkovo – in “normal” category. “Normal” in diameter is the stand in SFS Balchik and all other falls in the category “plus stands”. The stands in SFS Berkovica, Vidin, Byala, and Gurkovo can be classified in the category “absolute plus” (Table 4).

There are enough high-quality individuals in all stands, their share ranging from 56 % (SFS Byala) to 82 % (SFS Balchik) (Table 4).

After updating of the register the stands in SFS Balchik, stand 39m, must be kept (Fig. 2, Table 6). From the NS-FSPBB should be exclude the stands in SFS Botevgrad, stand 246d; Kotel, stand 3p; Tzonevo, stand 80a; Borima, stand 92c; and Aitos, stand 160b; Byala, stand 39g; Smyadovo, stand 11g; Tran, stand 148g (Fig. 2, Table 6).

Conclusions

The stands in which Norway maple participation is limited to single trees are not suitable for reproduction, because there are preconditions for self-pollination and homozygous offspring, from which the

Table 4. Breeding category and phenotypic structure of the investigated stands.

State forestry service	Forest stand	Category			Phenotypic quality structure						
					Good phenotypic quality, %	Non good phenotypic quality, %					
		by H	by D	Absolutely +		Sum	Y	V	S	OS	Damaged
Berkovitza	204 sh_2	+	+	yes	72	28	16	7	5	0	0
Vidin	390b, 391b	+	+	yes	71	25	7	3	7	8	4
Balchik	39m (part)	normal	normal	no	82	18	6	0	5	2	5
Byala	243v	+	+	yes	56	44	9	23	7	0	5
Gurkovo	30g (part)	normal	+	yes	71	29	19	5	5	0	0

Note: Y– forked stem, V – twin stem, S – crooked stem, OS – obliquely stem.

sowing qualities of seeds could be lowered. Further, inbreeding decreases the biodiversity within the species and the possibility for lower adaptive capacity and growing characteristics of the offspring appears.

Fig. 2. Location map of the investigated Norway maple stands.

Table 5. Young Norway maple stands, interest of a future investigations.

State forestry service	Forest stand	Area, ha	Altitude, m	Exposition	Slope gradient, degrees	Habitat Site type	Relief form	Soil type	Soil texture	Soil stoniness	Soil density	Basal rock	Soil richness
Kipilovo	144b	0.6	600	E	18	M-NBG-II-1/ C_2(30)	Slope lower part	Eutric Cambisols	Loamy sand	Stony	Optimum	Sandstone	Medium
Gurkovo	56v	0.4	800	SW	13	T-GT-II-1/ C_2(71)	Slope upper part	Eutric Cambisols	Loamy sand	Slightly stony	Optimum	Slate	Medium to high

For the above reasons, there is a need for establishment of stands with predominant participation of the species, as sources of reproductive materials.

As source of reproductive materials in the NSFSPBB should be included the stands in SFS Berkovitza, stand 204sh_2; Vidin, stand 390b and 391b; Byala, stand 243v; Gurkovo, stand 30g (Fig. 2, Table 6).

From tree breeding point of view the young stands in SFS Kipilovo, stand 144b in North Bulgaria and SFS Gurkovo, stand 56v in South Bulgaria are interesting for future investigations (Tables 5 and 6, Fig. 2). After tracing their development, growth indicators and genetic-selection characteristics, they could be considered as further opportunity for enrichment of the Bulgarian Forestry Seed Production Base from Norway maple.

The results shows that the number of valuable from selection point of view stands with predominant participation of *Acer platanoides,* is limited, especially in South Bulgaria. Meanwhile, the presence of valuable phenotypes, requires their preservation and wider use for production of seedlings for forestry and urban planting. For these reasons we suggest two plantations to be established by grafting for seed production for the needs of North and South Bulgaria and Moesian and Thracian forest areas, respectively.

The establishment of vegetative plantations for seed production in the other hand requires investigation of possibilities for cloning (*in vivo* or *in vitro*) of mature, valuable from selection point of view individuals, with high genetic potential.

Table 6. Geographic coordinates of the studied Norway maple stands.

State forestry Service	Forest stand	Longitude	Latitude
Botevgrad	246d	23°49'33.76"	42°51'20.63"
Balchik	39m (part)	28°21'26.03"	43°27'39.13"
Kotel	3p	26°19'23.52"	42°54'06.53"
Tzonevo	80a	27°27'34.56"	42°54'45.04"
Borima	92s	24°21'26.29"	42°56'42.65"
Aitos	160b	27°21'26.29"	42°54'52.76"
Byala	39g	25°46'09.60"	43°23'03.30"
Tran	148g	22°33'17.13"	42°43'29.10"
Smyadovo	11d	26°54'46.92"	43°02'19.05"
Berkovitza	204 sh_2	23°14'44.58"	43°11'10.54"
Vidin	390b, 391b	22°24'01.97"	43°44'22.52"
Byala	243v	26°00'37.84"	43°28'53.76"
Gurkovo	30g (part)	25°40'27.24"	42°42'21.56"
Kipilovo	144b	26°23'01.99"	42°51'40.46"
Gurkovo	56v	25°39'43.62"	42°47'08.02"

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