DOI: 10.2478/frp-2021-0003
Wersja PDF: www.lesne-prace-badawcze.pl

Leśne Prace Badawcze / *Forest Research Papers*
Marzec / March 2021, Vol. 82 (1): 23–30

ORIGINAL SCIENTIFIC ARTICLE

e-ISSN 2082-8926

Variability of wych elm *Ulmus glabra* Huds. characteristics growing on an *ex situ* conservation plantation in the Oleszyce Forest District

Jacek Banach [1], **Kinga Skrzyszewska** [1], **Izabela Puk** [1,2]

[1] University of Agriculture in Krakow, Faculty of Forestry, Department of Ecology and Silviculture, al. 29-Listopada 46, 31–425 Kraków, Poland; [2] Oleszyce Forest District, ul. Zielona 4B, 37–630 Oleszyce, Poland

*Tel. +48 12 6625125, e-mail: rlbanach@cyf-kr.edu.pl

Abstract. The aim of this work was to investigate the variability of different features in wych elm *Ulmus glabra* Huds. populations growing in a conservation plantation in the Kolonia Forest Subdistrict (Oleszyce Forest District). We examined the survival rate, height, and spring flushing of the elm trees as well as the occurrence of two leaf morphotypes after ten years since the establishment of the plantation. Statistically significant differences were found between the studied populations in terms of survival and height growth, while no difference was observed for spring flushing, which may be due to the close proximity in which the tested populations grow. The highest rate of survival was observed in the Bircza 33a population (87.3%), whereas the Lutowiska 40b population grew tallest (344.3 cm). Elms with leaves typical of the *U. glabra* ssp. *montana* (morphotype A – 84%) dominated the stand, while elms with leaves characteristic for the *U. glabra* ssp. *glabra* (morphotype B) were a minority with only 4%. However, within the Lutowiska 137g population, the share of morphotype B was as high as 25%.

Keywords: survival, height, spring flushing, leaf variability

1. Introduction

The conservation of genetic variability includes the restoration and maintenance of endangered gene resources. The first type of conservation consists in the permanent preservation of gene resources in their place of occurrence (*in situ*), the second, in their transfer to a place where they are not threatened (*ex situ*). Examples of *in vivo* (under natural conditions) conservation facilities are progeny plantations, conservation plantations, conservation seed orchards, clone archives and collections (Matras 2013).

Three species of elm occur in Poland: wych elm *Ulmus glabra* Huds., field elm *U. minor* Mill. and European white elm *U. laevis* Pall. (Bugała et al. 2015). Elm trees are classified as "post-pioneer species" that shape the forest environment (Falińska 2004). *U. glabra* has a wide distribution range, therefore two subspecies have been distinguished: *U. glabra* subsp. *glabra* in the southern part of its range and *U. glabra* subsp. *montana* in the northern part. In the Caucasus, a regional variant of *U. glabra* var. *trautvetteri* has also been distinguished, which is sometimes treated as a separate species – *Ulmus elliptica* K. Koch (Caudullo, de Rigo 2016). In Poland, wych elm occupies only 0.24% of the country's forest area, but there is a noticeable increase in its abundance compared to data from the 1970s (Napierała-Filipiak 2014).

Elm trees are increasingly included in conservation programmes, mainly *in situ* (Dunn 2000; Eriksson 2001; Collin et al. 2004; Collin, Bozzano 2015). Poland includes all elm species in genetic studies (Pałucka, Pasławska 2017; Chudzińska et al. 2018), while Spain includes *U. laevis* (Fuentes-Utrilla et al. 2014) and *U. glabra* (Puerto et al. 2017). The results obtained show a high level of genetic diversity. One of the actions aimed at preserving gene resources in living form (*in vivo*) is the establishment of so-called regional gene banks. One of these is the Carpathian Gene Bank [*Karpacki Bank Genów*], which serves to assess the genetic differentiation and breeding value of forests in the

Received: 16.02.2020 r., accepted after revision: 11.03.2021 r.

Carpathian region (Sabor 2006), and the results obtained can be used during stand reconstruction in this area (Sabor 1996). In the Carpathian Gene Bank, conservation crops have been established for the European silver fir *Abies alba* Mill., European beech *Fagus sylvatica* L. and European spruce *Picea abies* (L.) H.Karst, as well as seven plots for wych elm.

The aim of this study was to determine the adaptation and variability of selected traits of wych elm growing in a conservation crop of the Carpathian Gene Bank, established in Oleszyce Forest District. A survival analysis after 10 years of growth was performed on the crop and the growth of wych elm grown from seeds collected from 10 different locations in the south-eastern part of Poland (the Carpathian Province) was assessed. The research hypothesis assumed that there would be no difference in the analysed traits of the studied elm progeny in *ex situ* cultivation.

2. Material and methods

The conservation populations included in the study grow in the Carpathian natural-forest region, in locations of differing altitude, amounts of precipitation and mean temperature (Table 1). The seeds were collected in the spring of 2006 at the stage of morphological maturity (the so-called "green

Table 1. Location of the population of wych elm whose progeny is analyzed in conservative plantation in the Oleszyce Forest District

RFD*	Population No	Forest District Forest Subdistrict, Sub-compartment	Geographical coordinates		Altitude [m]	Mean annual temperature [°C]	Sum of annual precipitation [mm]	Vegetation period [days]	Forest habitat type**
			longitude E	latitude N					
Krosno	1	Stuposiany Widełki, 22a	22° 41'	49° 09'	610	6.3	1007	205	LGśw
	2	Lutowiska Dwernik, 5a	22° 39'	49° 13'	529	6.3	996	205	
	3	Lutowiska Lipie, 40b	22° 43'	49° 16'	762	6.3	996	205	
	4	Lutowiska Chmiel, 137g	22° 36'	49° 13'	650	6.3	996	205	
	5	Brzegi Dolne-I Żuków, 195c	22° 28'	49° 26'	439	6.3	980	207	Lwyż
	6	Brzegi Dolne-II Żuków, 195c	22° 28'	49° 26'	441	6.3	980	207	
	7	Krasiczyn Olszany, 160d	22° 38'	49° 42'	429	8.1	712	227	
Katowice	10	Wisła Łabajów, 38f	18° 51'	49° 36'	510	6.3	1316	198	LMGśw
Krosno	11	Bircza Krzywe, 33a	22° 32'	49° 41'	485	7.3	803	221	LŁwyż
	12	Lutowiska Dwerniczek, 123Ac	22° 40'	49° 13'	555	6.3	996	205	LGśw
Conservative plantation			22° 58	50° 11'	275	8.8	641	234	Lśw

*Regional Directorate of State Forests; **Lwyż – upland decidous forest, LŁwyż – upland riparian deciduous forest, LMGśw – fresh mountain mixed deciduous forest, LGśw – fresh mountain deciduous forest, Lśw – fresh deciduous forest harvest") and immediately sown at the Feleczyn Nursery Farm in the Nawojowa Forest District.

Ex situ conservation cultivation was established in the Oleszyce Forest District, in the Małopolskie Province in the Tarnogród Plateau mesoregion (Zielony, Kliczkowska 2012). In climatic terms, the area is located in the XVII Sandomierz -Rzeszów climatic and agricultural district (Kondracki 2011). The conservation area is located in compartment 190i of Kolonia range (Table 1).

The plot was divided into 3 replicates (blocks) with 100 trees each, representing 10 populations (Fig. 1). The elms were planted in a 1.5 × 1.5 m arrangement.

During the field study (2018), the survival rate was determined, height was measured, and variation in spring flushing and occurrence of leaf morphotypes were assessed. A six-level scale proposed by Mykking and Skrøppa (2007) was used to assess spring flushing: 0 – no development; 1 – slight swelling (light brown apical bud); 2 – swelling (green apical bud); 3 – flushing (leaves showing); 4 – all leaves visible; 5 – fully developed leaves with stalks. The assessment was made once on April 11–12. The occurrence of two leaf morphotypes was assessed on the analysed elm trees (Mykking, Yakovlev 2006): morphotype A – leaves relatively long, apex extended, low value of the proportion of blade width to length; morphotype B – leaves relatively wide, two sharp lateral lobes visible, apex narrowly extended, high value of the proportion of blade width to length (Fig. 2). When both morphotypes were present on one specimen, the tree was classified as morphotype A/B.

The population mean value was calculated for survival rate, height and spring flushing together with the standard error of the mean estimate (±SE). A two-factor analysis of variance with interaction, defined by the following formula, was performed to determine the significance of the effect of genotype (population), repetition (block) and the interaction of the two factors on the variation of these traits:

$$Y_{kjn} = \mu + P_k + B_j + PB_{kj} + e_{njk}$$

where:
y_{kjn} – the value of n observation in population k in repetition j,
μ – overall average,
P_k – effect of population k,
B_j – effect of repetition j,
PB_{kj} – effect of the interaction of population k with repetition j,
e_{njk} – error.

When analysing the occurrence of leaf morphotypes, a pie chart of the proportion of specimens with each morphotype, i.e. A, B and A/B, was made for the total of all elm trees in the crop. A bar chart of the proportion of morphotypes in each analysed population was also made and the differences between the fractions were checked using Pearson's χ^2 test. Pearson's linear correlation coefficients were also calculated between the assessed traits of wych elm and between the traits and location parameters of the populations whose progeny were studied in the conservation crop in Oleszyce Forest District. All statistical analyses were performed using Statistica 13.3 software (Tibco Software Inc. 2017).

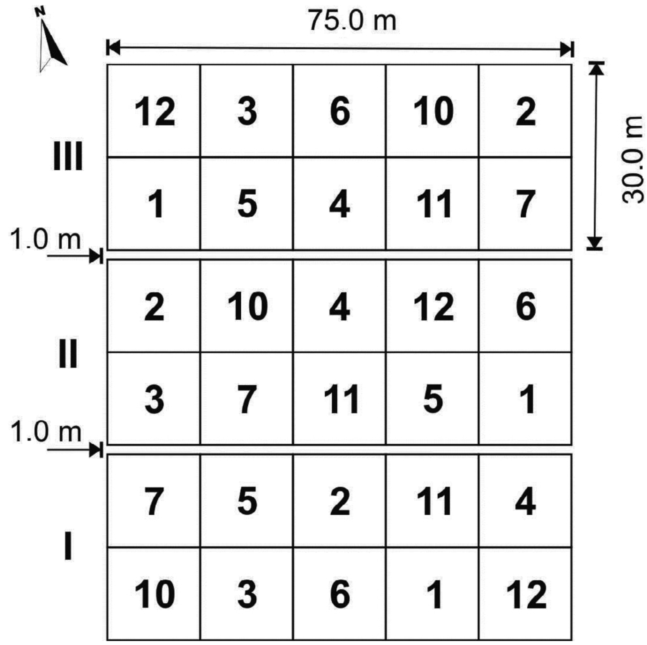

Figure 1. Scheme of conservative plantation of the Carpathian Gene Bank in the Oleszyce Forest District, 1–12 – population numbers, I–III – repetition (block) numbers

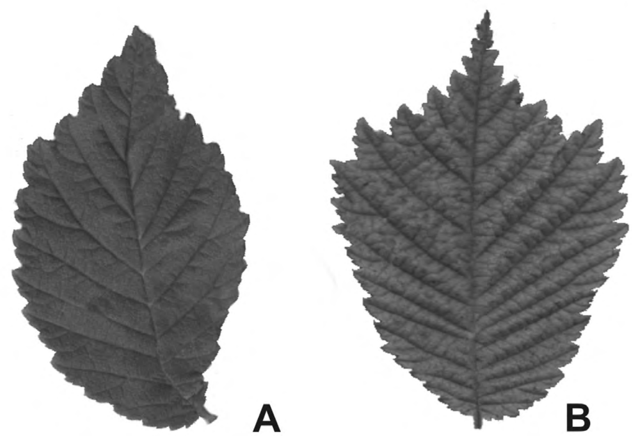

Figure 2. Leaf morphotypes in wych elm: *Ulmus glabra* ssp. *montana* (A), *U. glabra* ssp. *glabra* (B)

3. Results

3.1. Survival

For the 10 populations studied in the conservation plot in Oleszyce, the average survival rate of elm trees after 10 years of growth was about 68%. The lowest survival rate (56.3%) was observed for elm originating from the Wisła 38f population, and the highest (87.3%) from Bircza 33a (Table 2). The origin of the elm trees had a significant effect on their survival rate, while no statistically significant difference was observed between the cultivated conservation blocks. On the other hand, the effect of the "population × block" interaction proved to be significant, indicating different survival rates of elm trees in different parts of the cultivation (Table 3).

3. 2. Height

The mean height of the trees in the experimental plot was 234.8 cm. The group of elm trees characterised by the lowest height (<160 cm) included the populations of Bircza 33a and Wisła 38f, while the group with the highest mean value of this feature (344.3 cm) included the elm trees from Lutowi-

Table 2. Mean values of features (± SE) of wych elm after 10 years of growth on a conservative plot in the Oleszyce Forest District; a–e – homogeneous groups determined by Tukey's test, *p*=0.05)

Population No	Population name	Survival [%]	Height [cm]	Spring flushing (index)
1	Stuposiany 22a	63.3 ± 2.8 ^{cde}	297.1 ± 14.3 ^{b}	2.55 ± 0.12 ^{a}
2	Lutowiska 5a	69.3 ± 2.7 ^{bcd}	279.8 ± 14.3 ^{bc}	2.62 ± 0.10 ^{a}
3	Lutowiska 40b	75.3 ± 2.5 ^{b}	344.3 ± 8.9 ^{a}	2.62 ± 0.10 ^{a}
4	Lutowiska 137g	58.3 ± 2.9 ^{de}	176.7 ± 6.1 ^{e}	2.44 ± 0.12 ^{a}
5	Brzegi Dolne 195c-I	67.0 ± 2.7 ^{bcde}	225.2 ± 6.5 ^{d}	2.58 ± 0.10 ^{a}
6	Brzegi Dolne 195c-II	67.3 ± 2.7 ^{bcde}	184.4 ± 6.3 ^{e}	2.50 ± 0.11 ^{a}
7	Krasiczyn 160d	72.3 ± 2.6 ^{bc}	274.9 ± 8.0 ^{bc}	2.44 ± 0.10 ^{a}
10	Wisła 38f	56.3 ± 2.9 ^{e}	159.2 ± 6.7 ^{e}	2.45 ± 0.12 ^{a}
11	Bircza 33a	87.3 ± 1.9 ^{a}	154.1 ± 3.6 ^{e}	2.63 ± 0.09 ^{a}
12	Lutowiska 123Ac	63.0 ± 2.8 ^{cde}	252.7 ± 14.7 ^{cd}	2.46 ± 0.12 ^{a}
Mean value		67.9	234.8	2.53
Standard dev.		9.0	65.0	0.08
Variation coeff. [%]		13.3	27.7	3.2

Table 3. Results of the variance analysis of the wych elm features after 10 years of growth in a conservative plot in the Oleszyce Forest District

Source of variance	Survival		Height		Spring flushing	
	F-test	significance level	F-test	significance level	F-test	significance level
Population (P)	11.753	< 0.001	90.270	< 0.001	0.562	0.829
Block (B)	0.139	0.645	16.621	< 0.001	0.685	0.504
P × B interaction	5.336	< 0.001	86.453	< 0.001	0.566	0.925

ska 40b (Table 2). All analysed sources of variation had a significant effect on height (Table 3).

3.3. Spring flushing

The mean value of the spring flushing index – bud development was 2.53. The populations which began their vegetation the fastest were the elm trees from: Bircza 33a, Lutowiska 5a and Lutowiska 40b, while the latest to begin spring growth was Lutowiska 123Ac. The difference between the mean indices was small, and the analysis of variance did not show a significant effect of any of the sources of variation (Tables 2 and 3).

The calculated correlation coefficients were statistically significant (p=0.05) only in three cases. Higher survival rates were found to be characteristic for elm trees which began growing earlier and originated from an area with a longer growing season. On the other hand, higher annual precipitation in the location of a given population correlated negatively with elm survival (Table 4).

3.4. Occurrence of leaf morphotype

Leaf morphotype A dominated (84%) in the elm trees growing in the conservation plantation. The next most numerous leaf type in the elm trees was the simultaneous occurrence of A and B morphotypes (12%), and the least numerous were elm trees with leaf morphotype B, whose share was only 4%. In general, the occurrence of leaf morphotypes in individual populations was similar to the proportions observed for the whole crop, but the population from Lutowiska 137g had a more than a fourfold higher share of morphotype B (25.1%), while it did not occur at all in the elms from the Lutowiska 40b population. The $\chi2$ test showed significant differentiation ($p<0.001$) of the shares of morphotypes in the different populations (Fig. 3).

4. Discussion

Research conducted in the conservation plantation at Oleszyce Forest District after 10 years of wych elm growth from the Carpathian Region showed adaptation differences between the analysed populations after transferring them outside this region.

The significant differences obtained for wych elm survival and height growth indicates the possibility of selecting seed sources with better adaptive properties in the initial years after planting in a crop. However, the expected effectiveness of selection may be limited due to the significant “population × block” interaction of both traits, meaning that different populations (genotypes) of wych elm exhibit different abilities of adaptation to various micro-environmental conditions. Similar conclusions were reached by Mykking and Skrøppa (2007), who pointed to the possibility of selecting stable populations of wych elm with better adaptive predispositions to different environmental conditions. They also showed that the progeny of individual trees within a population were characterised by high adaptive variability. A similar result in this respect was shown by the assessment of the breeding value of vegetative progeny of 45 parent trees growing in conservation plantations in Gołdap and Czerwony Dwór Forest Districts (Mioduszewski, Korczyk 2013). This indicates that it is possible to perform the selection of wych elm at the population and provenance level, similar to other forest tree species (Wright, Osorio 1992; Baliuckas, Pliura 2003; Fober 2004; Jankowiak et al. 2013; Jansons et al. 2013).

When analysing the variation in spring flushing, no population effect was found for the magnitude of this index. Mykking and Skrøppa (2007) emphasize the great importance of the geographical location of the origin of the experimental material on the onset of the spring flushing of seedlings. According to Roberts and Main (1965), the va-

Table 4. Correlation between the features of the wych elm and the location parameters of the analyzed populations (correlation significant for p=0.05*)

Trait	Survival	Tree height	Spring flushing index
Tree height	0.11	–	–
Spring flushing index	0.67 *	0.31	–
Vegetation period	0.69 *	0.00	0.04
Sum of annual precipitation	–0.69 *	–0.20	–0.18
Mean annual temperature	0.54	–0.02	–0.13
Altitude	–0.10	0.48	0.19

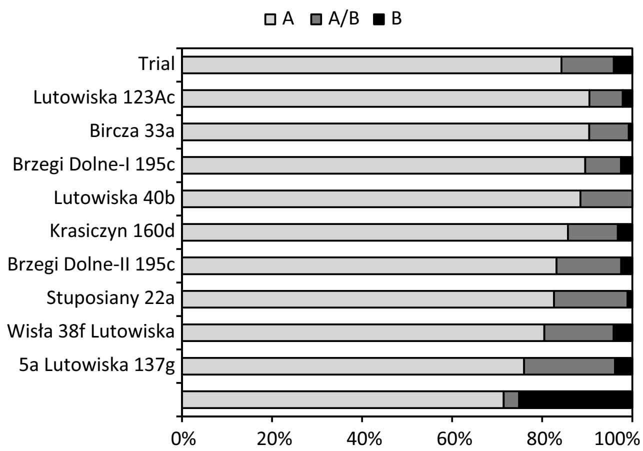

Figure 4. Share of trees with morphotypes of leaves in the populations studied in conservative plantation in the Oleszyce Forest District (χ^2=259.5, *df*=18, *p*<0.001)

riability of the timing in the onset of spring flushing of elm is related to external factors such as temperature and altitude. All populations analysed in the Oleszyce crop come from areas with different environmental conditions (precipitation, temperature, length of the growing season), but significantly different from the conditions at the conservation plantation, which is characterised by a longer growing season, higher mean annual temperature and lower annual precipitation. Hence, the suggestions given by the authors cited above may explain the lack of variation in spring flushing. This is also confirmed by the study of Santini et al. (2004), which showed a linear relationship between the number of warm (temp. > +5°C) and cool (temp. ≤ +5°C) days and the onset of the spring flushing of elms. Another explanation for the lack of variation in spring flushing may be the result obtained by Gheraldini (2007), who found that European elm species are characterised by a shallow dormancy and a short period of cold is needed to break it. However, an effect of transferring elm trees to other environmental conditions was observed, expressed in their survival rate. Elm trees from areas with a longer growing season, i.e. more similar to the value at the conservation plantation (234 days), survived better, whereas those from areas with higher precipitation, significantly different from that of the conservation plantation (641 mm), were less successful in their survival.

Two leaf morphotypes were found in the analysed populations of wych elm at the Oleszyce plantation. Individuals with leaves characteristic for *Ulmus glabra* ssp. *montana* predominated (morphotype A – 84%). The proportion of trees with leaves characteristic for *U. glabra* ssp. *glabra* (morphotype B) was only 4%, but this morphotype was more frequent in the population from Lutowiska 137g (25%), while it was not found in the Lutowiska 40b population. According to Mykking and Yakovlev (2006), who conducted identical analyses in Norway, the occurrence of two leaf varieties in *U. glabra* is connected with the existence of two post-glacial migration routes of this species. The existence of morphological variability in the assimilative apparatus of wych elm is also indicated by the analytical results of four Croatian populations of this species (Zebec et al. 2015).

5. Summary and conclusions

The study revealed statistically significant variation between the studied populations of wych elm in terms of survival and height growth. The effect of the "population × block" interaction proved to be significant for survival rate. No differentiation was obtained for spring flushing, which may be due to the small environmental distance between the tested populations.

A significant correlation was found between the survival rate of wych elm on the *ex situ* conservation plantation located in Oleszyce Forest District and some of the parameters of population location. This feature correlated positively with the length of the growing season and negatively with the sum of precipitation. The best survival under these conditions was characterised by the Bircza 33a population, for which both climatic parameters were most similar to those of the conservation plantation.

Future research should focus on further identifying the potential for interactions between genotype and the environment, enabling the selection of stable populations in various environments.

The analysed elm populations from south-eastern Poland showed both leaf morphotypes, i.e. *Ulmus glabra* ssp. *montana* (morphotype A) and ssp. *glabra* (morphotype B), i.e. the presence of both colonization lines after the last glaciation. The predominance of individuals with leaves characteristic for the western migration line was demonstrated (morphotype A – 84%).

Conflict of interest

The authors declare the absence of potential conflicts of interest.

Acknowledgements and funding sources

The authors would like to thank Oleszyce Forest District for making it possible to establish a conservation crop and for performing the necessary silviculture work every year. The study was financed from a subsidy of the Ministry of Science and Higher Education to the Hugo Kołłątaj Agricultural University in Kraków for 2021 (SUB/040012/D019).

References

Baliuckas V., Pliura A. 2003. Genetic variation and phenotypic plasticity of *Quercus robur* populations and open-pollinated families in Lithuania. *Scandinavian Journal of Forest Research* 18(4): 305–309. DOI 10.1080/02827580310005153.

Bugała W., Boratyński A., Iszkuło G. 2015. Wiązy. Wyd. PAN, Poznań, 477 s. ISBN 9788379860517.

Caudullo G., de Rigo D. 2016. *Ulmus* – elms in Europe: distribution, habitat, usage and threats.In San-Miguel-Ayanz J., de Rigo D., Caudullo G., Houston Durrant T., Mauri A. (Eds.) European Atlas of Forest Tree Species. Publ. Off. EU, Luxem-bourg, 186–188. DOI 10.2788/4251.

Chudzińska M., Pałucka M., Pasławska A., Litkowiec M., Lewandowski A., Kozioł C. 2018. Wyniki wstępnych badań nad zmiennością genetyczną oraz zróżnicowaniem genetycznym między populacjami wiązu górskiego (*Ulmus glabra* Huds.) w Polsce. *Sylwan* 162(9): 727−736. DOI 10.26202/sylwan.2018064.

Collin E., Rusanen M., Ackzell L., Bohnens J.,de Aguiar A., Diamandis S., Franke A., Gil L., Harvengt L., Hollingsworth P., Jenkins G., Meier-Dinkel A., Mittempergher L., Musch B., Nagy L., Pâques M., Pinon J., Piou D., Rotach P., Santini A., Vanden Broeck A., Wolf H. 2004. Methods and progress in the conservation of elm genetic resources in Europe. *Investigacion Agraria: Sistemas y Recursos Forestales* 13(1): 261–272.

Collin E., Bozzano M. 2015. Implementing the dynamic conservation of elm genetic resources in Europe: case studies and perspectives. *iForest* 8: 143–148. DOI 10.3832/ifor1206-008.

Dunn C.P. 2000. The elms: breeding, conservation and disease management. Kluwer Academic Publishers, Boston, 384 s.

Eriksson G. 2001. Conservation of noble hardwoods in Europe. *Canadian Journal of Forest Research* 31(4): 577–587. DOI 10.1139/cjfr-31-4-577.

Falińska K. 2004. Ekologia roślin. Wyd. PWN, Warszawa, 511 s. ISBN 8301142227.Fober H. 2004. Genetic reactivity of Nor-way spruce *Picea abies* (L.) Karst. to soil fertility. *Dendrobiology* 51 (Suppl.): 57–63.

Fuentes-Utrilla P., Venturas M., Hollingsworth P.M., Squirrell J., Collada C., Stone G.N., Gil L. 2014. Extending glacial refugia for a European tree: genetic markers show that Iberian populations of white elm are native relicts and not introductions. *Heredity* 112(2): 105–113. DOI 10.1038/hdy.2013.81.

Gheraldini L. 2007. Bud burst phenology, dormancy release and susceptibility to Dutch elm disease in elms (*Ulmus* spp.). Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala. *Acta Universitatis Agriculturae Sueciae* 134: 1–52.

Jankowiak R., Banach J., Balonek A. 2013. Susceptibility of Polish provenances and families of pedunculate oak (*Quercus robur* L.) to colonization by *Phytophthora cambivora*. *Leśne Prace Badawcze* 74(2): 161–170. DOI 10.2478/frp-2013-0016.

Jansons A., Sisenis L., Neimane U., Rieksts-Riekstins J. 2013. Biomass production of young lodgepole pine (*Pinus contorta* var. *latifolia*) stands in Latvia. *iForest* 6: 10–14. DOI 10.3832/ifor0637-006.

Kondracki J. 2011. Geografia regionalna Polski. Wydanie 3. Wydawnictwo Naukowe PWN, Warszawa, 440 s. ISBN 9788301160227.

Matras J. 2013. Ochrona różnorodności genetycznej drzew leśnych. *Polish Journal of Agronomy* 14: 22–36.

Mioduszewski S., Korczyk A.F. 2013. Wzrost szczepów wiązu górskiego (*Ulmus glabra* Huds.) w archiwum klonów w Nadleśnictwie Bielsk. *Leśne Prace Badawcze* 74 (2): 149–159. DOI 10.2478/frp-2013-0015.

Mykking T., Yakovlev I. 2006. Variation in leaf morphology and chloroplast DNA in *Ulmus glabra* in the northern suture zone: Effects of distinct glacial refugia. *Scandinavian Journal of Forest Research* 21(2): 99–107. DOI 10.1080/02827580500539265.

Mykking T., Skrøppa T. 2007. Variation in phenology and height increment of northern *Ulmus glabra* populations: Implication for conservation. *Scandinavian Journal of Forest Research* 22(5): 369–374. DOI 10.1080/02827580701672121.

Napierała-Filipiak A., Filipiak M., Jaworek J. 2014. Distribution of elms (*Ulmus* spp.) in Polish forests according to the forestry inventory data. *Sylwan* 158(11): 811−820. DOI 10.26202/sylwan.2014017.

Pałucka M., Pasławska A. (red.) 2017. Zachowanie różnorodności biologicznej siedlisk obszarów NATURA 2000, poprzez ochronę *ex situ* jesionu wyniosłego, wiązu górskiego, wiązu pospolitego oraz wiązu szypułkowego na terenie Polski (FraxUmLBG). Wyd. Poligrafia AD REM, Leśny Bank Genów Kostrzyca, 56 s. ISBN 9788365295859.

del Puerto M.M., García F.M., Mohanty A., Martín J.P. 2017. Genetic diversity in relict and fragmented populations of *Ulmus glabra* Hudson in the Central System of the Iberian Peninsula. *Forests* 8(5): 143. DOI 10.3390/f8050143.

Roberts B.R., Main H.V. 1965. The effect of chilling and photoperiod on bud break in American Elm. *Journal of Forestry* 63(3): 180–181. DOI 10.1093/jof/63.3.180.

Sabor J. 1996. Selekcja i zachowanie najwartościowszych genotypów w programie „Karpackiego Banku Genów”.*Sylwan*140(11): 45–60.

Sabor J. 2006. Idea regionalnych banków genów. In Elementy genetyki i hodowli drzew leśnych. J. Sabor (Ed.). Wyd. Centrum Informacyjne Lasów Państwowych, Warszawa, 619–636. Santini A., Ghelardini L., Falusi M., Bohnens J., Buron M., Collin E., Solla A., Vanden B.A. 2004. Vegetative bud-burst variability of European elms. *Investigacion Agraria: Sistemas y Recursos Forestales* 13(1): 37–45.

TIBCO Software Inc. 2017. Statistica (data analysis software system) (Wersja 13, http://statistica.io).

Wright J.A., Osorio L.F. 1992. Results of provenance and family within provenance trials of *Pinus tecunumanii* in Colombia, South America. *Forest Ecology and Management* 55(1–4): 107–116. DOI 10.1016/0378-1127(92)90095-Q.

Zebec M., Idžojtić M., Poljak I., Modrić I. 2015. Population variability of wych elm (*Ulmus glabra* Huds.) in the mountainous region of Croatia according to the leaf morphology. Šumarski list 135(9–10): 429–439.

Zielony R., Kliczkowska A. 2012. Regionalizacja przyrodniczo-leśna Polski 2010. Wyd. Centrum Informacyjne Lasów Państwowych, Warszawa, 356 s. ISBN 9788361633624.

Contribution of the authors

J.B. – study concept, statistical analysis of the results, literature review, graphics preparation, manuscript writing, manuscript editing; K.S. – analysis of the results, literature review, manuscript editing; I.P. – conducting the research, analysis of the results, manuscript writing.

Translated by: Barbara Przybyska