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Yulia Prokopuk, Olena Leshcheniuk, Maryna Sukhomlyn, Raisa Matiashuk, Vasyl Budzhak, Maksym Netsvetov*

Growth drivers of monumental wild service tree (*Sorbus torminalis*) out of its natural range in Kyiv, Ukraine

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Abstract: Wild service tree (*Sorbus torminalis*) is a rare, endangered, relict species, that is protected by law in many European countries. Outside the species distribution range, the trees are usually planted in botanical gardens, parks, arboretums, and at the roadside. Such old introduced trees are an important source of knowledge about species' acclimation process and current growth-limiting factors in the new environment. In Kyiv, the oldest live *S. torminalis* trees have been planted in botanical gardens and arboretums after the 1950s. In addition, some trees of this species are preserved in front of the historical building Liberman's mansion, but the year of their planting remains unknown. Regarding dendroclimatological investigations of this species are scarce and have been provided only in Central European forests, a detailed analysis of the species growth-to-climate relationships should be performed not only the species' natural range but also in its secondary ranges.

In this article, we studied three *S. torminalis* trees in a historical place in Kyiv to determine their age and evaluate environmental conditions driving the growth of this rare species out of its natural range in Kyiv.

To reach our goal we used the dendrochronological approaches, i.e. tree-ring dating, partial correlation analysis using stationary and moving time windows.

Our results showed that *S. torminalis* trees were planted after the last building owner S. Liberman's death (1917). The studied trees are the oldest of known alive *S. torminalis* trees in Kyiv. Dendroclimatological results revealed *S. torminalis* is sensitive to higher air temperature and moisture excess in the period of wood formation in Kyiv.

S. torminalis trees at 2 Bankova Street are the oldest species examples in Kyiv and have important historical, cultural, and scientific values. *S. torminalis* species could be widely used in urban forestry, particularly in regions with projected soil moisture shortening.

Keywords: wild service tree, tree-rings, growth pattern, climatic factors

Addresses: Y. Prokopuk, O. Leshcheniuk, M. Sukhomlyn, R. Matiashuk, V. Budzhak, M. Netsvetov, Institute for Evolutionary Ecology, National Academy of Sciences of Ukraine, 37, Academician Lebedev St, 03143, Kyiv, Ukraine;
YP https://orcid.org/0000-0001-8844-0219, e-mail: ju.prokopuk91@gmail.com;
OL https://orcid.org/0000-0003-0597-7251, afedorova550@gmail.com;
MS https://orcid.org/0000-0001-6573-9699, suhmary@ukr.net;
RM https://orcid.org/0000-0003-1929-0522, raisakiev2015@gmail.com;
VB https://orcid.org/0000-0002-7754-6437, budzhakv@gmail.com;
MN https://orcid.org/0000-0001-9037-3588, disfleur76@live.fr
*Corresponding author

Introduction

The wild service tree (*Sorbus torminalis* (L.) Crantz) is endangered relict species, which distributes from Great Britain and northern-west Africa (the slopes of the Atlas Mountains in Tunisia, Algeria and Morocco), in the west to northern Iran in the East. In the north, a range's border passes through the territories of south Sweden, Poland, Ukraine and Caucasus (Demesure-Musch & Oddou-Muratorio, 2004; Akatova & Ermakov, 2020).

In Ukraine, *S. torminalis* grows in Carpathian Ruthenia, Eastern Carpathian Foothills, Northern Bessarabia, Podilia territories (Termena et al., 1993; Budzhak, 1996), and in mountainous Crimea (Bondarenko & Pokinchera, 2013; Sakhno, 2014; Didukh et al., 2016). The rivers Neman, Prypiat, and Southern Bug limit the range in the east of Ukraine (Budzhak, 1996). *S. torminalis* is a typical species in broadleaved forests as G1.63 Medio-European neutrophile *Fagus* forests, G1.66 Medio-European limestone *Fagus* forests, G1.A Meso- and eutrophic *Quercus*, *Carpinus*, *Fraxinus*, *Acer*, *Tilia*, *Ulmus* and related woodland, G1.7 Thermophilous deciduous woodland, G3.4E. Ponto-Caucasian *Pinus sylvestris* forests (EUNIS, 2019).

Deforestation at the end of the XIX–early XX centuries has caused a significant decline of *S. torminalis* populations and even their extinction in forests across Europe and particularly in Ukraine (Chopyk, 1970). Natural populations of *S. torminalis* are often scattered, small and spatially isolated (Hoebee et al., 2007) and grow in rare plants' communities (Didukh, 2009). In many countries, *S. torminalis* is protected by law as a rare and endangered species (Úradnícek et al., 2010; Didukh, 2009; Bednorz, 2007).

As a young tree, *S. torminalis* is shade-tolerant and as an adult tree, it is more light-demanding (Thomas, 2017), although it is struggling under sudden forest clearance. *S. torminalis* tolerates well the range of soils characteristics growing on acid and basic soils (Rasse et al., 2005) as well as moderately rocky soils (Oria de Rueda et al., 2006). It is adapted to short flooding followed by dry periods later in the season (Ruiz de la Torre, 2006), but it avoids dry sandy and wet marshy soils (Rubțov, 1958). *S. torminalis* is warmth-demanding species (Bednorz, 2007; Bednorz, 2010) but it withstands low winter temperatures, spring frosts, strong winds and droughts up to two months (Haralamb, 1967; Montero et al., 2003). *S. torminalis* well adapts to a variety of climatic conditions and thereby it is a perspective species to use in facing a soil-moister deficit in the near future areas (Paganová, 2007, Termena & Budzhak, 1998).

S. torminalis is a long-lived plant resistant to the urban environment, insects and diseases, and thus it is used as an ornamental tree in urban forestry and greening (Hrybovych, 2018; Chepur & Rishko, 2018; Budzhak, 1996). In Ukraine, the oldest *S. torminalis* trees grow in ancient parks in the Bukovina region (Budzhak, 1996). There is a tree at the age of over 140 years exceeded 130 cm in the stem diameter in the Yuriy Fedkovych Chernivtsi National University's botanical garden. In the eastern Ukraine, outside the distribution range, this species was introduced in the XIX centenary. One of the oldest trees was planted here at the turn of the XIX and XX centuries and is still alive in a plantation of the Mariupol research station of forestry (Melnichenko, 1999). Since 1975 the species was planted in the Donetsk Botanical Garden of the National Academy of Sciences of Ukraine (Kharkhota & Vinogradova, 2016; Polyakov et al., 2010). In Kyiv's Botanical Gardens, S. *torminalis* has been planted after the 1950s (Glukhova et al., 2017). Additionally, three *S. torminalis* trees grow in the alley at 2 Bankova Street in front of Liberman's mansion, which was built in the 1880s (Drug & Malakov, 2004). If these trees are old-growth, they could have historical, cultural, and scientific values. Even century-old trees had been growing in urban landscapes for several historical periods and now complete our understanding of past city views, urban forestry development, old householders' preferences, etc. The oldest introduced trees are an essential source of knowledge about species' acclimation process, growth limiting factors, vulnerability to ongoing climate change, and longevity in the new environment.

In this article, we study the *S. torminalis* trees at 2 Bankova Street to determine their age and assess their sensitivity to climate variables employing a dendrochronological approach.

Materials and methods

Sampling and chronology building

Trees of *S. torminalis* have grown in Bankova Street in front of Liberman's mansion, that is currently the House of Association of Ukrainian Writers in Kyiv (Fig. 1A, B). In March 2021, two cores from each tree were extracted using a Haglof borer at 1.3 m above ground following a phytopathological observation. To avoid further stem injury holes were filled with garden waxes.

Air-dried cores had been glued onto wooden supports and then were polished with sanding paper gradually increasing fineness from 100 to 500 grids. After it the samples were scanned on the flatbed scanner Epson V33 under resolution 3200 dpi. The tree-ring widths were measured using "AxioVision" software (Carl Zeiss Microscopy GmbH) with an accuracy of 0.01 mm. Regarding light wood and difficulty in the tree ring distinguishing samples were additionally observed under the conventional microscope

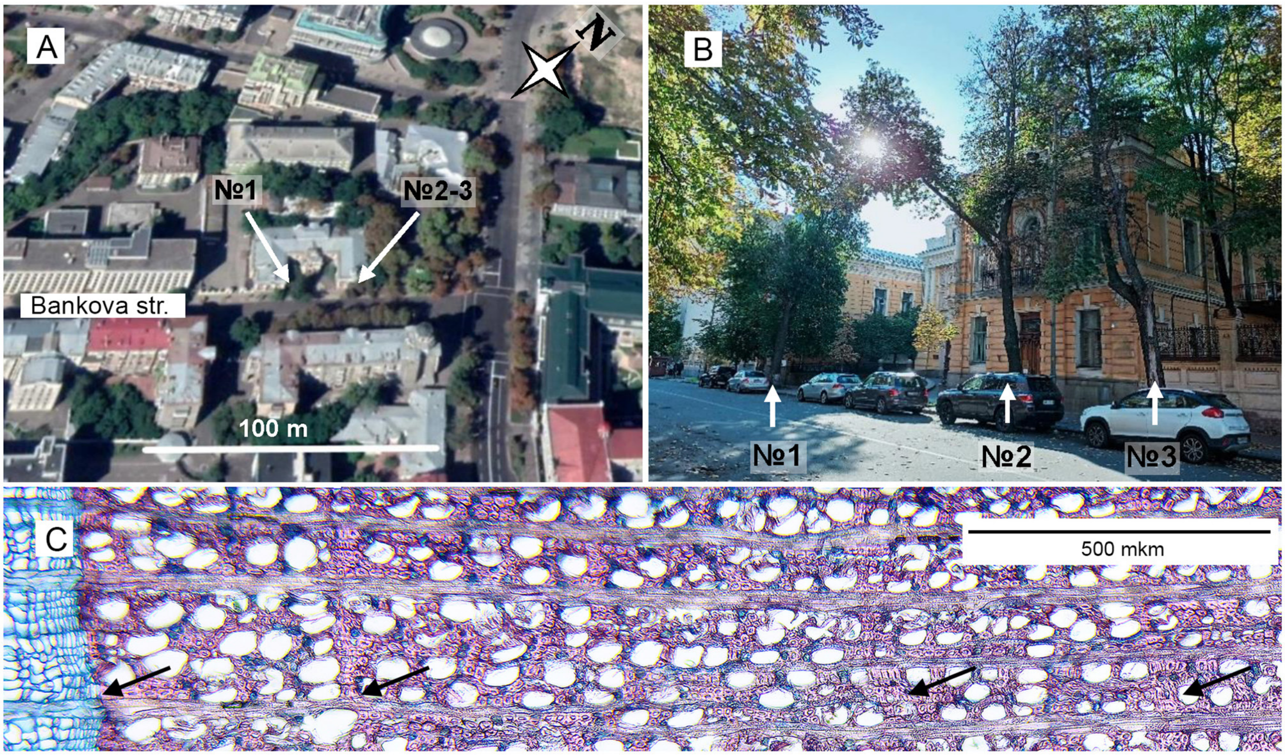

Fig. 1. Studied *Sorbus torminalis* trees. A: map of *S. torminalis* location; B: photo of roadside trees; C: cross-section of *S. torminalis* No 2 wood with tree-rings. White arrows point to the studied trees. Black arrows point to the boundaries of annual rings formed from 2017 to 2020

Fisher-scientific. To determine the age of trees which cores did not have a pith due to stem damage used a modified graphical method (Rozas, 2003).

Obtained cores' chronologies had been cross-dated and then used to build individual trees chronologies. Chronology dating was checked with Cofecha software, Version 6.06p (Holmes, 1983). The mean tree-ring chronology was built using the dplR (Bunn, 2010) package in R (R Core Team, 2020).

Analysis of trees radial growth with climatic variables

Daily temperature and precipitation data for Kyiv were obtained from European Climate Assessment and Dataset (2012). For the analysis, we employed the Dendrotools package (Jevšenak & Levanič, 2018) developed to consider time intervals in a wide range.

Mean temperatures and the sum of precipitation were aggregated into intervals of 14–270 days. Thus, we obtained 257 sets for each variable. The full period for the analysis included two years i.e. current growing season and the previous one.

To weaken the impact of climatic variables co-variation we used partial correlation in the analysis (Freund et al., 2010). The study period lasted from 1946 to 2020 and covered a common period for the studied trees. We conducted two types of analysis with different time windows. The first was based on the entire 75-years study period while in the second a 31-year window rolled through the whole period with a one-year step that allows the finding of growth-to-climate relationships and the assessment of their stability and duration. For this purpose, we extracted the optimal window width, i.e. aggregating period, and the starting day of the optimal window width calculated for each 31-year sequence by the daily_response() function (Jevsenak & Levanic, 2018). The results were stacked as a time series and then represented as a line-range plot to ease further interpretation.

Results

Age, growth and pathological assessment of *S. torminalis*

The number of annual rings in cores of *S. torminalis* trees No 1–3 was 78, 99, and 80 respectively (Fig. 2). The cambial age of the tree No 2 was 102 years. Considering rotted piths in other trees, we assessed the number of rings in the absent part using the geometric method. The estimated age of the trees No 1 and No 3 ranged between 90–99 years and 93–99 years respectively.

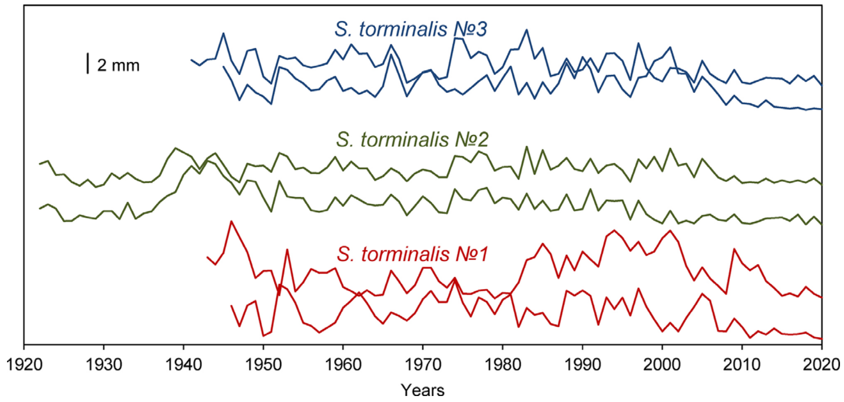

Fig. 2. Chronological series of radial growth of *Sorbus torminalis* cores. The colors vary with trees number

The stem's diameters of *S. torminalis* No 1, No 2, and No 3 at 1.3 m above the ground were 66.8 cm, 49.3 cm and 55.4 cm respectively. The mean radial growth of trees No 1–3 was 3.37±1.853 mm, 2.21±1.285 mm, and 2.75±1.432 mm respectively and for all tress was 2.73±1.591 mm on average. The longest individual tree-ring width chronology covers the period 1922–2020, while the shortest chronology spans the period 1946–2020 (Fig. 2) that determined a common study interval for all chronological series. The autocorrelation coefficient, that indicates the dependence of the current year's growth to previous ones, was 0.575. The expressed population signal (EPS) showing the representativeness of the chronology reached 0.843. The mean interseries correlation and the signal-to-noise ratio were 0.674 and 5.365 respectively.

The dry basidiocarps of *Auricularia mesenterica* (Dicks.) Pers. were found on the stem bark of the tree No 2 that was also damaged mechanically at the high of 0.6 m from the ground. Basidiocarps of *Pleurotus* spp. were found on the root crown of the tree No 1. On the stem bark of *S. torminalis* No 3, old basidiocarps of *Chondrostereum purpureum* (Pers.) Pouzar were revealed. The tree No 3 also had stem's bark-stripping damage and the partly drying crown.

S. torminalis growth-to-climate relationships

The stationary partial correlation analysis revealed that *S. torminalis* radial growth was sensitive to the high air temperature at the beginning of the previous growing season – from 14 May to 8 June. The coefficient of the partial correlation reached the value of −0.397. Excess of precipitation amount in the period from 2 June to 23 September depressed studied trees radial growth (Fig. 3).

The moving correlation analysis showed the mentioned temperature pattern was significant and dominated among other from 1952 to 2018, but it became

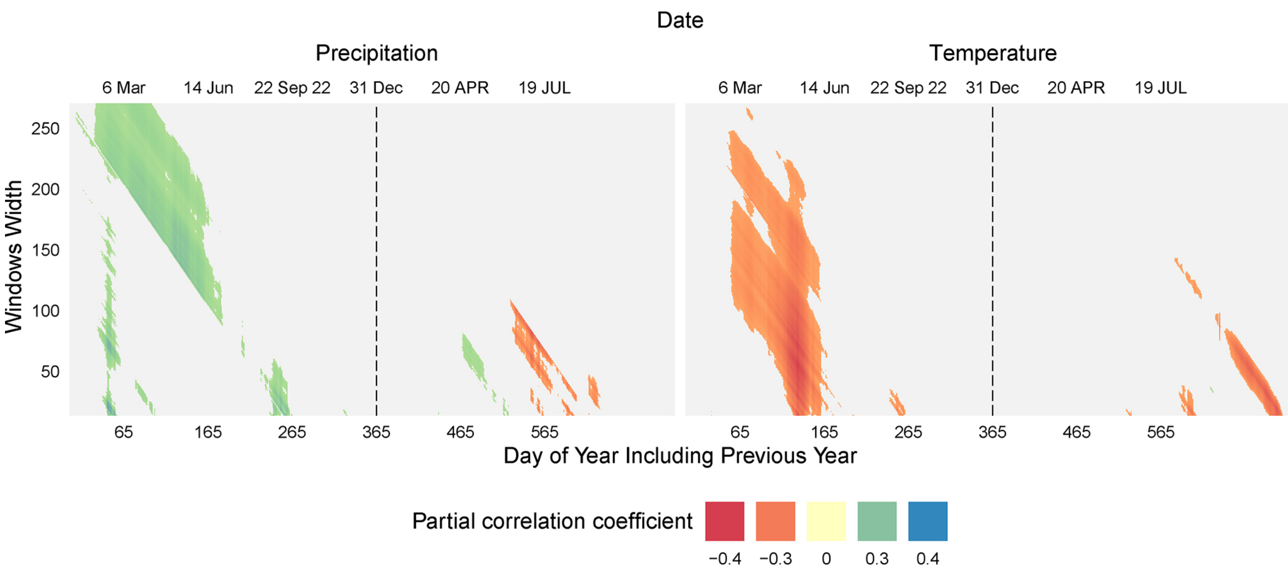

Fig. 3. The stationary partial correlation analysis of the *Sorbus torminalis* growth-to-climate relationships for the period 1946–2020. Vertical dashed lines indicate the crossing between the previous and current year

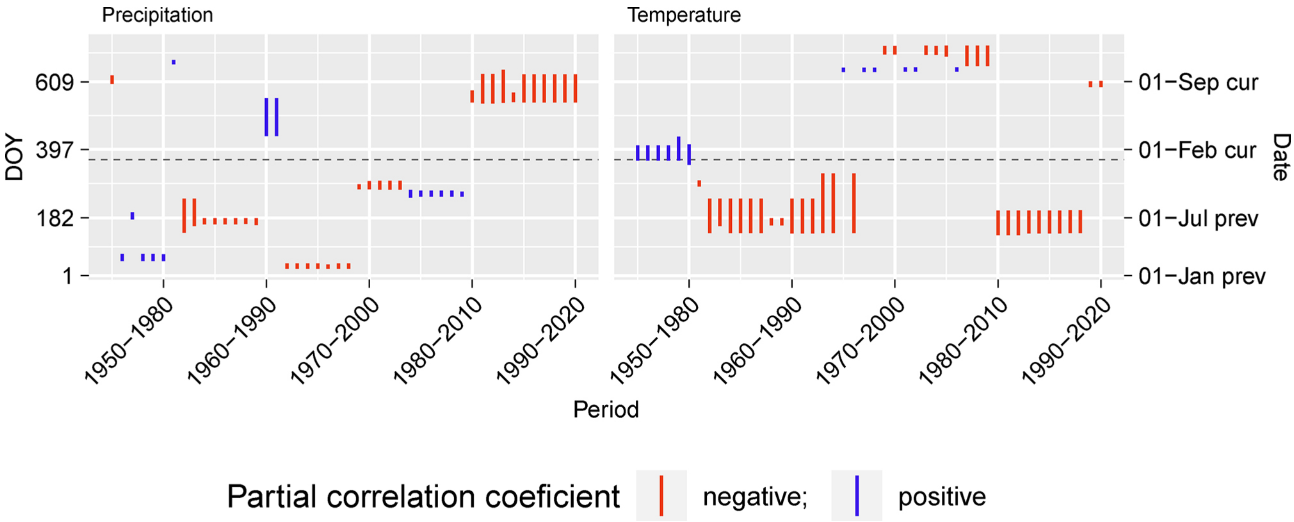

Fig. 4. The moving 31-year window partial correlation analysis of the *Sorbus torminalis* growth-to-climate relationships. The vertical lines represent an optimal time sequence with the highest correlation value calculated for each 31-year period. Lines start on the first day and end on the last day of the sequence. DOY is the day of a year in studied seasons that include both the year of tree-ring formation, the current year (cur), and the previous year (prev)

weaker in the period from 1967 to 1980. The other patterns with temperature were far shorter (Fig. 4). The relationships between *S. torminalis* growth and precipitation in the mid-end of the growing season has been dominant since 1980. In general, the precipitation impact on *S. torminalis* radial growth was unstable i.e. the period in the season when it was significantly changed, and also reversed the sign of correlation coefficient.

Discussion

The cambial age of *S. torminalis* No 2 reached 102 years that means it was approximately 1.3 m high in 1918. The stem piths in trees No 1 and No 3 were damaged and their estimated age was 90–99 and 93–99 years respectively. We imply the trees alley in front of the mansion was planted after the last owner S.I. Lieberman death in 1917 (Drug & Malakov, 2004). The photos taken in the 1930s in Bankova Street (Drug & Malakov, 2004) fixed at least six trees more than 5 m high. As the determined age of studied trees overlaps this period we can argue that *S. torminalis* No 1–3 are shown among the trees in the photo.

The mean ring width of the studied trees (2.73 mm) is between two known values reported from Central Europe: in the west of Poland – 0.77 mm (Cedro, 2016), in forests in the west of Germany – 3.5 mm (Kahle, 2004). *S. torminalis* growth usually decreases in the age of 60–70 years and drops off in the age of 90–100 years (Crave, 1985). After 2010, the growth of studied *S. torminalis* No 1–3 was depressed and reached 33–67% of the average increment value that was much higher than 10% thresholds of tree's dieback (Drobyshev et al., 2007). The diameters of *S. torminalis* No 1–3 in 2020 (49–66 cm) are in line with earlier reported data for matured and old trees with stem diameters of 50–80 cm (Jacquot, 1931; Becker et al., 1983).

The basidiocarps of the xylotroph fungi appear either on dead wood or on old trees. Thus, the basidiocarps of *Pleurotus* spp. found on a studied tree usually grow on dead wood of broadleaved trees, although they can develop as facultative parasites on living trees (Stamets, 2000) accelerating the decomposition of wood (Pavlik & Pavlik, 2013). The basidiocarps of *Auricularia mesenterica* usually develop as a saprotroph on dead wood of deciduous species or as a parasite on old trees in the terminal phase (Laux von, 2001). *Chondrostereum purpureum* forms basidiocarps on stumps and deadwood of broadleaved trees. It also infects living trees through fresh wounds in branches, stems, or roots (Hamberg et al., 2017; Becker et al., 2005) and causes cambial necrosis, decay, sapwood staining, and death of the plant (Wall, 1986; Rayner, 1977).

Although the lifespan of *S. torminalis* is 200–300 years (Crave, 1985; Favre-d'Anne, 1990; Pokorny, 1990), the species is rarely used in dendrochronological studies due to difficulty in identifying annual ring boundaries particularly in sapwood and frequent formation of false rings (Cedro & Cedro, 2015; Cedro, 2016; Rasmussen, 2007). In forests, *S. torminalis* usually grows at the midstory (Shpak et al., 2017,), which decreases trees climatic signal in chronological series (Cook & Kairiukstis, 1990).

The negative impact of the previous growing season temperature on *S. torminalis* radial growth is a common pattern in Europe. Thus, the previous year temperature had a negative influence on *S. torminalis* growth in Germany, Denmark (Rasmussen, 2007), and Poland (Cedro, 2016). The precipitation impact on *S. torminalis* radial growth in Kyiv was unstable and negative during last decades especially in the period from June to September when Kyiv receives the most precipitation amount. This is not consistent with data from Central Europe (Cedro, 2016; Rasmussen, 2007), where precipitation has a positive influence on species growth. In the eastern Iceland forests, *S. aucuparia* changes of growth-to-precipitation relationships was similar to our results, i.g. the reversion of positive effect of June precipitation to the negative July–August precipitation impact (Hannak & Eggertsson, 2020). Revealed sensitivity to precipitation excess confirms known ecological features of *S. torminalis* as its sensitivity to soil moister excess during the growing season (Pagan, 1996).

Study limitations

The number of *S. torminalis* trees and sample size were limitations of the study. The presence of fungi basidiocarps on the tree stems and mechanical damage could be considered to weaken the research. However, the studied *S. torminalis* trees are the remnant of the old population in Kyiv. The available fungi and damages did not affect trees' annual ring width, although we discussed the possible fungi impact on trees in the future above. Considering the rarity of the species and the lack of studies in urban conditions, the findings of this study contain new, potentially practical information.

Concluding remarks

The cambial age of *S. torminalis* trees at 2 Bankova Street in front of the former Liberman's mansion is 90–102 years. These trees are the oldest species examples in Kyiv and are sensitive to high temperature, but not to lack of precipitation in Kyiv's conditions. Though *S. torminalis* is a host plant for some fungi species, their presence does not influence radial growth of the studied trees. Thus *S. torminalis* is a potential alternative to species used in the urban forestry particularly at dry sites, although further growth-to-climate investigations could clarify if it matches to the climate conditions of Kyiv region out of urban space.

References

Akatova YS & Ermakov NB (2020) Communities of broadleaved woodlands of the lower part of the forest belt of the Belaya River basin (North-Western Caucasus). Plant Biology and Horticulture: theory, innovation 156: 65–78. doi:10.36305/2712-7788-2020-3-156-65-78.

Becker E, Shamoun S & Hintz W (2005) Efficacy and environmental fate of *Chondrostereum purpureum* used as a biological control for red alder (*Alnus rubra*). Biological Control 33: 269–277. doi:10.1016/j.biocontrol.2005.02.013.

Becker M, Picard J-F & Timbal J (1983) Les arbres. Masson, Paris-New York-Barcelone-Milan-Mexico-Sao Paulo.

Bednorz L (2007) Conservation of genetic resources *of Sorbus torminalis* in Poland. Dendrobiology 58: 3–7.

Bednorz L (2010) Jarząb brekinia *Sorbus torminalis* (L.) Crantz w Polsce. Bogucki Wydawnictwo Naukowe, Poznań.

Bondarenko ZD & Pokinchera VF (2013) Ancient beech forests of Crimea – potential components parts of the world heritage site (ed. by FD Hamor) Uzhhorodska miska drykarnia, Uzhhorod, pp. 38–41.

Budzhak VV (1996) Bereka (*Sorbus torminalis* (L.) Crantz) in Northern Bukovina and Northern Bessarabia (chorology, bioecology, protection). Bunn AG (2010) Statistical and visual crossdating in R using the dplR library. Dendrochronologia 28: 251–258. doi:10.1016/j.dendro.2009.12.001.

Cedro A (2016) The influence of climatic conditions on the tree-ring width of wild service trees (*Sorbus torminalis* L.) in Wielkopolska. Forest Research Papers 77: 117–123. doi:10.1515/frp-2016-0013.

Cedro A & Cedro B (2015) Growth-climate relationships at yew and wild service trees on the eastern edge of their range in Europe. Forest Systems 24: e044. doi:10.5424/fs/2015243-07480.

Chepur SS & Rishko YV (2018) Optimization of landscaping of the territory of preschool educational institutions in Uzhhorod (ed. by IV Kalynych) Hoverla, Uzhhorod, pp. 54–61. Chopyk VI (1970) Rare plants of Ukraine. Naukova dumka, Kyiv. Cook E & Kairiukstis L (1990) Methods of dendrochronology – applications in the environmental sciences. Springer Netherlands, Dordrecht.

Crave MF (1985) Un frutier meconnu: l'alisier torminal. Forêt-entreprise 28: 14–20.

Demesure-Musch B & Oddou-Muratorio S (2004) EUFORGEN Technical Guidelines for genetic conservation and use for wild service tree (*Sorbus torminalis*). International Plant Genetic Resources Institute, Italy.

Didukh YP (2009) Red book of Ukraine. Globalkonsalting, Kyiv.

Didukh YP (2009) Green book of Ukraine. Alterpress, Kyiv.

Didukh YP, Mala YI, Pashkevych NA, Fitsaylo TV & Khodosovtsev OY (2016) Biotopes of the Mountain Crimea. TOV «NVP Interservis», Kyiv.

Drobyshev I, Linderson H & Sonneson K (2007) Temporal mortality pattern of pedunculate oaks in southern Sweden. Dendrochronologia 24: 98–108. doi:10.1016/j.dendro.2006.10.004.

Drug OM & Malakov DV (2004) Mansions of Kyiv. Kiy, Kyiv. EUNIS (2019) Habitat type hierarchical view. https://eunis.eea.europa.eu/habitats-code-browser.jsp.

European Climate Assessment & Dataset Algorithm (2012) Theoretical Basis Document (ATBD), version 10.5. De Bilt, the Netherlands. https://www.ecad.eu/.

Favre-d'Anne E (1990) L'alisier torminal (*Sorbus torminalis* Crantz): Synthese bibliographique. Recherche sur la densité du bois. ENGREF, Nancy.

Freund RJ, Wilson WJ & Mohr DL (2010) Statistical methods. Academic Press, Boston.

Glukhova SA, Shynder OI & Mykhailyk SM (2017) Rare species of Ukrainian flora in collection of Syrets arboretum. Forestry and Landscape Gardening 13.

Hamberg L, Lemola J & Hantula J (2017) The potential of the decay fungus *Chondrostereum purpureum* in the biocontrol of broadleaved tree species. Fungal Ecology 30: 67–75. doi:10.1016/j.funeco.2017.09.001.

Hannak N & Eggertsson O (2020) The long-term effects of climatic factors on radial growth of downy birch (*Betula pubescens*) and rowan (*Sorbus aucuparia*) in East. Icelandic Agricultural Sciences 33: 73–87. doi:10.16886/IAS.2020.07.

Haralamb A (1967) Cultura speciilor forestiere. Editura Agro-Silvică de Stat, București.

Hoebee S, Arnold U, Düggelin C, Gugerli F, Brodbeck S, Rotach P & Holderegger R (2007) Mating patterns and contemporary gene flow by pollen in a large continuous and a small isolated population of the scattered forest tree *Sorbus torminalis*. Heredity 99: 47–55. doi:10.1038/sj.hdy.6800962.

Holmes RL (1983) Computer assisted quality control in tree-ring dating and measurement. Tree-Ring Bulletin 43: 69–78.

Hrybovych YS (2018) Current state and adaptability of wood collections of introducers of parks of Poltava (ed. by OH Yakumenko) Malyn, pp. 166–170.

Jacquot A (1931) Manuel pratique de Sylviculture. Baillière et Fils, Paris.

Jevšenak J & Levanič T (2018) Dendro Tools: R package for studying linear and nonlinear responses between tree-rings and daily environmental data. Dendrochronologia 48: 32–39. doi:10.1016/j.dendro.2018.01.005.

Kahle M (2004) Untersuchungen zum Wachstum der Elsbeere (*Sorbus torminalis* [L.] Crantz) am Beispiel einiger Mischbestände in Norrhein-Westfalen. Landesanst. für Ökologie, Bodenordnung und Forsten, Recklinghausen.

Kharkhota L & Vinogradova E (2016) Rare woody plants in the collection of Donetsk botanic garden. Agrobiodiversity for Improving Nutrition, Health, and Life Quality 1: 173–177.

Laux von HE (2001) Der große Kosmos-Pilzführer - Alle Speisepilze mit ihren giftigen Doppelgängern. Frankh-Kosmos, Stuttgart.

Melnichenko NV (1999) Introduction of species of the genus *Sorbus* L. in Ukraine and prospects for their use. Plants Introduction 2: 37–42.

Montero G, Cisneros O & Cañellas I (2003) Manual de selvicultura para plantaciones de especies productoras de madera de calidad. Mundi-Prensa, Madrid.

Oria de Rueda J, Martinez de Azagra A & Nieto A (2006) Botánica forestal del género Sorbus en España. Investigaciones Agrarias: Sistemas y Recursos Fore-stales. Fuera de Serie 15: 166–186. doi:10.5424/srf/200615S1-00990.

Pagan J (1996) Lesnícka dendrológia. TU vo Zvolene, Zvolen.

Paganová V (2007) Ecology and distribution of *Sorbus torminalis* (L.) Crantz. in Slovakia. Horticultural Science 34: 138–151. doi:10.17221/1896-HORTSCI.

Pavlik M & Pavlik S (2013) Wood decomposition activity of oyster mushroom (*Pleurotus ostreatus*) isolate in situ. Journal of forest science 59: 28–33. doi:10.17221/60/2012-JFS.

Pokorny J (1990) Arbres. Gründ, Paris.

Polyakov AK, Suslova EP, Netsvetov MV, Datsko AM, Kozlenko DA & Likhatskaya EN (2010) Bioecological peculiarities of rare species of tree and schrubs ex situ. Industrial Botany 10: 67–71.

Rasmussen KK (2007) Dendroecological analysis of a rare subcanopy tree: effects of climate, latitude, habitat conditions and forest history. Dendrochronologia 25: 3–17. doi:10.1016/j.dendro.2007.01.002.

Rasse N, Santi F, Dufour J & Gauthier A (2005) Adaptation et performance de merisiers testés dans et hors deleur région d'origine. Conséquences pour l'utilisation des variétés. Revue Forestiere Francaise LVII: 277–288. doi:10.4267/2042/5044.

Rayner ADM (1977) Fungal colonization of hardwood stumps from natural sources. II. Basidiomycetes. Transactions of the British Mycological Society 69: 303–312. doi:10.1016/S0007-1536(77)80051-X.

R Core Team (2020) A Language and Environment for Statistical Computing. Vienna, R Foundation for Statistical Computing. http://www.r-project.org/index.html.

Rozas V (2003) Tree age estimates in *Fagus sylvatica* and *Quercus robur*: testing previous and improved methods. Plant Ecology 167: 193–212. doi:10.1023/A:1023969822044.

Rubțov Șt (1958) Cultura speciilor forestiere in pepi-niere (forestiere si decorative). Editura Agro-Silvică de Stat, București.
Ruiz de la Torre J (2006) Flora Mayor. Organismo Autónomo Parques Nacionales, Madrid.
Sakhno TM (2014) Rare species of trees and shrubs in the Yalta Mountain-Forest Nature Reserve. Bulletin of the HNBS 111: 25–31.
Shpak NP, Shlapak VP & Leontyak GP (2017) Some peculiarities of cultivation of common oak stands involving bereka medicinal in Southern Podillya. Scientific Bulletin of UNFU 27: 71–74.
Stamets PE (2000) Growing Gourmet and Medicinal Mushrooms. Ten Speed Press, Berkeley.
Termena BK & Budzhak VV (1998) Adaptive possibilities of the mountain ash (*Sorbus torminalis* (L.) Crantz). Forest Journal 5: 26–31.
Termena BK, Viklyuk MI & Budzhak VV (1993) Distribution of *Sorbus torminalis* (L.) Crantz. in Northern Bukovina (Ukraine). The Ukrainian Botanical Journal 50: 80–83.
Thomas PA (2017) Biological flora of the British Isles: *Sorbus torminalis*. Journal of Ecology 105: 1806–1831. doi:10.1111/1365-2745.12857.
Úradnícek L, Maděra P, Tichá S & Koblížek J (2010) Woody plants of the Czech Republic. Kostelec nad Cernými lesy, Lesnickápráce.
Wall RE (1986) Pathogenicity of *Chondrostereum purpureum* to yellow birch. Plant Disease 70: 158–160. doi:10.1094/PD-70-158.