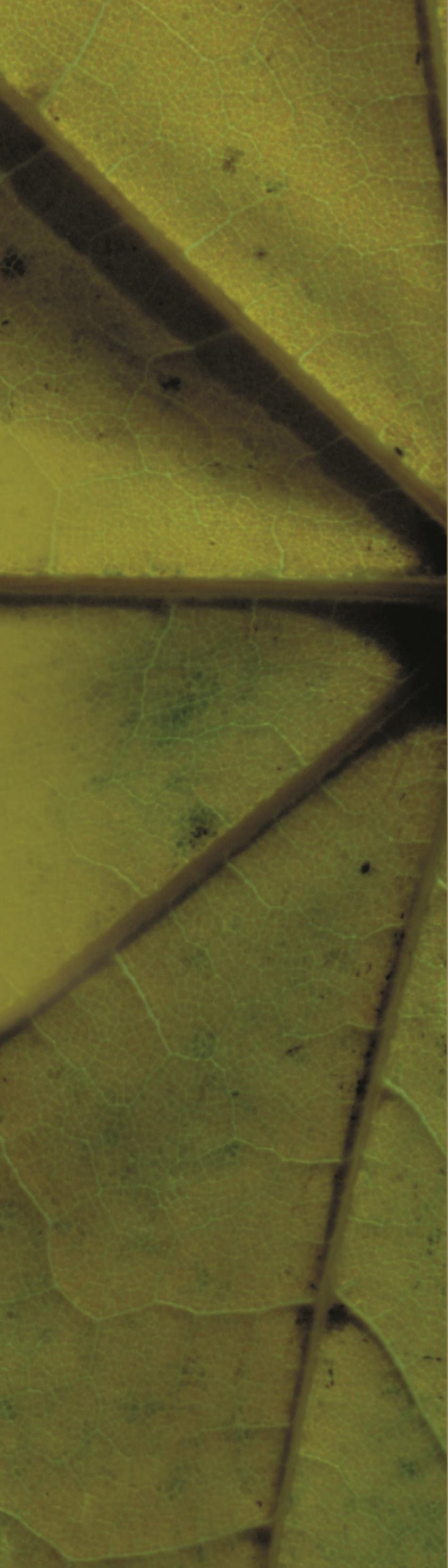

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Changes in Structure, Tree Species Composition, and Diversity of the Abu Geili Riverine Forest Reserve, Sinnar State, Sudan

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ABSTRACT

This study assesses the structure, composition, diversity, and conservation status of the Abu Geili Riverine Forest Reserve (AGRFR), Sudan, to evaluate changes in these attributes between 2011 and 2021. Thirty sample plots (radius = 17.84 m) were established systematically. The distance between plots was 50 m and 100 m between survey lines to facilitate the identification, counting, and measuring of diameter at breast height (DBH) and height of all living trees and compare that with 2011 data. The results identified 462 trees across 32 species and 15 families in 2021, reflecting an increase in species and family diversity from 2011, which reported 626 trees from 23 species and 12 families. The Fabaceae family was most dominant, with ten species in 2021 and six in 2011. In both years, the Miliaceae and Moraceae had three species each. Three of the four calculated diversity indices displayed increasing trends, highlighting the rich diversity of the area and its importance for conservation and management.

TANULMÁNY INFÓ

Kulcsszavak:
Fafaj diverzitás
AbuGeili erdőrezervátum
Biodiverzitás index elemzés
Erdei ökoszisztéma kezelés

KIVONAT

Változások a szerkezetben, a fajösszetételben és a diverzitásban az Abu Geili Folyómenti Erdőrezervátumban (Szinnár állam, Szudán). A tanulmány célja a szudáni AbuGeili folyóparti erdőrezervátum (AGRFR) szerkezetének, összetételének, sokféleségének és védettségi helyzetének felmérése, valamint e jellemzők 2011 és 2021 közötti változásainak értékelése. Harminc mintaterületet (Sugár = 17,84 m) alakítottak ki rendszeresen. A parcellák közötti távolság 50 m, a felmérési vonalak közötti távolság 100 m volt, hogy azonosítani lehessen, megszámoljuk és megmérjük a mellmagassági átmérőt (DBH) famagasságit minden élő fa esetében, és összehasonlítsuk a 2011-es adatokkal. Az eredmények azt mutatják, hogy 2021-ben 32 fajból és 15 családból 462 fa volt, ami tükrözi a fajok és a családok sokféleségének növekedését 2011-hez képest, amikor 23 faj és 12 család 626 fájáról számoltak be. A Fabaceae család volt a legdominánsabb, 2021-ben tíz, 2011-ben pedig hat faj. Mindkét évben a Miliaceae és a Moraceae három-három fajjal rendelkezett. A négy kiszámított diverzitási indexből három növekvő trendet mutatott, kiemelve a terület gazdag diverzitását és fontosságát a megőrzés és a kezelés szempontjából.

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1 INTRODUCTION

The vital role of forests in maintaining ecological balance, supporting economic growth, and providing livelihoods is undeniable, as highlighted by UNEP, 2007; Rajasugunasekar et al., 2023; Serbouti et al., 2023; Musa et al., 2024 and the Food and Agriculture Organization (FAO 2009a). Tropical forests are biodiversity hotspots that contain about 70 % of all animal and plant species despite covering only 7% of the Earth's dry surface area (Ulyshen et al., 2023; Debebe et al., 2023). Such biodiversity is crucial for fundamental ecological processes and the survival of many species. Yet, these ecosystems face significant threats from deforestation and forest degradation, driven by the immense pressure from human activities and natural factors. Forest degradation leads to species extinction and reduced diversity; however, it also decreases primary productivity.

The Sahel's trees and shrubs are vital to combating desertification, providing many useful products, and maintaining the natural ecosystem (Lu et al., 2023; Rajasugunasekar et al., 2023). The role of indigenous fruit trees in food security and nutrition, especially in semi-arid regions, is increasingly recognized. Similarly, the AGRFR in Sudan, characterized by its low rainfall savanna woodland, has seen the introduction of diverse species, both exotic and native, making it a significant area for biodiversity within the tropical forest ecosystem (FAO, 2010; IUCN, 2010; Yasin and Mulyana, 2022).

However, forest managers face challenges aligning national goals with forest-level management plans amid global emphasis on timber production and biodiversity conservation, carbon sequestration, and providing wildlife habitats and amenities (Elsiddig, 2002). Transforming these goals into actionable strategies is complex and is exacerbated by the increasing human population and land use changes, including agricultural expansion, increased livestock density, and altered fire regimes and fallow periods (Ouedraogo et al., 2010; Alcamo et al., 2011; Oke and Jamala, 2013). These changes threaten forest structure, composition, and biodiversity, necessitating management interventions to preserve and enhance their conservation value and sustainability (Kumar et al., 2006).

Tree species inventory and diversity studies are pivotal in understanding trends in structure, composition, and diversity (Yakubu et al., 2020). Such information is crucial for conservation efforts, yet the documentation of trees and shrubs in areas like the Abu Geili Riverine Forest Reserve is lacking. Despite the significance of these ecosystems, only a few studies have focused on tree diversity in the natural forests of the Blue Nile state and the Tozi natural forest in Sinnar state (Mohammed et al., 2021a; Dafa-Alla et al., 2022; Yasin and Mulyana, 2022).

This study assesses the structure, composition, diversity, and conservation status of the AGRFR and evaluates changes in these attributes between 2011 and 2021. Additionally, it provides information to assist policymakers and resource management planners in creating effective strategies to manage and sustain these crucial ecosystems.

2 MATERIALS AND METHODS

2.1 Description of the study area

The study was conducted in the AGRFR, Sudan, between latitude 13°34'41.51" N and longitude 33°35'20.08" E (*Figure 1*). The AGRFR is a tropical dry forest, covering a total area of about 807 feddans (338.94 hectares) with original species such as *Acacia nilotica*, *Balanities aegyptiaca*, *Acacia seyal*, *Acacia nubic*, and *Capparis decidua*. New species such as Eucalyptus spp, Khaya spp., Moringa oleifera, bamboo spp, and others were introduced after the forest was designated as a reserved area on August 18, 1940, and registered in Gazeta No. 1. The vegetation cover of the AGRFR primarily consists of *Acacia nilotica* in a pure stand located in the flood basin in the northern part. In contrast, the southern part of the forest predominantly features other species, such as *Eucalyptus spp*. and *Khaya senegalensis*. This area also includes small experimental plots of *Sclerocarya birrea*, *Albizia lebbek*, *Dalbergia melanoxylon*, *Moringa oleifera*, and *Cordia africana*, all intermingled within the Eucalyptus plots. Additionally, the forest hosts a small nursery and a mango tree garden. Clumps of bamboo are present along the river bank. Many species grow in the Gerif land, including *Faidherbia albida*, *Calotropis procera*, *Maytenus senegalensis*, *Boscia senegalensis*, and *Cordia rothii*. *Capparis decidua* and *Acacia seyal* are also present outside the basin in the Karab site, featuring a mix of planted and naturally occurring tree species. The primary objectives of the forest are timber production including sawn timber and fuel wood and the conservation of tree and shrub biodiversity. The government controls the area through the Forests National Corporation of Sinnar State. Villages surround the forest, bordered to the north by Kandwat, to the east by Al-Tekina and Abu Geili, and to the west and south by the Blue Nile. Despite its importance, the AGRFR faces several challenges from human activities such as agricultural expansion, livestock overgrazing, and firewood collection, all of which threaten the ecosystem's balance. Regulated forestry including selective logging and the planting of exotic species local uses such as harvesting construction wood and fuel and gathering non-timber products like medicinal plants and livestock fodder have all influenced the forest's structure and diversity over the decades. However, illegal logging and farmland expansion have significantly degraded the reserve, altering its ecological dynamics and necessitating robust conservation efforts to maintain forest health. The soil of the area is classified as dark cracking clay soil (vertisol) in the "Mayaa" site, sand and gravel (eroded slopes) soil in the Karab slopes, and permeable silt deposits soil in the Gerif slopes (Fahmi, 2017). The AGRFR was already extremely degraded and some part of AGRFR was already converted to farmlands while a portion has been designated for the plantation of exotic species such as *Khaya senegalensis, Tectona grandis, Eucalyptus camaldulensis,* and *Dalbergia sisso*. The wet season in the study area is between June and October, while the dry season is from November to April. Annual rainfall ranges from 450 to 750 mm, with annual temperatures varying from (31˚C) in April to (22˚C.) in January and relative humidity from 78–80 % in August to 8–9 % in March (Abdelrahim, 2015; Mohammed et al., 2021a; Gurashi, 2022; Yasin and Mulyana, 2022).

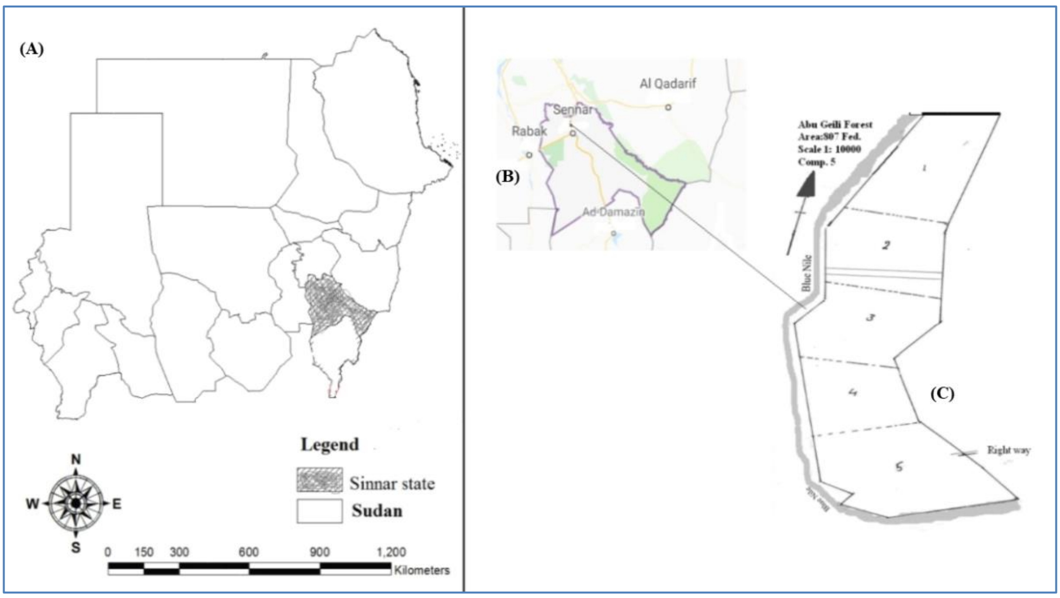

Figure 1. Map of the study area (A: Sudan; B: Sinnar State; C: AbuGeili Riverine Forest Reserve).

2.2 Data collection

Data collection was conducted in two phases; the Forest National Corporation (FNC) Sinnar state conducted the first in 2011, collecting data by establishing 30 circular sampling plots (Radius 17.84 m = 0.1 ha), which were determined in the systematic sampling grid using ArcGIS software. The second data collection phase was conducted in February–May 2021 using the same sample plots and procedure to assess the structure, composition, diversity, and conservation status of AGRFR and evaluate changes in these attributes between 2011 and 2021. The grid consisted of several parallel survey lines spaced 100 m apart, and the distance between each sample plot was 50 m. Where 30 % of sample plots were placed in a degraded stand (low diversity, e.g., one or two species) and 70 % in a non-degraded stand (high diversity, e.g., more than two species), ensuring the representativeness of the sample plots. A survey method to assess the species composition that used a 0.1 ha sampling plot with systematic distribution sampling has been conducted in the Tozi reserved forest, Sudan (Yasin and Mulyana, 2022), and Abu Gadaf natural reserved forest in Sudan (Mohammed et al. 2021a). In each plot, the recorded data were the name of the species, number of individuals for each species, diameter at breast height, height using caliper and Haga, and coordinates using GPS.

2.3 Statistical methods

The collected data were processed and analyzed using Microsoft Excel 2016. Important Value Index (IVI) was calculated based on the sum of ecological parameters, namely relative frequency (RF), relative density (RD), and relative dominance (RDo). Frequency is the occurrence of species in the sampling plot. Density represents the total number of individuals of each species in the sampling plot. Dominance is the total basal area for each species in the sampling plot. Relative Abundance (RA) represents the species abundance in the sample plot (Yasin and Mulyana, 2022) – *Table 1*. We used descriptive statistics, similar means, maximum, minimum, percentages, tables, and charts. Using diversity directories, the RF, RD, RDO, IVI, Shannon–Wiener diversity index, Margalef's index (Species Richness), Species Evenness index (E_H), Simpson's Species Diversity index, Index of Dominance of tree species were computed (Ogwu et al., 2016) – *Table 1*. The tree species were classified according to their relative densities (RD) to represent their conservation status. The categories are as follows: abundant (RD ≥ 5.00), Frequent (4.00 ≤ RD ≥ 4.99), occasional (3.00 ≤ RD ≥ 3.99), rare (1.00 ≤ RD ≥ 2.99), and threatened (0.00 < RD ≥ 1.00) (Ogwu et al., 2016).

Table 1. *The equations used to calculate tree basal area, relative frequency, dominance, and abundance, importance value index (IVI), Simpson's Species Diversity index (D), Margalef species richness index, Shannon-Weiner diversity index (H), and Species Evenness Index of the tree species measured in the AGRFR.*

Equation	Reference
Tree basal area (cm) = $\frac{\pi * (DBH)^2}{4}$	(Mohammed et al., 2021a)
Frequency (F) = Presence or absence of the species per site	(Mohammed et al., 2021b)
Relative frequency (RF) = $\left(\frac{Tree\ species\ frequency}{Total\ frequency\ for\ all\ species}\right) * 100$	(Idrissa et al., 2018)
Dominance (D) = Total basal area of the species	(Ibrahim et al., 2015)
Relative dominance (RD) = $\left(\frac{Species\ dominance}{Total\ dominance\ for\ all\ species}\right) * 100$	(Ibrahim and Osman, 2014)
Abundance (A) = Number of trees per area measured	(Maua et al., 2020)

Relative abundance (RA) = $\left(\frac{Tree\ species\ abundance}{Total\ abundance\ for\ all\ species}\right) * 100$	(Mohammed et al. 2021c)
IVI = Relative frequency + Relative dominance + Relative abundance	(Mohammed, 2019)
Simpson's Species Diversity index (D) = $\left(\frac{\Sigma n(n-1)}{N(N-1)}\right)$, then 1-D.	(Frerebeau, 2019)
Margalef species richness index (M) = $\frac{(s-1)}{InN}$	(Gamito, 2010)
Species Evenness Index; EH = H / Hmax = $\sum_{i=1}^{s} \frac{piln(pi)}{In(S)}$	(Okpiliya, 2012)
Shannon-Weiner diversity index (H') = $- \Sigma^{s}_{i=1} P_i \ln P_i$	(Shannon and Weaver,1949)

* DBH is a tree diameter measured 1.3 m from the ground and called diameter at breast height (DBH), and IVI is the importance value index.

3 RESULTS

3.1 Tree species diversity trend in the AGRFR during 2011 to 2021

A total of 462 individual trees belonging to 32 species from 15 different families were counted in 2021. The highest species numbers were recorded in the Fabaceae family (10 species), followed by the Moraceae and Meliaceae families, each with (three species). The Fabaceae family had the highest number of individual trees, totaling 146, followed by the Meliaceae with 78 and the Myrtaceae with 74 (*Tables 2 and 3)*.

However, the 2011 inventory of the AGRFR showed 626 individual trees or shrubs, belonging to 23 species from 12 families, as recorded in *Tables 1 and 2*. *Acacia nilotica* had the highest relative density, accounting for 39.94 % in 2011 and 31.6 % in 2021 (*Tables 4 and 5*). The Fabaceae family had the highest species diversity in the ecosystem, with 10 species in 2021 and six species in 2011. The Meliaceae and Moraceae families had three species in both inventory years. Among the 23 species identified in 2011, 21 were classified as trees and two as shrubs. In 2021, 32 species were identified, with 28 classified as trees and six as shrubs (*Tables 2 and 5*).

Table 2. Tree and shrub species type and presence in AGRFR in 2011 and 2021

Family	Species	2011	2021	Local name	Type
Anacardiaceae	*Mangifra indica* L.	✓	✓	Manga	Tree
	Anacardium occidentale L.		✓	Cashew-Nut tree	Tree
Arecaceae	*Elaeis guineensis* Jacq		✓	Oil palm	Tree
	Phoenix dactylifera L.	✓	✓	Nakheel At Tamr	Tree
Balanitaceae	*Balanites aegyptiaca* (Linn.) Del	✓	✓	Helglig, Lalob	Tree
Bombacaceae	*Adansonia digitata* L.	✓	✓	Tabaldi	Tree
Capparaceae	*Boscia senegalensis* (pers.) Lam. Ex poir		✓	Mokhait	Shrub
	Capparis decidua (Forsk) Edgew		✓	Tundub	Shrub
Combretaceae	*Conocarpus lancifolius* Engl. & Diels	✓	✓	Damas	Tree
Fabaceae	*Acacia. nilotica sub sp. tomentosa* (Benth) Brerian	✓	✓	Sunt	Tree
	Acacia siebriana DC.	✓		Kuk	Tree
	Acacia seyal Delile.	✓		Talh	Tree
	Dalbergia sisso DC		✓	Sisso	Shrub
	Fadherbia albida (Del.) A. chev	✓	✓	Haraz	Tree
	Cassia fistula L.		✓	El khoreim	Tree

	*Albizia lebbeck (*L.) Benth		✓	Dign Al Pasha	Tree
	Acacia ehrenbergiana Hayne	✓	✓	Salam	Tree
	Acacia polycantha Willed		✓	Kakamut	Tree
	Dalbergia melanoxylon Guill. & perr		✓	Babanous	Tree
	Delonix regia (Boj.ex Hook.) Raf	✓	✓	Gold moar	Tree
	*Peltophorum petrocarpum (*Dc.) Bacher ex K. Heyne	✓	✓	Peltophorum	Tree
	Khaya senegalensis (Desr.) A. juss	✓	✓	Mahogany	Tree
	Azadirachta indica A. Juss	✓	✓	Neem	Tree
Meliaceae	*Khaya grandifoliola* C. DC	✓	✓	Mahogany	Tree
	Milicia excels (Welw.) C.C. Berg	✓	✓	Abu Hajar	Tree
Moraceae	*Ficus microcarpa* L. F	✓	✓	Ficus	Tree
	Ficus sycomorus L.	✓	✓	Gumaiz	Tree
	Eucalyptus camaldulensis Dehn	✓	✓	Kafoor kamal	Tree
Myrtaceae	*Eucalyptus microtheca* F.Muell	✓	✓	Ban	Tree
Ramnaceae	*Ziziphus spina christi (*Linn.) Desf	✓	✓	Sidr	Shrub
Rutaceae	*Aegle marmelos* corr		✓	elephant apple	Tree
Santalaceae	*Santalum album* L.		✓	Sandal	Shrub
Simaroubaceae	*Ailanthus excels* Roxb	✓	✓	Ailanthus/Alkabriet	Tree
Verbenaceae	*Tectonia grandis* L.F	✓	✓	Teak	Tree

Table 3. Number of genera, number of species and relative frequency (RF) of genus and species within identified families

Family	2011				2021			
	No. genera	No. species	Genus RF (%)	Species RF (%)	No. genera	No. species	Genus RF (%)	Species RF (%)
Anacardiaceae	1	1	5.56	3.7	2	2	7.69	5.88
Arecaceae	1	1	5.56	3.7	2	2	7.69	5.88
Balanitaceae	1	1	5.56	3.7	1	1	3.85	2.94
Bombacaceae	1	1	5.56	3.7	1	1	3.85	2.94
Capparaceae	0	0	0	0	2	2	7.69	5.88
Combretaceae	1	1	5.56	3.7	1	1	3.85	2.94
Fabaceae	3	6	22.2	33.33	7	10	26.9	35.29
Meliaceae	2	3	11.1	11.11	2	3	7.69	8.82
Moraceae	2	3	11.1	11.11	2	3	7.69	8.82
Myrtaceae	1	3	5.56	11.11	1	2	3.85	5.88
Ramnaceae	1	1	5.56	3.7	1	1	3.85	2.94
Rutaceae	0	0	0	0	1	1	3.85	2.94
Santalaceae	0	0	5.56	3.7	1	1	3.85	2.94
Simaroubaceae	1	1	5.56	3.7	1	1	3.85	2.94
Verbenaceae	1	1	5.56	3.7	1	1	3.85	2.94
	16	23			26	32		

3.2 The AGRFR forest structure

Based on the 2021 inventory, the recorded base diameters ranged from a minimum of 6.1 cm to a maximum of 115 cm, with an average of 17.04 cm and a standard deviation (SD) of 11.43 cm. The average total height was 8.94 m, with a standard deviation of 8.07 m. The total heights ranged from a minimum of 5 m to a maximum of 23 m (*Table 4*).

In contrast, the 2011 inventory data revealed that the DBH values varied between 3 cm and 107 cm, with an average of 16.86 cm and a standard deviation of 10.46 cm. The mean total height for this year was 14 m, with a standard deviation of 5.62 m, and the heights ranged from a minimum of 7 m to a maximum of 32 m. The changes in tree diameter and height between the 2011 and 2021 inventories are likely due to a combination of selective logging, environmental changes, forest management practices, natural disturbances, and the age structure of the forest. These factors collectively influence the growth patterns and overall forest structure (Asner et al., 2005).

Table 4. Summary statistics of growing variables in AGRFR

Variables	2021		2011	
	DBH (cm)	Height (m)	DBH (cm)	Height (m)
Maximum	115	23	107	32
Minimum	6.1	5	3	7
Mean	17.04	8.94	16.85	14.29
SD	11.43	8.07	10.46	5.62
Total No. of Individuals	*462*	*277*	*626*	*57*

We found that the distribution of tree diameters at breast height (DBH) ranged from less than 10 cm to more than 60 cm in 2011 (*Figure 2*). The DBH class of 10 cm to 19 cm contained the highest percentage of individual trees, totaling 44.71%, making it the most common category in the area. The DBH class of less than 10 cm included 25.54% of trees. The least represented categories were those with diameters of 50 cm to 59 cm and more than 60 cm, with 1.32% and 0.30% of individual trees, respectively.

Similarly, the 2021 inventory results indicated that the DBH distribution ranged from less than 10 cm to more than 60 cm, with 43% of individual trees falling within the 10 cm to 19 cm DBH class, making it the most common category again. The lowest percentage of individual trees, 0.56% in each category, were found in the diameter classes of 50 cm to 59 cm and more than 60 cm, respectively.

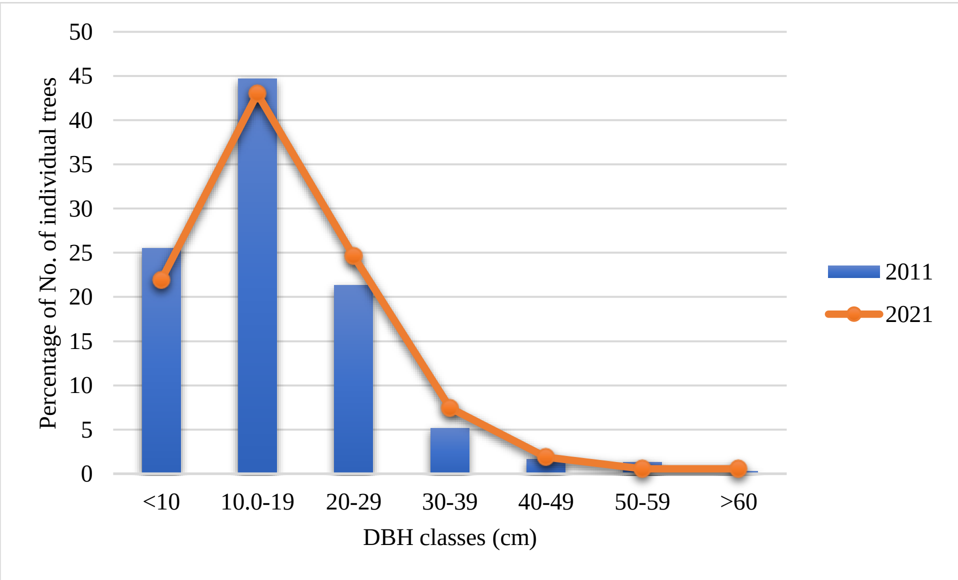

Figure 2. DBH classes distribution of individual tree species count in AGRFR

The results illustrated in *Figure 3* show that the total height of tree species in the study area ranged from less than 10 to 39 meters, according to the 2011 inventory. Moreover, 22.81 % of individual trees were found in the height classes of 15–19 meters and 20–24 meters. This was followed by height classes of less than 10 meters and 10–14 meters, each with 17.55 % of individual trees. The least common height class, 35–39 meters, contained only 1.75 % of individual trees. According to the 2021 inventory, 41.23 % of individual trees were recorded in the height class of 10–14 meters, making it the most common height range in the study area. This was followed by 32.23 % of individual trees in the height class of less than 10 meters and 4.74 % of individual trees in the 20–24 meter height class.

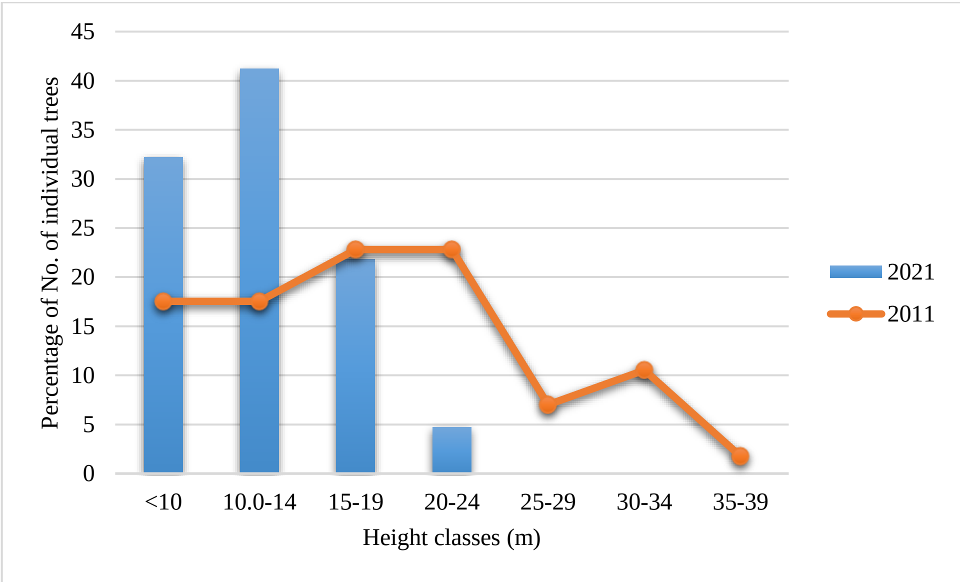

Figure 3. Height classes distribution of individual tree species count in the AGRFR

3.3 Mean basal area, density, and Importance Value Index (IVI) of tree species in the AGRFR

The 2021 inventory results, as shown in *Table 5*, indicate that the basal area for all tree species in the study area ranged from 0.018 to 8.50 m²/ha, with an overall average basal area of 2.41 m²/ha. *Khaya senegalensis*, which belongs to the family Meliaceae, had the highest basal area of 8.50 m²/ha, followed by *Acacia nilotica* at 3.98 m²/ha and *Faidherbia albida* at 1.90 m²/ha. *Santalum album* recorded the lowest basal area at 0.018 m²/ha.

Based on the 2011 inventory, *Acacia nilotica* was identified as the species with the highest density per hectare, with 146.54 trees in 2021 and 390.88 in 2011 in AGRFR (*Table 5)*. On the other hand, species like *Ficus sycomorus*, *Mangifera indica*, *Phoenix dactylifera*, *Santalum album*, *Boscia senegalensis*, *Capparis decidua*, *Anacardium occidentale*, and *Aegle marmelos* had the lowest density, at 10 per hectare. The basal area varied from 0.064 to 14.92 m²/ha, with an average basal area of 3.42 m²/ha. *Azadirachta indica* had the highest basal area at 14.92 m²/ha, followed by *Khaya senegalensis* at 14.59 m²/ha and *Acacia nilotica* at 8.29 m²/ha. *Ziziphus spina-christi* had the lowest basal area at 0.064 m²/ha (*Table 5*).

The Importance Value Index (IVI) in both the 2011 and 2021 inventories shows that *Acacia nilotica* had the highest IVI of 63.46 and 47.97, followed by *Khaya senegalensis* with an IVI 33.77 and 36.55, and *Eucalyptus camaldulensis with an IVI 53.98 and 32.55,* respectively. It was followed by *Azadirachta indica* with an IVI of 31.82 and *Ailanthus excelsa* with 25.83 in 2011. *Khaya grandifoliola* had an IVI of 15.76 in the 2021. *Ziziphus spina-christi* and *Santalum album* had the least dominant values of 1.43 and 1.20 in 2011 and 2021, respectively. The IVI also highlights *Acacia nilotica* as the most dominant tree species, with an IVI value above 47 (*Table 5*).

Table 5. Tree Species density, basal area, and Importance Value Index in the AGRFR in 2011 and 2021

Species	Inventory 2011				Inventory 2021			
	No. of individual tree	Mean density No. ha^{-1}	Mean BA (m^2 ha^{-1})	IVI	No. of individual tree	Mean density No. ha^{-1}	Mean BA (m^2 ha^{-1})	IVI
Acacia nilotica	250	390.88	8.29	63.46	146	146.54	4.00	47.97
Acacia siebriana	2	20	4.49	8.42	0	0	0	0
Acacia seyal	4	40	1.17	6.89	0	0	0	0
Acacia ehrenbergiana	1	10	1.39	3.11	3	30	0	0
Acacia polycantha	0	0	0	0	2	20	0.76	2.94
Adansonia digitata	2	10	2.40	4.40	2	20	7.69	11.91
Aegle marmelos	0	0	0	0	1	10	0.35	1.42
Ailanthus excels	62	124	7.12	25.83	20	28.57	1.06	7.88
Albizia lebbeck	0	0	0	0	2	20	3.96	7.08
Anacardium occidentale	0	0	0	0	1	10	0.20	1.24
Azadirachta indica	19	95	14.92	31.82	21	52.5	1.26	10.19
Balanites aegyptiaca	4	20	1.24	4.28	6	20	0.45	3.40
*Boscia senegalensis*r	0	0	0	0	1	10	0.86	2.08
Capparis decidua	0	0	0	0	2	10	0	0
Cassia fistula	0	0	0	0	16	80	1.93	12.06
Conocarpus lancifolius	6	20	1.02	4.00	4	20	1.51	4.34
Dalbergia sisso	0	0	0	0	48	240	4.29	34.27
Dalbergia melanoxylon	0	0	0	0	4	40	0.62	4.71
Delonix regia	5	16.66	0.38	2.73	6	20	0.69	3.72
Elaeis guineensis	0	0	0	0	2	20	3.47	6.44
Eucalyptus microtheca	6	20	1.23	4.27	8	26.6	2.56	7.07
Eucalyptus camaldulensis	189	378	2.21	53.98	66	165	4.37	32.55
Fadherbia albida	4	20	2.58	5.98	23	46	3.80	13.41
Ficus microcarpa	3	15	0.34	2.46	4	20	0.83	3.46
Ficus sycomorus	3	30	0.60	4.82	2	10	0.80	2.23
Khaya grandifoliola	4	40	6.08	13.14	4	40	9.16	15.76
Khaya senegalensis	45	112.5	14.59	33.77	53	88.3	14.17	36.55
Mangifra indica	3	30	4.64	9.96	1	10	2.83	4.63
Milicia excels	4	20	2.90	6.39	3	15	3.18	5.91
Peltophorum petrocarpum	2	20	0.45	3.28	2	20	0.83	3.03
Phoenix dactylifera	2	10	0.42	1.88	1	10	0.71	1.89
Santalum album	0	0	0	0	1	10	0.18	1.2
Tectonia grandis	5	25	0.16	3.58	3	30	0.53	3.62
Ziziphus spina Christi	1	10	0.06	1.43	4	20	0.27	2.73
Total	626		78.67		462		77.31	

3.4 Trend in species conservation status between 2011 and 2021

Based on the inventories conducted in 2011 and 2021, the relative tree species density (RD) ranged from 0.16 % to 39.94 % and 0.216 % to 31.6 %, respectively. *Acacia nilotica*, which belongs to the family Fabaceae, recorded the highest densities of 39.94 % and 31.6 % each year, respectively. In the 2011 inventory, *Ziziphus spina Christi* and *Acacia ehrenbergiana* had the lowest density at 0.16 %. In the 2021 inventory, the lowest density at 0.22 % was noted for

Anacardium occidentale, Boscia senegalensis, Mangifera indica, Phoenix dactylifera, and *Santalum album*. The Shannon-Weiner diversity index (H') for 2021 and 2011 was calculated at 2.39 and 1.75, respectively. These results also indicated that *Acacia nilotica* species were categorized as abundant. Most tree species were classified as threatened, with a few categorized as rare, occasional, or frequent (*Table 6*).

Table 6. Temporal changes in tree species diversity, relative density, and conservation status in 2011 and 2021

Tree species	2011			2021		
	Diversity index (H')	RD	Classification Based on RD	Diversity index (H')	RD	Classification Based on RD
Acacia nilotica	0.37	39.94	Abundant	0.01	31.60	Abundant
Acacia siebriana	0.02	0.32	Threatened	0.00	0.00	-
Acacia seyal	0.03	0.64	Threatened	0.00	0.00	-
Acacia ehrenbergiana	0.01	0.16	Threatened	0.02	0.65	Threatened
Acacia polycantha	0.00	0.00	-	0.06	0.43	Threatened
Adansonia digitata	0.02	0.32	Threatened	0.01	0.43	Threatened
Aegle marmelos	0.00	0.00	-	0.02	0.22	Threatened
Ailanthus excels	0.23	9.90	Abundant	0.36	4.32	Frequent
Albizia lebbeck	0.00	0.00	-	0.24	0.43	Threatened
Anacardium occidentale	0.00	0.00	-	0.15	0.22	Threatened
Azadirachta indica	0.11	3.04	Occasional	0.12	4.54	Frequent
Balanites aegyptiaca	0.03	0.64	Threatened	0.02	1.30	Rare
*Boscia senegalensis*r	0.00	0.00	-	0.03	0.22	Threatened
Capparis decidua	0.00	0.00	-	0.25	0.43	Threatened
Cassia fistula	0.00	0.00	-	0.14	3.46	Occasional.
Conocarpus lancifolius	0.05	0.96	Threatened	0.28	0.87	Threatened
Dalbergia melanoxylon	0.00	0.00	-	0.14	0.87	Threatened
Dalbergia sisso	0.00	0.00	-	0.02	10.39	Abundant
Delonix regia	0.04	0.80	Threatened	0.02	1.29	Rare
Elaeis guineensis	0.00	0.00	-	0.01	0.43	Threatened
Eucalyptus microtheca	0.05	0.96	Threatened	0.01	1.73	Rare
Eucalyptus camaldulensis	0.36	30.19	Abundant	0.03	14.29	Abundant
Fadherbia albida	0.03	0.64	Threatened	0.04	4.97	Frequent
Ficus microcarpa	0.03	0.48	Threatened	0.04	0.87	Threatened
Ficus sycomorus	0.03	0.48	Threatened	0.06	0.43	Threatened
Khaya grandifoliola	0.03	0.64	Threatened	0.07	0.87	Threatened
Khaya senegalensis	0.19	7.19	Abundant	0.04	11.47	Abundant
Mangifra indica	0.03	0.48	Threatened	0.02	0.22	Threatened
Milicia excels	0.03	0.64	Threatened	0.04	0.65	Threatened
Peltophorum petrocarpum	0.02	0.32	Threatened	0.02	0.43	Threatened
Phoenix dactylifera	0.02	0.32	Threatened	0.01	0.22	Threatened
Santalum album	0.00	0.00	-	0.01	0.22	Threatened
Tectonia grandis	0.04	0.80	Threatened	0.03	0.65	Threatened
Ziziphus spina Christi	0.01	0.16	Threatened	0.04	0.87	Threatened

The data in *Table 7* illustrate the growth variables and diversity indices for various tree families, genera, and species based on inventories taken in 2011 and 2021. The 2011 inventory recorded 12 families, 16 genera, 23 species, and 626 individual trees, with a total basal area of 78.67 m^2. In contrast, the 2021 documentation showed an increase in the number of families, genera, and species to 15, 26, and 32, respectively. However, the number of individual trees decreased to 462, with a total basal area of 77.31 m^2. The results from inventories taken in 2011 and 2021 indicate variations in species abundance and threat status. In 2011, 17.39 % of species were classified as abundant, which decreased to 12.5 % by 2021. Conversely, threatened species constituted a substantial majority, with 78.26 % in 2011 and 65.63 % in 2021. Occasional species accounted for 4.35 % in 2011 and declined slightly to 3.13 % in 2021. Furthermore, the 2021 inventory also identified 9.38 % of species as frequent and rare (*Table 7*).

The Shannon-Wiener diversity index (H) recorded values of 1.75 in 2011 and 2.39 in 2021, indicating an increase in species diversity. The Margalef index, which measures species richness, showed values of 93.64 in 2011 and 70.8 in 2021 for the forest ecosystem. Species evenness also improved, from 0.56 in 2011 to 0.69 in 2021. Furthermore, Simpson's diversity index, which assesses the diversity of a community by considering the number of species and the abundance of each species, 0.73 in 2011 increased to 0.84 in 2021 (*Table 7*).

Table 7. Summary of stand structural variables and diversity indices in the AGRFR in 2011 and 2021

Growth variables and diversity indices	Inventory year 2011	Inventory year 2021
Number of families	12	15
Genera	16	26
Number of tree species	23	32
Density (Tree ha^{-1})	208.67	154
Number of trees	626	462
Total basal area (m^2 ha^{-1})	78.67	77.31
Basal area (m^2 ha^{-1})	3.42	2.41
Abundant (Relative density; RD ≥ 5)	4 (17.39%)	4 (12.50%)
Frequent (4.00 ≤ RD ≥ 4.99)		3 (9.38%)
Occasional (3.00 ≤ RD ≥ 3.99)	1 (4.35%)	1 (3.13%)
Rare (1.00 ≤ RD ≥ 2.99)		3 (9.38%)
Threatened/ Endangered (0.00 < RD ≤ 1)	18 (78.26%	21 (65.63%)
Shannon–Wiener (Diversity index (H)	1.75	2.39
Margalef's index (Species Richness)	93.64	70.8
Species Evenness index (E_H)	0.56	0.69
Simpson's Species Diversity index	0.73	0.85
Index of Dominance	14.58	5.71

4 DISCUSSION

4.1 Trends of structural variables of the AGRFR

The AGRFR has minimum and maximum diameters at breast height (DBH) of trees recorded at 6.1 cm and 115 cm, respectively. This reserve is noted for its abundance of trees with smaller DBH, a common feature of tropical forests. This observation aligns with findings from previous studies in other tropical rainforests of Nigeria, as reported by Adekunle and Olagoke (2008), Adekunle et al. (2013), Akindele (2013) and Aigbe et al. (2014). The relatively lower number of trees with larger DBH values, exceeding 50 cm, is primarily due to selective logging practices, including removing large trees through logging for various uses in the past, as noted by Hadi et al. (2009). According to Adekunle et al. (2013), the distribution of diameter and height reflects the forest's horizontal structure and vertical patterns, indicating the forest's potential for continuous growth. Furthermore, the presence of large trees is often considered a sign of a mature tropical rainforest.

4.2 Trends of species somposition, diversity, and IVI

The 32 tree species from 15 different families documented in the Abu Geili River Forest Reserve (AGRFR) underscore the area's considerable diversity, a hallmark of robust ecosystems, as noted by Okey et al. (2022) and Mohamed et al. (2021). Among these, the Fabaceae, Moraceae, and Meliaceae families were most prevalent. Although the count of individual tree species diminished in 2021 compared to 2011, the diversity of species and families increased in the same period.

In contrast, studies in other regions have reported varying levels of diversity. For instance, Dafa-Alla et al. (2022) found just 14 species, representing a significantly lower diversity in Jebel Elgarri forest, Blue Nile state, Sudan. Similarly, minimal diversity was recorded in Sinnar state, Sudan's Tozi tropical dry forest, with only four species across two families reported by Yasin and Mulyana (2022). Conversely, Mohammed et al. (2021a) observed greater diversity in the Abu Gadaf natural reserve, Sudan, with 47 species from 20 families. A much richer biodiversity was noted in the Ehor forest reserve, Edo State, southern Nigeria by Ihenyen et al. (2009), who identified 99 species from 87 genera and 36 families. Ecological zones and anthropogenic activities such as logging and deforestation particularly affect the AGRFR (Yeom and Kim, 2011; Liu et al., 2024) and significantly influence the variability in species.

The prevalence of the Fabaceae, Meliaceae, and Moraceae families, known for their resilience and rapid regeneration, mirrors findings from other studies in Nigerian forest reserves by Mukhtar (2002), Edet et al. (2012) and Aigbe et al. (2014) in Sudanese tropical forests. These characteristics likely help these families dominate in varied environments despite the threats from human activity.

Ecological indices further highlight these dynamics. The Shannon-Wiener diversity index values increased from 1.75 in 2011 to 2.39 in 2021, suggesting an improvement in biodiversity within the reserve. This index value surpasses the 1.928 noted by Dafa-Alla et al. (2022) in Sudan but is below the higher values reported in rainforests in India and Nigeria by Pragasan and Parthasarathy (2010), Adekunle and Olagoke (2008), respectively. This positive trend may reflect natural regeneration, reduced disturbances, and successful conservation efforts.

Despite the overall growth in the index, its comparatively low value may reflect ongoing natural and human pressures, underscoring the need for enhanced governance and regulatory reforms to protect and enhance the forest's biodiversity.

The importance value index (IVI) further elucidates species dominance within the reserve. *Acacia nilotica* topped the 2011 inventory with an IVI of 80.7, while the 2021 survey showed a decrease, with *Khaya grandifoliola* following at an IVI of 46.3. The lowest IVIs were recorded for *Santalum album* and *Ziziphus spina-christi*, likely impacted by their commercial and medicinal value, leading to higher logging rates. This indicates the economic implications of tree species removal, emphasizing the necessity for targeted conservation efforts for both dominant and lesser-represented species (Abdullahi, 2021; Wilfahrt et al., 2023).

4.3 Trend in species conservation status between 2011 and 2021

The inventories conducted in 2011 and 2021 revealed significant changes in the relative density (RD) and conservation status of tree species within the Abu Geili Riverine Forest Reserve (AGRFR). *Acacia nilotica* consistently recorded the highest densities, though its RD decreased from 39.94 % in 2011 to 31.6 % in 2021, indicating a slight decline in its dominance. Meanwhile, *Ziziphus spina christi* and *Acacia ehrenbergiana* had the lowest density at 0.16 % in 2011. By 2021, the lowest density of 0.216 % was shared by *Anacardium occidentale*, *Boscia senegalensis*, *Mangifera indica*, *Phoenix dactylifera*, and *Santalum album*, showing an increase in the diversity of species with very low densities.

The Shannon-Weiner diversity index (H') increased from 1.75 in 2011 to 2.39 in 2021, indicating a significant improvement in species diversity. This increase suggests that the forest ecosystem has become more balanced, with a greater variety of species contributing to its overall composition. Despite this improvement in diversity, most tree species were still classified as threatened in both years. However, the data shows some progress: in 2011, 78.26 % of species were considered threatened, which decreased to 65.63 % in 2021. This decline reflects positive changes in the conservation status of several species, likely due to effective management and conservation efforts.

Overall, while the forest has seen improvements in species diversity and a decline in the percentage of threatened species, challenges remain. The decrease in *Acacia nilotica's* relative density, along with the still high proportion of threatened species, underscores the need for ongoing conservation efforts, highlighting the importance of continued monitoring and adaptive management strategies to enhance the forest's health and ensure the long-term sustainability of its diverse species.

5 CONCLUSIONS

The comparative analysis of the AGRFR across the years 2011 and 2021 reveals substantial shifts in the forest's diversity and tree composition. The 2021 inventory counted 462 trees across 32 species and 15 families, whereas less than 626 trees were identified in 2011. The Fabaceae family had the highest number of species recorded (10 species), followed by Moraceae and Meliaceae families, each with (three species), emphasizing the ecological diversity within the forest. Despite shifts in tree density and diversity measures, the forest still shows resilience and a rich ecological environment. In particular, *Acacia nilotica* demonstrated its ecological significance through its abundance and high Importance Value Index (IVI). The most common trees were found in the height range of 10 to 14 meters and a DBH class of 20 to 29 cm. With smaller trees, DBH of 17 cm and below was also dominant.

Nevertheless, the decline in tree numbers and changes in species richness and evenness point to the impacts of environmental stress and human activities, highlighting the urgent need for conservation initiatives to ensure forest sustainability. Despite this, the AGRFR exhibited low tree species density alongside high species diversity. Urgent conservation measures are required to mitigate the risk of species extinction and address the adverse effects of logging and other illegal activities on the forest's structure and diversity. Protecting the AGRFR from anthropogenic impacts is essential to prevent further deforestation and degradation, ensuring the long-term preservation of its unique species and ecological balance.

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Examination of the Effect of Four Pesticides Used in Practice on *Beauveria* Strains Under Laboratory Conditions

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ABSTRACT

Biological pest control is increasingly crucial and emphasized in research, leading to the frequent use of entomopathogenic fungi such as *Beauveria bassiana* and *B. brongniartii*. Integrated pest management often requires multiple control agents to address various species simultaneously, raising the question of the interaction between the utilized fungi and the other active agents applied simultaneously. The present study examined the interactions between active ingredients and entomopathogenic fungi in laboratory conditions. The results indicate that insecticides and herbicides containing diazinon or glyphosate have neutral or positive effects on the examined *Beauveria* species. However, fungicides with the active ingredients penconazole or sulfur demonstrated adverse effects when used alongside the tested entomopathogenic fungi. The combined use of fungicides and fungi deserves examination because, in many cases, fungal diseases appear simultaneously with pests, e.g., powdery mildew.

TANULMÁNY INFÓ

Kulcsszavak:
Erdővédelem
Biológiai védekezés
Entomopatogén
Beauveria bassiana
Beauveria brongniartii

KIVONAT

Négy, a gyakorlatban használt növényvédő szer hatásának vizsgálata különböző *Beauveria* törzsekre laboratóriumi körülmények között. Az erdővédelemben egyre inkább előtérbe kerül a biológiai védekezés. Ennek keretein belül gyakran alkalmaznak entomopatogén gombákat, mint például a *Beauveria bassiana* és a *B. brongniartii*. Sokszor szükséges kombinált módon a károsítók és kórokozók ellen egyaránt védekezni, melynek során különböző hatóanyagok egyidejű kijuttatása elkerülhetetlen. Felvetődik a kérdés, hogy ezen gombafajok és a leggyakrabban velük együttesen használt egyéb növényvédő szerek hatóanyagai milyen hatással vannak egymásra. Különböző *Beauveria* törzsek növényvédőszer-hatóanyagokkal való kölcsönhatását vizsgáltuk laboratóriumi körülmények között. A gyakorlatban használt diazinon, illetve glifozát hatóanyagú rovar- és gyomirtó szerek egyidejű alkalmazása többnyire semleges, vagy egymást erősítő hatást mutatott. A penkonazol vagy kén hatóanyagú gombaölő szerek esetében viszont az azonos területre történő kijuttatás nem célravezető, mert a gomba hatását gátolta mindkét hatóanyag. A gombaölő szerek és a gomba együttes használatát azért kell vizsgálni, mert sok esetben megjelenik a kártevőkkel párhuzamosan gombabetegség is a kezelni kívánt állományban pl. lisztharmatok.

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1 INTRODUCTION

Soil-dwelling pests have significant adverse effects on forest management and agriculture in Europe. Various Melolonthinae species larvae are particularly major limiting factors of any afforestation, reforestation, or tree planting activities because they feed on the roots of freshly planted seedlings (Fröschle, 1996; Luisa and Mauro, 1996; Hirka and Csóka, 2011). Pest control methods are numerous, including mechanical, chemical, and biological control agents, but most are complicated to apply due to the complex biology and life cycle of the target insect pests. Although biological control is favored over chemical and mechanical methods, efficient and user-friendly methods are often lacking, emphasizing the need to develop new biocontrol agents and methods. Unfortunately, climate change only exacerbates the problem.

The European Union aims for a climate-neutral continent by 2050 and has recently implemented its Farm to Fork Strategy, which supports the transition towards sustainable food systems by reducing chemical pesticide use by 50% and encouraging organic farming. (European Green Deal, 2019-2020-2022; European Commission - Farm to Fork strategy, 2020).

Various herbicides, insecticides, fungicides, and soil disinfectants are utilized in chemical control to enhance crop and tree growth. Agriculture on large, connected monocultural fields increases disease frequency and infestation severity. Applying soil disinfectants and fungicides prepares the soil for the seeds and seedlings by protecting vulnerable roots and sprouts. Such disinfectants and fungicides are usually only harmful to the target organisms. However, herbicides and insecticides often contain substances that can accumulate and harm beneficial creatures like bees (it raises concerns lately) and, over the long term, mammals, including humans (Nikolopoulou-Stamati et al., 2016; Pathak et al., 2022; Kaur et al., 2024).

Oak forests experience the most soil-living insect damage in forestry, regardless of the reforestation method. Young plants are significantly impacted by powdery mildew infection and cockchafer grub feeding on their roots in nurseries and during natural reforestation. Simultaneously controlling powdery mildew and cockchafer damage is the main focus of oak reforestation efforts. When using entomopathogenic fungi for insect damage control, it is also crucial to focus on the agents involved in powdery mildew control and examine the interactions of these agents.

Herbicides and insecticides are less likely to interact with the fungi but still require inspection. Soil disinfectants and fungicides applied in the same medium – soil – are in direct contact with such agents, entailing a considerable likelihood of interaction between the chemicals and the fungi. Diazinon is a widespread and commonly used active soil disinfection ingredient. Some studies have labeled diazinon as harmful to fungi (Khun et al., 2020), but this claim requires investigation because it is likely that the sterile circumstances secured by the disinfectant hold more benefits than harms for fungal growth. Since fungicides destroy or hinder fungi, they also harm Beauveria species. The open question is, to what degree?

As 'good fungi,' Beauveria species are neutral to plants and a good biological alternative to insecticides. Simultaneous application with the above-mentioned chemical control agents needs to be studied to decide which can be used safely together without affecting the other negatively.

Beauveria species are asexually reproducing, cosmopolitan, and entomopathogenic; such characteristics are all pathogenic to insects. The majority of *Beauveria species* breed in soils where their target organisms live. The most common of these fungi is *Beauveria bassiana*, widely used as a biocontrol agent in agriculture. Another species of the genus, *Beauveria brongniartii*, appears to be a specific pathogen of scarab beetles (Zimmermann, 2007).

Unlike bacteria and viruses, fungi act via contact. and infect directly through insect exoskeletons. Hyphae grow from the spores and produce enzymes that dissolve the cuticle, thus providing entry into insect bodies. Once inside, *B. bassiana* produces a variety of toxins such as beauvericin, bassianin, bassianolide, beauverolides, tenellin, oosporein and oxalic acid, calcium oxalate, and many beauvericin analogs (Wang et al., 2021; Charnley, 2003; Kučera – Samšiňáková, 1968; Quesada-Moraga – Vey, 2004). Beauvericin is the most significant toxin because it weakens the host's immune system via nutrient deprivation, eventually killing the infected individual (Fan et al., 2017).

Beauveria spp. has been used in experiments for decades. The first recorded research dates to 1956, when the target species was *Cylas formicarius* (Li, 2007). Other species, such as *Dendrolimus punctatus*, *Scolytus multistriatus,* long-horn beetles, *Tetranychus evansi*, *Myzus persicae*, *Corythucha arcuata*, *Hylobius abietis,* and many others, were also experimented on (Li, 2007; Barson, 1977; Higuchi et al., 1997; Bugeme et al., 2008; Kim et al. 2013; Sönmez et al., 2016; Lalík et al., 2021), revealing that the fungus has a wide range of application potential.

Many experiments with *Beauveria bassiana* and *B. brongniartii* against *Melolontha* and other species have also been conducted in Italy, Switzerland, Austria, Poland, Turkey, and China (Keller, 2000; Enkerli et al., 2004; Kessler et al., 2004; Chałańska et al., 2017; Malusá et al., 2020; Yaman, 2019; Zhou et al., 2020).

In addition to proving that *Beauveria* species can withstand different environmental conditions, these studies confirmed that pest problems are present all over Europe and Asia.

The present study investigated the following hypotheses to discover how *Beauveria bassiana* and *B. brongniartii* are integrable as biological control agents in pest management:

H1.) The reactions of *Beauveria bassiana* and *B. brongniartii* strains differed (inhibitory or supportive) during the various treatments.

H2.) Fungicide treatments (penkonazol and sulfur) inhibit the growth of both *Beauveria bassiana* and *B. brongniartii* strains.

H3.) The soil disinfectant diazinon creates a sterile environment for *Beauveria bassiana* and *B. brongniartii* strains, thus enhancing their growth.

2 MATERIALS AND METHODS

The experiment was conducted in the University of Sopron laboratory. The samples were grown in parafilm-sealed Petri dishes that ensured constant humidity. The dishes were kept at constant room temperature (22±1 °C) with natural light conditions without shading and received approximately 10–11 hours of light daily.

One *Beauveria bassiana* strain (labeled BORA) and three *Beauveria brongniartii* strains (labeled ART8, ART64, and ART315) were chosen based on earlier field trial results (Merő, 2016) for this experiment.

The strains originated from mycelia grown in Petri dishes on PDA (potato dextrose agar), with 15 replications per strain. Mycelia were placed in the middle of the petri dish to allow for the radial growth of the fungi. After two weeks, the samples were sprayed with four different chemicals, 3-3 repetitions each, and three control samples were left untreated per strain. *Table 1* lists the main attributes of the chosen chemicals.

Solutions were made of each of the four chemicals dissolved in distilled water, based on the recommended usage amount calculated for the Petri dish area (63.6 cm^2), as given in *Table 2*.

Table 1. Main attributes of the used chemicals

Name	Active ingredient	Target	Mode of action
Taifun 360	360 g/l glyphosate	herbicide	contact
Basudin	5 % diazinon	insecticide, soil disinfectant	contact
Vegesol eReS	23 % m/m sulfur	fungicide	contact
Topaz	10 % penkonazol	fungicide	absorbable

Table 2. Applied concentrations of the chemicals

Name	Recommended usage amount	Amount/Petri dish	In solution	
			Chemical	Water
Taifun 360	5 l/ha	3.2 µl	64 µl	6.4 ml
Basudin	35 kg/ha	22.4 µg	448 µg	6.4 ml
Vegesol eReS	5 l/ha	3.2 µl	64 µl	6.4 ml
Topaz	0.5 l/ha	0.32 µl	0.64 µl	6.4 ml

Each sample was sprayed with 320 µl solution. Three samples per chemical per strain and three control samples of each strain were left untreated. Measurements The surface area of the fungal culture was measured after seven days. Every sample was photographed and placed on millimeter paper. Manual calculations were completed based on this scale.

The following statistical methods were used to evaluate results:

- The Shapiro-Wilk normality test to determine if the samples represent normal distribution
- Cochran C homogeneity test of variance

The above-mentioned tests are preconditions for any parametric statistical test. According to the normality test and homogeneity of variances test results, ANOVA tests can be used for the samples.

- ANOVA (=Analysis of Variance) to assess the effect of the chemicals
- Dunnet post hoc test to compare treated samples with control samples because this test has been developed especially for comparing samples or sample groups to one given sample or sample group (usually control group) (Lee and Lee, 2018) and
- Tukey HSD (= Honest Significant Difference) post hoc test to compare the treatments and the reaction of the strains to each other because this post hoc test is used to compare different samples or sample groups with each other. This widely used and accepted post hoc test has a high trust index to determine where and how the significant effect occurred (Lee and Lee, 2018).

Statistica software (version 13.5.0.17) was used with default settings for the above-mentioned evaluations.

3 RESULTS

3.1 Effects of the used pesticides

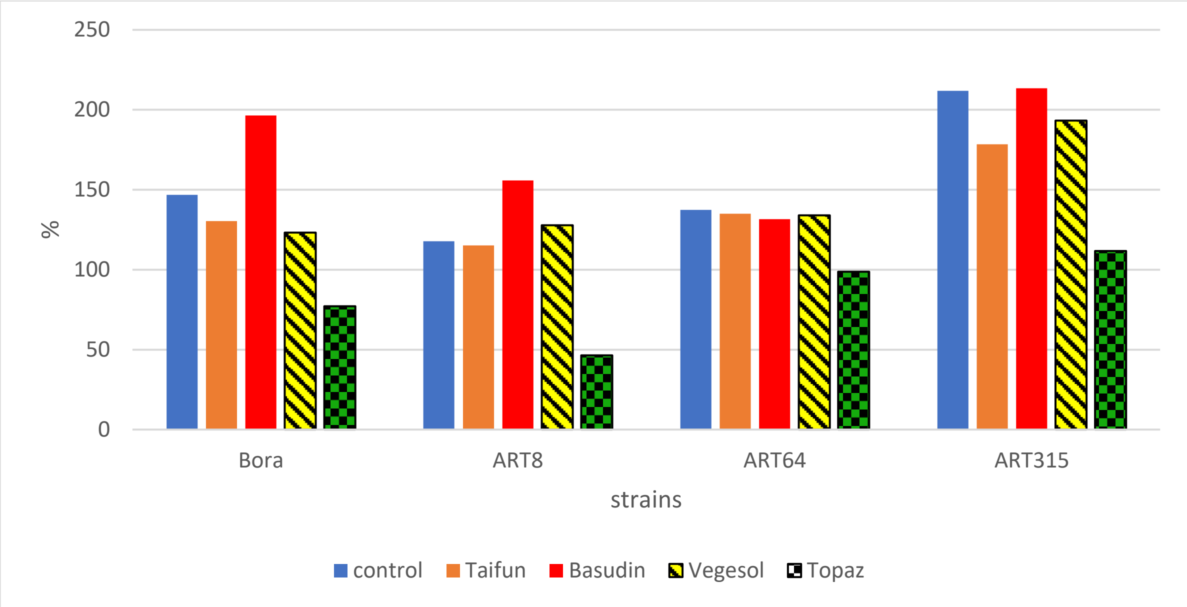

Figure 1. The effect of treatments on the growth of fungal strains seven days after spraying compared to the control samples

Vegesol eReS

As seen in *Figure 1*, the Vegesol eReS treatment promoted slight growth inhibition except in ART8. Since growth inhibition was insignificant, no detailed evaluation and results are provided here. ANOVA and Dunnett post hoc tests showed p = 0.72 for *B. bassiana* samples and p = 0.83 for *B. brongniartii* at $p < 0.05$.

The above-mentioned three treatments had no significant effect on the treated fungi; therefore, their data were not analyzed further.

Topaz

Samples treated with Topaz displayed growth inhibition in all cases (Figure 1), ranging from 38.58% to 100.08%, depending on the strains compared to the control samples. These Statistical analyses (Tables 3 and 4) confirm these significant results.

Table 3. Effect of Topaz treatment on strains - ANOVA, p = 0.05

Effect	Univariate Tests of Significance for % Sigma-restricted parameterization Effective hypothesis decomposition				
	SS	DF	MS	F	p
Intercept	1145475	1	1145475	2604.240	0.000
Strain	19400	3	6467	14.702	0.000
Treatment	29348	1	29348	66.723	0.000
Strain*treatment	2841	3	947	2.153	0.134
Error	7038	16	440		

SS-sum of squares; DF – degree of freedom; MS-mean square; F-value of F distribution; p-probability

Table 3 highlights the significance within the 'strain' row. When comparing control samples of the various strains, considerable differences can be detected among growth rates, especially when comparing any sample to the ART315 control samples (*Table 4.* - column {7}). The Topaz treatment shows notable growth inhibition; however, when examined with the different growth rates in the control samples, the result is insignificant. This can be explained by the outstanding value of the ART315 control samples' growth rates.

The Dunnett post hoc test showed p = 0.04 for *B. bassiana* samples and p = 0.002 for *B. brongniartii* at $p < 0.05$. For detailed evaluation, the Tukey post hoc test was used to compare the treatments (*Table 4*).

Control samples

From an average colony size of 153.435 mm^2 at the beginning of the experiment, the examined *Beauveria* spp. grew to a maximum of 311.78 mm^2 colony size within seven days. Even the slowest growing strain did more than double its size on average (ART8 – 117.88 % growth), and the fastest growing one – ART315 – showed 211.78 % growth on average, more than three times the starting size in seven days.

Several samples exhibited coloring ability, resulting in a pinkish decolorization of the agar. That was independent of the treatment, so it also appeared in the treated and the control samples.

Table 4. Effect of Topaz treatment on strains – TUKEY HSD, p = 0.05

Tukey HSD test; variable %
Approximate Probabilities for Post Hoc Tests
Error: Between MS = 439.85, df = 16.000

Cell No.	Strain	Treatment	{1} 246.78	{2} 177.14	{3} 217.88	{4} 146.43	{5} 237.30	{6} 198.72	{7} 311.78	{8} 211.70
1	1	1		0.016	0.695	0.001	0.999	0.161	0.027	0.483
2	1	2	0.016		0.313	0.633	0.045	0.901	0.000	0.500
3	2	1	0.695	0.313		0.013	0.939	0.943	0.001	1.000
4	2	2	0.001	0.633	0.013		0.002	0.105	0.000	0.026
5	3	1	0.999	0.045	0.939	0.002		0.373	0.009	0.799
6	3	2	0.161	0.901	0.943	0.105	0.373		0.000	0.993
7	4	1	0.027	0.000	0.001	0.000	0.009	0.000		0.001
8	4	2	0.483	0.500	1.000	0.026	0.799	0.993	0.001	

Strain: 1 – BORA; 2 – ART8; 3 – ART64; 4 – ART315; Treatments: 1 – control; 2 – Topaz; horizontal column header numbers {1}-{8} correspond to the 'Cell' column respectively and the values show the growth rates in % - for example {1} 246.78 means that the average growth rate of the BORA control samples was 246.78 % in the experiment.

4 DISCUSSION

The study found that Topaz – the fungicide with the active ingredient penconazole – was the only one of the tested chemicals to unequivocally inhibit the growth of the used *Beauveria bassiana* and *B. brongniartii* strains (*Figure 1*), entailing why this treatment's results were evaluated in more detail.

Relation to objectives

The effect of the four chemicals used was different on the growth of the tested *Beauveria* strains. *Beauveria bassiana* and *B. brongniartii* strain reactions differed in the same treatments. Displayed inhibition in one did not entail the same in the other, contradicting the first hypothesis. The strains reacted differently in Basudin (diazinon) and Vegesol eReS (sulfur). The former increased the growth rates of *B. bassiana*, while the latter decreased them. Basudin had a variable effect on *B. brongniartii* – in one case, it caused a notable increase, while in another case, it caused only a slight increase. In the third case, a slight inhibition in mycelium growth occurred. Growth inhibition was detected with Taifun (glyphosate) and Topaz (penkonazol) in all cases.

Both fungicides inhibited fungal growth in the samples, except for ART8, which was treated with Vegesol eReS. The lack of growth was likely caused by masking or a mixing defect. Inhibition rate ranged from 3.36 % to 100.08 %. The percentage value over 100 % means that colony size was even smaller by the end of the experiment (seven days after spraying) than at the time of the treatments. The treatment caused it to shrink. This difference is induced by the various modes of action (contact and absorbable) and the efficacy of the varying active ingredients. Penkonazol was a stronger inhibitor due to its absorbability. Simultaneous usage of *Beauveria* species and penkonazol or sulfur is not recommended. This result verifies the second hypothesis that fungicidal treatments (penkonazol and sulfur) inhibit the growth of *Beauveria bassiana* and *B. brongniartii* strains used in the experiment.

Previous experiments where *Beauveria* and fungicides were used together also demonstrated this growth inhibition (Clark et al., 1982; Todorova et al., 1998; Khun et al., 2020). Daconil and maneb showed remarkable inhibition in *B. bassiana* growth (Olmert and Kenneth, 1974), but mancozeb and metiram also reduced the survival chances of the fungus (Loria et al., 1983). Zineb with copper-oxychloride caused the same effect (Majchrowicz et al., 1993). Some experiments revealed a neutral connection between certain fungicides – such as chlorothalonil and methalaxil – and mycelial development (Loria et al., 1983); however, in other experiments, they induced a positive effect in fungal growth thanks to fungicides (Anderson et al., 1989), even in case of copper-oxychloride, which earlier appeared to be inhibitory (Challa – Sanivada, 2014).

Basudin treatment exhibited a significant increase in BORA growth rate. Growth in *B. brongniartii* samples differed. One strain developed unequivocally, another was slightly supported, and the third strain showed a slight growth inhibition due to the diazinon treatment. These results modify the third hypothesis. The soil disinfection happens, but growth enhancement can firmly be stated only in *B. bassiana*.

Contrary to our experiment, Khun et al. (2020) found diazinon highly toxic to the fungi. In insecticides, Anderson and Roberts (1983) established that the studied pyrethroids all inhibited *B. bassiana* growth. Clark et al. (1982) stated that permethrin was the least harmful concerning this trait. Furlong and Groden (2001) described imidacloprid as synergistic with *B. bassiana*. Alizadeh et al. (2007) demonstrated less than 27% growth inhibition on the fungus and recommended parallel application. Other experiments suggested that chlorpyriphos can be used simultaneously with *Beauveria* species without inhibitory effects (Amutha et al., 2010). Wari et al. (2020) also determined the simultaneous applicability of *Beauveria* strains and various insecticides.

Experiments with herbicides showed the inhibitory effect on *Beauveria* growth, flurochloridone and prosulfocarb implementing the strongest inhibition (Celar – Kos, 2016). Todorova et al. (1998) described diquat as harmless to *B. bassiana*.

In all four chemicals, the appearance of the mycelia changed the most, even when the effect on growth was not indicated. This is likely connected to the hydrophobic feature of the mycelia, as the chemicals were dissolved in distilled water for application, and the contact chemicals

(Taifun 360, Basudin, Vegesol eReS) could only take effect on the small surface areas where the droplets touched the mycelia. Topaz could go deeper and cause a more severe effect due to its absorbability.

After we applied the recommended amount, none of the chemicals exceedingly inhibited fungi growth; however, the fungicides, and mainly Topaz with the active ingredient penkonazol, are not recommended for simultaneous application with *Beauveria* species because even the slightest growth inhibition can cause severe efficacy loss.

Novelties and recommendations for further experiments

Only *Beauveria bassiana* strains have been applied in forestry practice in Hungary, thus far without any remarkable effect, so studying *B. brongniartii* strains can be considered a first attempt to introduce this species in practice. The results can be used effectively in plant protection practice and integrated pest management, but additional experiments are welcome. Concerning the control samples, the growth of ART315 – a *B. brongniartii* strain – was the most powerful; therefore, further experiments with this strain are highly recommended. Studying the interaction between other agents and the fungi, the effect of the used strains on other target species or applying another application amount to boost effectiveness can provide utilizable information. Experiments with different application timing procedures are proposed. Even if simultaneous application is feasible, a few weeks' difference in usage may be more economical in the long run than the double (or triple) cost of returning to the site. This contributes to fungicides or other chemicals that could potentially hinder the development of *Beauveria* species. The present study recommends experiments in applying *Beauveria bassiana* and *B. brongniartii* simultaneously to determine if they have any effect on each other, something similar to the experiment of Canfora et al. (2017), which found that the two fungus species have some interaction related to their different ecological niches.

Recommendations for practical use

Previous studies showed that Beauveria has a maximum growth rate and infectability at higher temperatures. The optimum range for B. brongniartii is 20–25 °C, according to Kessler et al. (2003). Fargues et al. (1997) posit a 25–28 °C range for B. bassiana. This range varies from 25-30°C in Ekesi et al. (1999) and Bugeme et al. (2008), rising to 25–32°C in James et al. (1998). Based on these studies, it is recommended to apply the fungi when the average soil temperature reaches 20–25 °C. Traditionally, these temperatures correspond with the end of May, but climate change can push the temperatures earlier. The application mode depends on the properties of the stand to be treated and the land features. Planting together with watering pipes, using an interrow cultivator, or direct injection are all effective. Upon application, simultaneous usage with substances supporting the fungus (e.g., Trichoderma sp.) or treatment with higher concentrations are recommended. Adding moisture-fixing substances or continuous water supplementation is essential if applied in late spring. Simultaneous application with Taifun 360 and Basudin is encouraged, but Vegesol eReS and Topaz fungicides should be avoided if not crucial.

5 CONCLUSIONS

The present study examined *Beauveria bassiana* and *B. brongniartii* species and their simultaneous application with several chemicals used in plant protection practice.

The main result is the affirmation that these fungi experimentally used in biological control as part of integrated pest management are not recommended to be applied together with fungicides, especially if the active ingredient is penkonazol. This part of the experiment is notable, and the data also produce spectacular and significant statistical results.

The growth-enhancing effect of Basudin soil disinfectant is beneficial; however, the main goal is not fungal growth inhibition. The helping feature is a ‘bonus’ in this case.

The two fungus species are not interchangeable because their reactions differed under the same treatments.

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Radial and Vertical Distribution of Dissoluble Total Carbohydrate Content in the Beech (*Fagus sylvatica* L.): Relationships with Red Heartwood Formation

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ABSTRACT

Red heartwood forms in most old beech stands, which reduces the commercial value of the wood considerably. Many of the chemical and biochemical processes involved in red heartwood formation are known, but research has been limited to a single level of the stem (usually at breast height). The present study investigated the radial and vertical distribution of dissoluble carbohydrates at different height levels within a red heartwood (17 levels) and a non-red heartwood (12 levels) beech stem. The radial changes of the concentrations differ notably in beech with or without red heartwood. An increase in the transition zone is not a mandatory condition for red heartwood formation, but a decrease in concentration always occurs after the transition zone. Intense sugar metabolism at the color boundary contributes to the surplus energy required in red heartwood formation and the *in situ* synthesis of polyphenolic compounds.

TANULMÁNY INFÓ

Kulcsszavak:
Bükk
Álgesztesedés
Kioldható összcukor tartalom eloszlás

KIVONAT

A kioldható összcukor tartalom radiális és vertikális megoszlása a bükk (*Fagus sylvatica* L.) törzsben: összefüggések az álgesztesedés folyamataival. Az idős bükkállományok nagy részében álgeszt képződik, ami a faanyag kereskedelmi forgalmi értékét jelentősen csökkenti. Az álgesztesedés kémiai és biokémiai folyamatainak jelentős részét feltárták, de az eddigi kutatások csak a törzs egy adott szintjére korlátozódtak (általában a mellmagassági átmérő). Jelen munkánkban vizsgáltuk egy álgesztes és egy álgesztmentes bükk (*Fagus sylvatica* L.) kioldható összcukor tartalmának radiális és vertikális eloszlását. Mértük az álgesztes törzs 17 és az álgesztmentes törzs 12 magassági szintjén a koncentrációk sugárirányú eloszlását. Megállapítottuk, hogy a kioldható összcukrok koncentrációja, valamint radiális és vertikális megoszlása mind az álgesztes, mind az álgesztmentes törzsben magasságfüggő. A koncentrációk sugár irányú változásai szignifikánsan különböznek az álgesztes és az álgesztmentes bükkben. Az álgesztesedésnek nem kötelező feltétele a kioldható szénhidrátok koncentrációjának megemelkedése a tranzicionális zónában, de a koncentráció csökkenés a tranzicionális zóna után minden esetben bekövetkezik. Az intenzív cukor metabolizmus egyrészt az álgesztesedés folyamatait fedezheti, másrészt hozzárulhat a polifenol vegyületek *in situ* szintéziséhez az álgeszt határon.

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1 INTRODUCTION

Beech is a widespread broadleaved tree species in Europe. Its wood is of high economic, ecological, and silvicultural value and acts to stabilize forest ecosystems (Frýdl et al., 2011). Compared to conifers (Sáenz-Romero et al., 2019), beech has demonstrated higher adaptability and acclimation potential (Visi-Rajczi et al., 2021). Beech comprised 5.5 % of forested land in Hungary in 2019 (103 thousand hectares) (URL1). Red heartwood, a color and technological beech defect, forms in most old beech stands. Profound morphological and anatomical changes occur when red heartwood forms. These changes significantly affect wood properties, which differ from non-discolored ripewood in some of its properties. The moisture content drops below 60 %, and the distribution changes inside the stem. The wood cracks, warps, dries slower, is difficult to saturate, and attains poor adhesiveness (Pöhler et al., 2006; Vek et al., 2013). However, determining this color defect in standing trees is challenging (Knoke, 2002, 2003; Wernsdörfer et al., 2005, 2006). It does not show worse technological properties than non-discolored beech wood in terms of volume density, flexibility, bending, and compressive strength (Pöhler et al., 2006; Todorovic et al., 2012); however, the furniture industry seldom uses discolored beech because of its lower economic value (Molnar et al., 2001; Zell et al., 2004). Marketing efforts have done little to change this perception, and discolored timber remains a lower-value wood.

The crown base height, growth rate, defect prevalence, and the presence of forks can influence red heartwood development, which depends on forest ecosystem characteristics (Knoke, 2003). Defects and damage render the tree susceptible to oxygen, which penetrates the stem and increases microorganism activity (Sorz and Hietz, 2008). Oxygen degrades soluble carbohydrates and starch involved in the enzymatic transformation of colored phenolic substances (Koch et al., 2000, 2001; Albert et al., 2003; Hofmann et al., 2008). Chemical and biochemical processes occur in red heartwood formation, prominently in the transitional zone. Large amounts of soluble carbohydrates accumulate during these processes (Albert et al., 2002; Visi-Rajczi et al., 2002, 2003), the free and bound acid content decreases (Albert et al., 1998a, 1999), the pH increases, the buffer capacity changes (Albert et al., 1999), and the concentration of polyphenols (Koch et al., 2001; Albert et al., 2003; Hofmann et al., 2004, 2021) and the activity of phenol-oxidizing enzymes increase (Magel, 2000; Albert et al., 2000).

Carbohydrates provide the building blocks for plant structures and versatile resources for metabolic processes. Non-structural carbohydrates (NSC), mainly sugars and starch, fulfill distinct functional roles, including transport, energy metabolism, and osmoregulation. They also provide substrates for defense compound synthesis or exchange with symbionts involved in nutrient acquisition or defense. NSCs are crucial forms of tree carbon storage, mainly composed of soluble sugar and starch. NSC concentration represents a trade-off between carbon source gain via photosynthesis and carbon sink costs through metabolism and growth. It also reflects the relationship between supply and demand across plant tissues (Hartmann and Trumbore, 2016).

The soluble non-structural carbohydrate fraction of woody tissues consists primarily of sucrose, glucose, and fructose (Höll, 1997; Magel et al., 1997) but may also contain maltose or sugar alcohols (Höll, 1981; Sauter and VanCleve, 1993; Popp et al., 1997). Considerable amounts of raffinose and stachyose can also be detected in the living tissues in cold seasons (Magel et al., 1994; Sauter et al., 1989, 1998). Furthermore, disaccharide trehalose was identified in beech wood extracts (Dietrichs, 1964b; Vek et al., 2014). In all the examined trees, starch is the polymer-carbohydrate that fulfills the defining non-structural and reserve nutrient function, but very rarely, fructans are also detectable. Metabolic processes (physiological reactions) in wood tissues depend on the mobility and distribution of soluble carbohydrates and starch. These substances play a role in biochemical reactions of heartwood formation as starting and synthesis products of primary and secondary metabolic processes.

Research results indicate that dissoluble carbohydrates, polyphenols, and their oxidizing enzymes are decisive in red heartwood formation. However, most previous research focused on only one stem level (diameter at breast height). The moisture content distribution in red heartwood beech changes inside the stem (Pöhler et al. 2006; Vek et al. 2013). Within one stem, the tissue structure and stem diameters also differ vertically, so it can be assumed that the dissoluble total carbohydrate (DTC) concentrations vary at different altitude levels, and their radial and vertical distribution also varies.

The present study assessed the radial distribution of the DTC content at different height levels within a red heartwood stem (17 levels) and a non-red heartwood (12 levels) stem. The measurements also made it possible to follow the vertical distributions. We also examined whether differences in red heartwood beech processes can be detected as a function of height. The beech without red heartwood also served as a comparison basis. Results were compared to previous findings on sugar distributions in the stem of other woody species, and conclusions on the role of dissoluble sugars in the biochemical processes of red heartwood formation were made.

2 MATERIALS AND METHODS

2.1 Sample assignment and collection

The present study analyzed one red heartwood stem and one non-red heartwood stem from the TAEG (Tanulmányi Erdőgazdaság) Forestry Company, Sopron (Hungary). The trees were between 100–110 years old.

In the height tests, we extracted sample discs at every meter of the tested stems up to the first fork. *Tables 1 and 2* summarize the sampling heights. The red heartwood stem was cut into five (I-V) logs (*Figure 1*), and the logs were then split in the middle. Red heartwood diameters varied from 1 cm to 13.1 cm along the 19 m, depending on stem height. Red heartwood was absent below 1 m, above 15 m, and in the middle of logs IV and V. We cut 17 sample discs from the red heartwood stem and 12 from the non-red heartwood stem. Eight samples were taken along the radius of the red heartwood discs, while five samples were taken between the bark and the pith of the non-discolored stem (*Figure 2)*. The letter f represents the sapwood; g, the heartwood (g) on each side of the transition zone (color boundary) in the red heartwood stems. The present study examined 196 samples.

The stems were taken to the laboratory immediately, where they were sectioned, rasped, and extracted within one day.

2.2 DTC content extraction and measurement

We extracted 0.25 g of wood grist fractions with 25 ml methanol:water 80:20 (v/v) solution for 6 hours using a Variomag Poly15 magnetic stirrer. The extracts were filtered through a Whatman GF/A grade glass fiber filter. The DTC content was determined by the Dubois method (Dubois et al., 1956), using glucose as standard. We mixed 1 ml of 5% aqueous phenol solution with 1 ml extract solution. After homogenization, 5.0 ml of concentrated sulfuric acid solution was carefully added to the mixture and homogenized again. After 10 minutes at room temperature, the mixture was cooled in a 25 °C water bath for 20 minutes. The sugar content was determined spectrophotometrically at 490 nm using glucose as standard. Assays were run in triplicates for each extract. Results were given in mg dissoluble total sugar/g dry weight (mg/g dry wood).

I. log (0-3 m) II. log (4-6 m) III. log (7-9 m) IV. log (10-12 m) V. log (12-15 m)

Figure 1. Red heartwood beech logs (I-V)

Table 1. Analysis by red heartwood beech height – Stem diameters of red heartwood in different sampling heights

Height (m)	*0.04*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*12.5*	*13.5*	*14.5*	*15*
Log	*I.*				*II.*			*III.*			*IV.*			*V.*			
Stem diameter (cm)	54	46	44	42	42	43	43	38	36	38	34	28	32	32	30	32	30
Red-hw. diameter (cm)	0	7	10	13	12.5	13.1	12.8	10	8	9.3	2	6	8.5	6	1	5.6	0

Table 2. Analysis of beech without red heartwood by height – Stem diameters at different sampling heights

Height (m)	*0.05*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11.4*
Log	*I.*				*II.*			*III.*			*IV.*	
Stem diameter (cm)	48	40	40	42	42	42	39	32	32	30	30	28

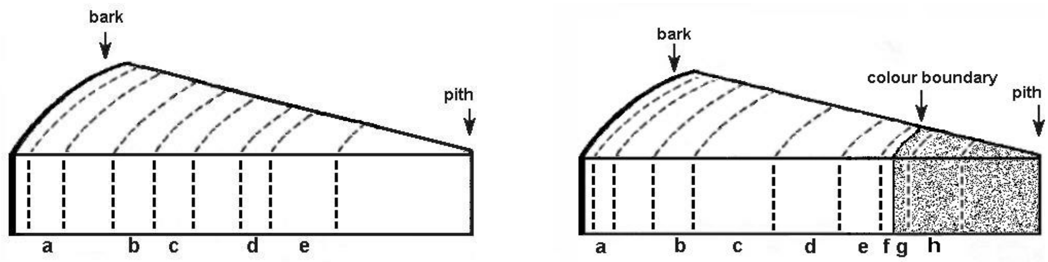

Figure 2. The graphic description of wood section assignments from sample disks; a–e: sapwood/ripewood tissues; f: red heartwood boundary white, g: red heartwood boundary red, f/g: sapwood/red heartwood transition zone; h: inner red heartwood.

3 RESULTS AND DISCUSSION

3.1 Radial distribution of DTC content at different height levels

Aligning with previous investigations, similar radial tendencies were observed in the red heartwood stem at nine levels (Albert et al., 1998b, 2002, 2003, 2005) for individual levels: a continuous radial decrease of the concentration to the inner ripewood (e) tissues, an increase in the transition zone (f) and a sharp decrease in the outer red heartwood (g) with minor or low concentrations in the inner red heartwood (h). The radial concentration distribution at the other levels deviated from this trend. *Figure 3* illustrates the characteristic changes. The general trend can be observed at 1 m: the concentration decreases up to the inner ripewood (e) tissues, increases in the transitional zone (f), and decreases dramatically in the outer red heartwood (g). At 5 m, the radial decrease is continuous; at 10 m, the decrease lasts only to the outer ripewood (d) tissues. The increase begins in the inner ripewood (e) tissues and then spikes in the transitional zone (f). At 12 m, the concentration is highest in the inner ripewood (e) tissues and decreases in the transitional zone (f). At 13.5 m, the concentration rose continuously in the radial direction. After the transition zone (f), the concentration drops sharply. The inner red heartwood tissues (h) also contain some soluble carbohydrates.

As seen in *Figure 3*, not all investigated heights experienced DTC content increases at the red heartwood boundary. This can be explained by the DTC assay being non-specific for simple sugars and measuring glycosides or by random extraction errors and the DTC assay and by deterministic trends with the heights, all of which make the vertical evaluation of the values necessary for each tissue.

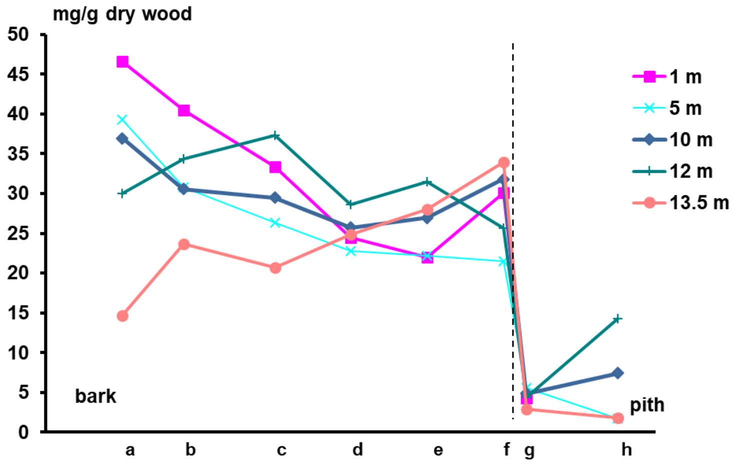

Figure 3. Radial distribution of the dissoluble total sugar content in red heartwood beech at 1, 5, 10, 12, and 13.5 m

The dissoluble total sugar content was high in the lower and upper parts of the stem and low in the middle part of the **non-red heartwood beech** samples. In tissues (a-e), the lowest total value was measured at 8 m, the highest at 0.05 m. According to the literature, the DTC content of the sapwood tissues in non-red heartwood beech continuously decreased in the radial direction, but the decrease did not become notable in heartwood (Visi-Rajczi et al., 2002; Albert et al. 2002). The radial changes of the concentrations at the five height levels of the investigated non-red heartwood stem followed the trend described in the literature and differed at seven height levels.

The DTC content in the inner ripewood (e) tissues increased at 1 m, 9 m, and 11.4 m, where it increased or remained constant in the inner sapwood (b) and outer ripewood (d) tissues but only decreased in the inner ripewood (e) at 3 m. There was a continuous increase from the outer ripewood (d) tissues at 9 m, and this increased significantly in the inner sapwood (b) tissues, decreased in the outer ripewood (d) tissues, and increased in the inner heartwood (e) at 11.4 m. *Figure 4* shows the radial variation of the soluble total sugar content at 0.05 m, 3 m, 9 m, and 11.4 m.

The trend-like radial decrease of the concentration can be followed at 0.05 m. At 3 m, the concentration increases in the sapwood (b, c) tissues, remains constant in the outer ripewood (d) tissues, and decreases in the inner ripewood (e). At 9 m, it rises continuously after the sapwood tissues (c). At 11.4 m, it increases significantly in the sapwood (b-c) tissues, decreases in the outer ripewood (d) tissues, and increases in the inner ripewood (e).

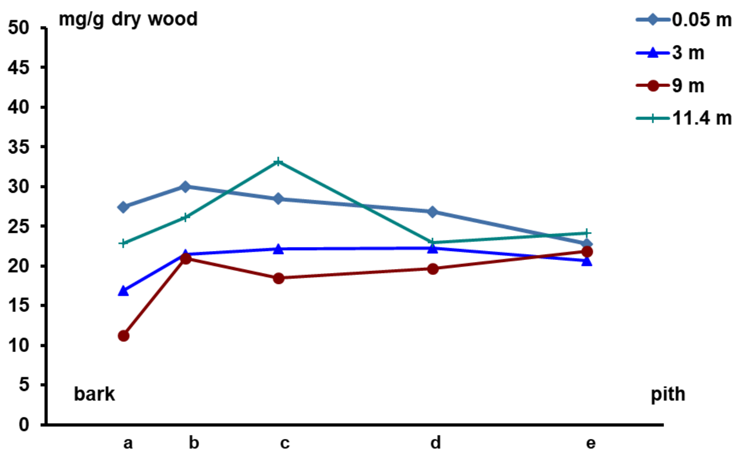

Figure 4. Radial distribution of the dissoluble total sugar content in the beech without red heartwood at 0.05, 3, 9, and 11.4 m

Dietrichs (1964b) was the first to examine the distribution of soluble carbohydrates from the cambium to the pith in beech (*Fagus sylvatica* L.), oak (*Quercus* sp.), birch (*Betula alba* L.), Norway spruce (*Picea abies* KARST.) and limba (*Terminalia superba* ENG. & DIELS.). The dominant sugars (sucrose, fructose, and glucose) are present primarily in the outer sapwood, and their amount decreases from the cambium to the pith (Dietrichs, 1964b; Höll 1985). All the non-structural carbohydrates are distributed relatively evenly within the sapwood for all species that do not have obligatory colored heartwood.

Starch and sugar concentrations continuously decrease in the sapwood tissues while moving toward the heartwood boundary. However, this decrease follows different patterns for different species: it is much more noticeable in *Robinia pseudoacacia* and less visible in the case of *Pinus sylvestris*. Interestingly, the sugar content showed the opposite trend and reached its maximum near the color boundary in *Angophora costata* tissues examined in early summer (Hillis et al., 1962).

In several investigated tree species, starch content is the highest in the inner sapwood, and values decrease inwards (Dietrichs, 1964a; Hillis, 1968) to the color boundary, where they disappear (Dietrichs, 1964a). Magel et al. (1997) confirmed these results in measurements detecting the enzymatic hydrolysis of starch in the border zone.

In most trees (conifers and hardwood species), the heartwood contains almost no non-structural carbohydrates (Magel et al., 1997; Dietrichs, 1964b; Höll, 1972), yet there are exceptions. Mannose was evidenced in spruce heartwood of spruce, while xylose and arabinose were detected in oak heartwood (Hillis, 1987).

According to Saranpää and Höll (1989), the sugars present in small amounts in Scots pine heartwood (e.g., mannose or arabinose) may originate from a hemicellulose decomposition during the sapwood/heartwood transformation. Like other coniferous species, larch sapwood (*Larix* spp.) contains only trace amounts of water-soluble polysaccharides. In contrast, the heartwood contains a large amount of arabinogalactan-type compounds, which can be dissolved in hot water and are thus loosely bound to the cell wall structure (Hillis, 1968).

Researchers attribute the appearance of arabinogalactans in the heartwood tissues to changed biosynthetic pathways during the heartwood formation processes (Ziegler, 1968). According to Magel et al. (2001), the glucose in black walnut heartwood tissues is released from the cleavage of the phenolic-glycoside precursors involved in the heartwood formation reactions.

Magel (1993) identified glucose, fructose, raffinose/stachyose, starch, and adenosine mono-di- and triphosphates from red-heartwood beech trunks using thin-layer chromatography and enzymatic determination. In general, the sugar concentrations were high in the sapwood and low in the colored wood, with the young (outer sapwood) tissues showing the highest raffinose/stachyose levels. Starch amounts decreased from the outer sapwood towards the inner sapwood and were not detectable in red heartwood. Adenine nucleotide concentrations were the highest in the outer sapwood, while inner sapwood showed very low levels, and the red heartwood contained no adenine nucleotides. The presented decrease in carbohydrate levels indicates that they are transformed and participate in active hydrolysis and syntheses.

Our previous research established that the total polyphenol concentration (Albert et al., 2003) and the amount of individual polyphenolic compounds (Hofmann et al., 2022) increased in front of the red heartwood boundary. Compared with the current measurements, it can be concluded that intense processes occur at the border zone. These involve sugar metabolism, which fuels sapwood/heartwood transformation reactions and produces substrate for the *in situ* synthesis of phenolic compounds.

As mentioned, radial tendencies of the DTC content may vary at different heights. Hence, the vertical trends of the concentrations were also investigated for each tissue to improve interpretation.

3.2 Vertical distribution of the DTC content at different height levels

Figure 5 depicts the vertical variation of the DTC contents in different tissues of a red heartwood beech stem. The highest values occurred in sapwood (a, b) tissues, especially at the stem base (0-5 m), and concentrations decreased up the stem. Similarly, as in *Figure 3*, concentrations decreased in the inner sapwood tissues (e), and an increase in front of the red heartwood boundary (f) was found only at certain height levels. Interestingly, the increase of DTC content in tissue (f) was not experienced at the heights with the highest red heartwood diameter (3-7 m), which can be explained by the fact that red heartwood formation is the most expressed in the stem at these altitudes. Consequently, the biochemical reactions of red heartwood formation consume quickly. Behind the color boundary (g, h), DTC content was very low at all height levels.

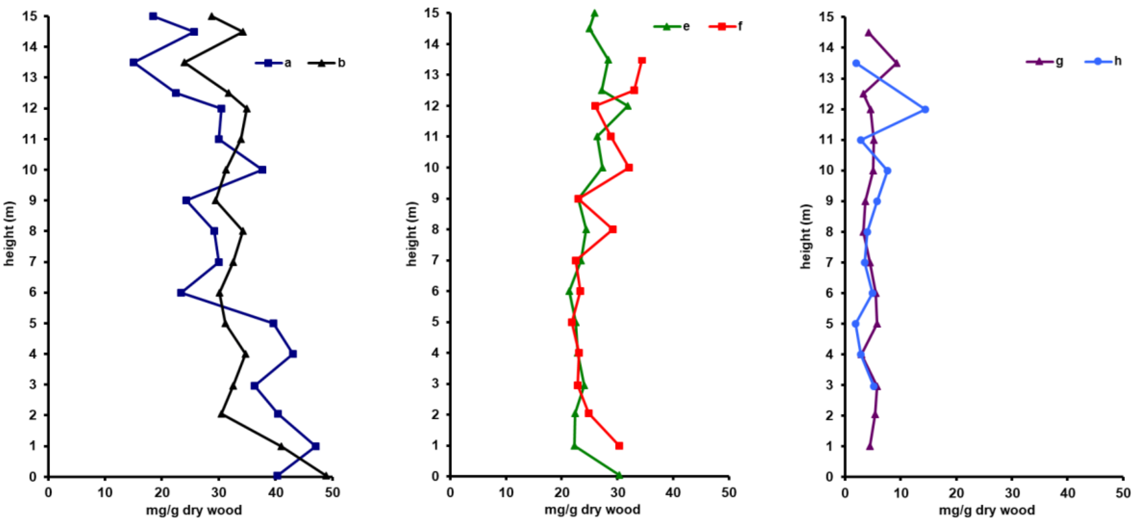

Figure 5. Vertical distribution of the dissoluble carbohydrate concentration in red heartwood beech tissues. a: outer sapwood, b: inner sapwood, e: inner heartwood, f: transition zone, g: outer red heartwood, h: inner red heartwood.

The DTC content of **non-red heartwood beech** tissues was high in the lower and upper parts of the stem and low in the middle part: the lowest total concentration was measured at 8 m; the highest at 0.05 m. Unlike the red-heartwood stem, stem concentrations increased above 9 meters in the non-red heartwood. The soluble carbohydrate concentration in the vertical tissue bands corresponding to the same anatomical locations varied between 10–35 mg/g of dry wood at all height levels (*Figure 6*).

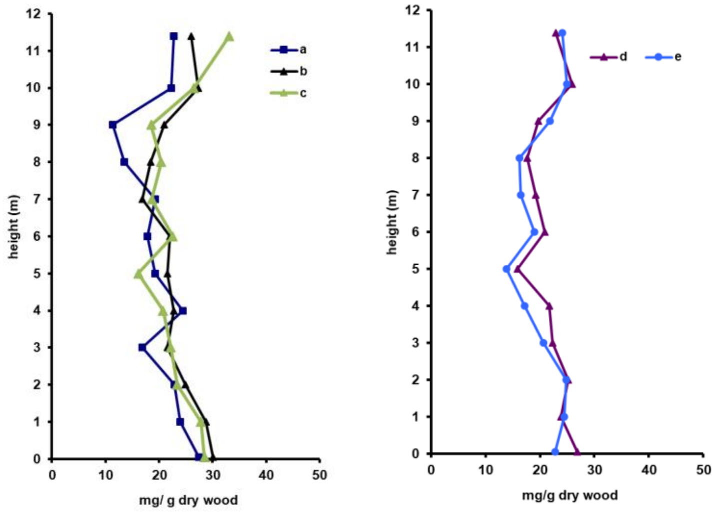

Figure 6. Vertical distribution of the dissoluble carbohydrate concentration in beech tissues without red heartwood. a, b, c: outer and inner sapwood tissues, d, e: outer and inner heartwood

Tables 3 and 4 in the Appendix show the statistical evaluation of the data.

4 CONCLUSIONS

The radial and vertical distributions and the concentration of dissoluble carbohydrates are height-dependent in both investigated beech stems with and without the red heartwood, with different radial tendencies. In accordance with previous results, the present study discovered that outer sapwood contained the highest levels of total dissoluble sugars, especially at the stem base (0–5 m), and concentrations decreased while moving up the stem. Concentrations increased above 9 meters in the non-red heartwood stem. Inner sapwood contained lower amounts of dissoluble sugars than outer sapwood. The concentration drops dramatically behind the color boundary in red heartwood beech. A non-obligatory condition for red heartwood formation is a sudden increase in the concentration of dissoluble carbohydrates in the transition zone, especially at heights between 0–2 meters and above 7 meters. Interestingly, between 2–7 meters, where red heartwood diameter is the highest, such an increase was not experienced in tissue f, which was explained by the rapid metabolism of sugars in these tissues due to expressed heartwood formation processes. In accordance with previous results, we found that sugar metabolism is especially significant in the processes of red heartwood formation in beech. Carbohydrate contents have distinct radial and vertical tendencies connected to red heartwood diameter. Increased levels of carbohydrate contents before the red heartwood boundary are responsible for fueling the metabolic pathways of red heartwood formation and for the *in-situ* production of polyphenolic compounds needed for the synthesis of the red heartwood coloring substances.

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URL 1 : https://www.ksh.hu/stadat_files/kor/hu/kor0082.html

APPENDIX

Table 3. Radial and vertical distribution of total soluble carbohydrate content (mean(std. dev)) in red heartwooded beech

h (m)	0.04	1	2.05	2.96	4	5	6	7	8
a	$39,8(2,1)_{ab}^{EF}$	$46.6(3.0)_{f}^{F}$	39.9(4,9)d^{EF}	35.8(3.5)d^{DEF}	$42.7(4.3)_{d}^{F}$	$39.3(2.4)_{d}^{EF}$	$23.1(2.3)_{b}^{ABC}$	$29.6(3.4)_{cd}^{CDE}$	$28.8(1.9)_{bc}^{BCDE}$
b	$48.3(5,9)_{b}^{D}$	$40.5(3.7)_{ef}^{CD}$	$30.2(1.8)_{bc}^{AB}$	$32.2(1.3)_{cd}^{ABC}$	$34.4(4.1)_{c}^{BC}$	$30.8(0.7)_{c}^{AB}$	$29.8(1.6)_{c}^{AB}$	$32.2(2.0)_{d}^{ABC}$	$34.0(2.2)_{c}^{BC}$
c	$43.9(2,6)_{b}^{F}$	$33.3(4.6)_{de}^{DE}$	$31.9(2.5)_{cd}^{CDE}$	$27.1(1.4)_{bc}^{ABCD}$	$25.0(2.5)_{b}^{ABC}$	$26.4(0.7)_{bc}^{ABCD}$	$25.1(0.5)_{bc}^{ABC}$	$23.8(2.6)_{bc}^{AB}$	$24.8(2.8)_{b}^{ABC}$
d	$39.2(3,6)_{ab}^{C}$	$24.5(0.4)_{bc}^{AB}$	$24.5(4.7)_{bc}^{AB}$	$24.1(1.2)_{b}^{AB}$	$23.7(0.6)_{b}^{AB}$	$22.8(1.5)_{b}^{AB}$	$22.1(1.8)_{b}^{AB}$	$20.2(1.8)_{b}^{A}$	$22.8(2.0)_{b}^{AB}$
e	$29.9(3,3)_{a}^{CD}$	$22.0(0.8)_{d}^{AB}$	$22.2(0.5)_{b}^{AB}$	$23.7(0.5)_{b}^{ABC}$	$22.6(1.1)_{b}^{ABC}$	$22.2(0.6)_{b}^{AB}$	$21.1(3.2)_{b}^{A}$	$23.2(3.3)_{b}^{ABC}$	$24.1(0.6)_{b}^{ABCD}$
f		$30.1(0.7)_{cd}^{ABCD}$	$24.6(3.7)_{bc}^{ABCD}$	$22.6(1.9)_{b}^{ABb}$	$22.9(1.2)_{b}^{AB}$	$21.5(4.2)_{b}^{A}$	$23.1(1.5)_{b}^{ABC}$	$22.3(2.1)_{b}^{AB}$	$28.9(4.6)_{bc}^{ABCD}$
g		$4.3(1.9)_{a}^{AB}$	$5.2(1.4)_{a}^{AB}$	$5.6(1.1)_{a}^{B}$	$2.7(0.3)_{a}^{A}$	$5.6(0.3)_{a}^{B}$	$5.4(0.4)_{a}^{AB}$	$3.9(0.6)_{a}^{AB}$	$3.1(0.0)_{a}^{AB}$
h				$5.0(2.3)_{a}^{AB}$	$2.5(0.2)_{a}^{A}$	$1.8(0.2)_{a}^{A}$	$4.7(0.5)_{a}^{AB}$	$3.4(0.2)_{a}^{AB}$	$3.9(0.6)_{a}^{AB}$

h (m)	9	10	11	12	12.5	13.5	14.5	15
a	$24.0(1.1)_{b}^{ABC}$	$36.9(3.8)_{c}^{EF}$	$29.5(1.9)_{b}^{CDE}$	$30.0(9.9)_{bc}^{CDE}$	$22.2(4.1)_{b}^{ABC}$	$14.7(1.0)_{b}^{A}$	$25.3(1.0)_{b}^{ABCD}$	$18.2(1.5)_{a}^{AB}$
b	$29.1(1.7)_{c}^{AB}$	$30.6(4.1)_{bc}^{AB}$	$33.4(3.6)_{b}^{BC}$	$34.3(3.2)_{bc}^{BC}$	$31.1(2.0)_{cd}^{AB}$	$23.7(2.5)_{c}^{A}$	$34.0(2.1)_{c}^{BC}$	$28.4(3.0)_{b}^{AB}$
c	$24.2(1.9)_{bc}^{AB}$	$29.5(4.9)_{bc}^{BCD}$	$29.7(1.3)_{b}^{BCD}$	$37.3(1.4)_{c}^{EF}$	$25.3(2.7)_{bc}^{ABC}$	$20.7(0.4)_{bc}^{A}$	$26.8(1.4)_{b}^{ABCD}$	$28.4(1.2)_{b}^{BCD}$
d	$23.3(2.7)_{b}^{AB}$	$25.7(1.1)_{b}^{AB}$	$26.4(2.5)_{b}^{AB}$	$28.6(0.6)_{bc}^{B}$	$21.8(1.9)_{b}^{AB}$	$24.9(3.0)_{c}^{AB}$	$26.6(1.3)_{b}^{AB}$	$23.2(3.2)_{ab}^{AB}$
e	$22.7(2.9)_{b}^{ABC}$	$27.0(4.5)_{b}^{ABCD}$	$26.0(3.6)_{b}^{ABCD}$	$31.4(3.5)_{bc}^{D}$	$26.8(0.6)_{bcd}^{ABCD}$	$28.0(1.7)_{cd}^{ABCD}$	$24.7(0.7)_{b}^{ABCD}$	$28.6(3.0)_{b}^{BCD}$
f	$22.7(0.6)_{b}^{AB}$	$31.8(2.3)_{bc}^{BCD}$	$28.3(3.6)_{b}^{ABCD}$	$25.6(0.5)_{b}^{ABCD}$	$32.7(3.9)_{d}^{CD}$	$33.9(7.2)_{d}^{D}$		
g	$3.4(0.5)_{a}^{AB}$	$4.8(0.3)_{a}^{AB}$	$5.0(0.9)_{a}^{AB}$	$4.4(0.1)_{ab}^{A}$	$3.1(0.3)_{a}^{AB}$	$2.9(1.5)_{a}^{AB}$	$4.1(1.1)_{a}^{AB}$	
h	$5.6(0.1)_{a}^{AB}$	$7.4(1.2)_{a}^{A}$	$2.6(3.5)_{a}^{A}$	$14.3(1.0)_{a}^{C}$		$1.8(0.7)_{a}^{A}$		

Table 4. Radial and vertical distribution of total soluble carbohydrate content (mean(std. dev)) in beech without red heartwood

h (m)	0.05	1	2	3	4	5	6	7	8	9
a	$27.4(4.4)_{a}^{F}$	$24.0(3.5)_{a}^{DEF}$	$22.9(2.8)_{a}^{CDEF}$	$16.9(1.9)_{a}^{ABC}$	$24.4(1.3)_{a}^{EF}$	$19.2(1.4)_{bc}^{BCDE}$	$17.7(1.1)_{a}^{ABCD}$	$19.3(2.3)_{a}^{BCDE}$	$13.4(0.4)_{a}^{AB}$	$11.2(1.0)_{a}^{A}$
b	$30.0(0.8)_{a}^{C}$	$28.8(5.3)_{a}^{C}$	$24.9(2.8)_{a}^{ABC}$	$21.5(2.0)_{a}^{ABC}$	$22.7(3.6)_{a}^{ABC}$	$21.5(1.7)_{c}^{ABC}$	$22.0(1.4)_{bc}^{ABC}$	$16.9(2.3)_{a}^{A}$	$18.4(1.5)_{bc}^{AB}$	$21.0(0.9)_{bc}^{ABC}$
c	$28.5(1.4)_{a}^{E}$	$27.8(2.5)_{a}^{E}$	$24.2(1.3)_{a}^{CDE}$	$22.2(2.6)_{a}^{BCD}$	$20.7(0.7)_{a}^{BC}$	$16.1(1.0)_{ab}^{A}$	$22.5(0.3)_{c}^{BCD}$	$18.6(1.5)_{a}^{AB}$	$20.3(1.9)_{c}^{ABC}$	$18.5(1.2)_{b}^{AB}$
d	$26.8(5.0)_{a}^{C}$	$23.9(1.8)_{a}^{ABC}$	$25.1(2.2)_{a}^{BC}$	$22.3(5.9)_{a}^{ABC}$	$21.7(3.5)_{a}^{ABC}$	$15.8(1.0)_{a}^{A}$	$20.9(1.4)_{abc}^{ABC}$	$19.3(1.3)_{a}^{ABC}$	$17.6(1.1)_{bc}^{AB}$	$19.7(0.4)_{bc}^{ABC}$
e	$22.8(1.4)_{a}^{BC}$	$24.5(3.4)_{a}^{C}$	$24.8(2.0)_{a}^{ABC}$	$20.6(2.2)_{a}^{AB}$	$17.1(3.5)_{a}^{ABC}$	$13.8(0.4)_{a}^{A}$	$18.9(1.2)_{ab}^{ABC}$	$16.4(0.5)_{a}^{AB}$	$16.1(1.4)_{ab}^{A}$	$21.8(1.9)_{c}^{AB}$

h (m)	10	11.4
a	$22.3(1.9)_{a}^{CDEF}$	$22.8(1.2)_{a}^{CDEF}$
b	$27.4(7.2)_{a}^{BC}$	$26.1(0.3)_{a}^{ABC}$
c	$26.5(0.8)_{a}^{DE}$	$33.1(0.4)_{b}^{F}$
d	$25.9(2.2)_{a}^{C}$	$22.9(1.5)_{a}^{ABC}$
e	$25.0(0.6)_{a}^{BC}$	$24.1(2.7)_{a}^{ABC}$

Different capital letters in the same row (vertical direction) indicate a significant difference at the p = 0.05 % level. Different lowercase letters in the same column (radial direction) indicate a significant difference at the p= 0.05 % level.

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Tree Health Survey Results of Juvenile Black Locust Clones

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ABSTRACT

The black locust (*Robinia pseudoacacia* L.) is a significant tree species in many European countries, especially Hungary. The Hungarian Forest Research Institute initiated a project in the 1960s to improve *Robinia* stem quality and yield. Five newly bred clones (Laposi, Napkori, Hajdúsági, Farkasszigeti, Püspökladányi) are currently undergoing tests in three trials (Debrecen, Napkor, and Nyírbogdány). Studying the health status of these clones is vital to the cultivar certification process. In September 2022 (Napkor) and August 2023 (Nyírbogdány, Debrecen), we investigated 30 trees per clone by estimating average foliage loss per individual and observing the extent and causes of damage to the crown (canopy), branches, and trunk in each experimental plot. At the same time as the tree health survey, NDVI measurements were also performed in Debrecen using Trimble Greenseeker handheld sensor. Our results indicate that the clones possess good drought tolerance; however, the NDVI results revealed significant differences between the clones: Laposi and Farkasszigeti have the highest NDVI values (0.76 and 0.77), and Püspökladány has the lowest (0.74). Napkori is the most susceptible to fungal disease, exhibiting significant incidences of bark necrosis caused by *Phomopsis petiolorum*. The rate of insect damage was negligible, even with low levels of damage by leaf miners, which are very common in black locust plantations.

TANULMÁNY INFÓ

Kulcsszavak:
Növényvédelem
Akácnemesítés
Stressz tolerancia
NDVI

KIVONAT

Új akácklónok növényegészségi vizsgálatának eredménye. Az akác (*Robinia pseudoacacia* L.) egyike a legfontosabb fafajoknak Európában, különösen Magyarországon. Hazánkban az 1960-as években kutatási projekt indult a fafaj törzsminőségének javítására, fatermésének fokozására. Napjainkban 5 újonnan szelektált akácklónt (Laposi, Napkori, Hajdúsági, Farkasszigeti, Püspökladányi) vizsgálunk 3 klónkísérletben (Debrecen, Napkor és Nyírbogdány). A növényegészségi vizsgálatok kiemelt fontosságúak a fajta elismerési eljárás során. 2022 szeptemberében (Napkor) és 2023 augusztusában (Nyírbogdány, Debrecen) klónonként 30 fát vizsgáltunk minden kísérleti területen. Az állományvizsgálat során egyedenként megbecsültük az átlagos lombvesztést, valamint a koronában (lombozaton), ágakon és a törzsön előforduló károsodások mértékét és a kiváltó okokat. Debrecenben, ezzel egyidőben, NDVI mérest is végeztünk Trimble Greenseeker kézi műszer segítségével. Összegezve az eredményeket, megállapítható, hogy a vizsgált akácklónok jó szárazságtűrő képességgel rendelkeznek, ugyanakkor az NDVI értékek tekintetében szignifikáns különbség mutatkozott: a Laposi és Farkasszigeti (0,76 és 0,77) esetében mértük a legnagyobb és a Püspökladányinál a legkisebb NDVI értékeket (0,74). Továbbá az is bizonyítást nyert, hogy a Napkori klón a *Phomopsis petiolorum* gombás fertőzésével szemben fogékonyabb. A rovarkárok aránya elhanyagolható volt, még a közönséges akácosokban igen gyakran előforduló aknázómolyok károsításának mértéke is igen alacsony volt a vizsgálati években.

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1 INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) is a fast-growing, relatively drought tolerant, N-fixing, multi-purpose tree species native to eastern North America. Used for timber and firewood production and apiculture, it also plays a significant role in forest management and ecosystem services in many countries, including Hungary, Romania, Bulgaria, Poland, Germany, Greece, China, and South Korea for its CO_2 sequestration, landscape reclamation, and erosion control. Black locust adapts to many sites and climates (Keresztesi, 1988; Mantovani et al., 2014; Li et al., 2018; Nicolescu et al., 2020; Spyroglou et al., 2021; Ciuvăț et al., 2022; Martin, 2023). Its high resistance to pests and diseases has also contributed to its rapid spread in Europe since the 1600s. However, in recent decades, several insects (*Parectopa robiniella* Clemens, *Macrosaccus robiniella* Clemens, *Obolodiplosis robiniae* Hald.) and fungi (*Phloeospora robiniae* Höhn., *Phomopsis petiolorum* Desm. Grove) have been reported to damage mature trees and seedlings (Bakó and Seprős, 1987; Szabóky and Csóka, 1997; Vajna, 2002; Bálint et al., 2010; Wilkaniec et al., 2021; Ermolaev et al., 2023). Fortunately, the locust borer (*Megacyllene robiniae* Forst.) is not yet present in Europe (Nicolescu et al., 2020).

Concerning other insects, leaf miner caterpillars (*Parectopa robiniella* and *Macrosaccus robiniella*) reduce leaf assimilation by mining. High populations of these pests can cause early defoliation of black locust (Tóth, 2002; Medzihorský et al., 2023). The black locust gall midge (*Obolodiplosis robiniae*) can cause considerable damage in some years. The female lays the eggs on the leaves, and the hatching larvae deform the leaves severely, inhibiting proper leaf development and significantly reducing assimilation surfaces (Csóka, 2006; Skuhravá et al., 2007).

Major black locust fungal pathogens are rare; however, two are worth mentioning. The first is a canker disease caused by *Phomopsis petiolorum* (syn *Phomopsis oncostoma*), which most often occurs in weakened one- to four-year-old juvenile stands. Infections develop from May onwards on dead shoots caused by late frosts but can also affect pruning wounds and other damage. As the disease progresses, the bark becomes increasingly necrotic, turning brown on the thinner green shoots in the infected parts. Callus canker sores develop on the trunk and around the stub of limbs. Bark disease also exposes the xylem of trunks, which break, causing tree death. Prevention is the best control against *P. petiolorum* (e.g., suitable site selection, avoiding frost pocket sites, and healthy plant material). Dead specimens and parts of branches should be removed as soon as possible and then destroyed (burned) if infestation has already occurred. Pruning should be performed carefully (Michalopoulos-Skarmoutsos and Skarmoutsos, 1999; Tóth, 2002; Vajna, 2002). Infection by the other pathogen, *Phloeospora robiniae*, also starts in early summer, with increasingly large, continuous brown spots on the leaves. Infected leaves often become deformed (Kehr and Butin, 1996; Wilkaniec et al., 2021).

We must mention game damage: European hare (*Lepus europaeus* L.) and European rabbit (*Oryctolagus cuniculus* L.) peel the bark from trees, while deer (*Cervus elaphus* L., *Capreolus capreolus* L.) browse young shoots, leaves, and buds. The black locust stands that the current paper studied are often fenced, which limits game damage (Tóth, 2002; Nicolescu et al., 2020).

Robinia has some abiotic stress factors (e.g., breakage by wind or heavy snow), but the most significant is frost, which damages unhardened twigs, causing forking. Although black locust trees are drought tolerant, heat and extreme drought negatively affect their growth (Tóth, 2002; Nicolescu et al., 2020).

We have detailed the abiotic and biotic stress factors. It is also worth mentioning human-induced (mechanical) damage caused by cultivation tools.

Many countries conduct black locust improvement research, with Hungary at the forefront of producing many black locust cultivars and candidate varieties. The Hungarian research program to improve the stem quality of *Robinia* and increase its yield started in the 1960s

(Keresztesi 1988). Five newly bred black locust clones (Laposi, Napkori, Hajdúsági, Farkasszigeti, Püspökladányi) are undergoing tests in three clone trials (Napkor, Nyírbogdány, Debrecen). Growth, vitality, and plant physiological characteristics are studied at these sites. (Ábri et al., 2022, 2023a, 2023b)

This paper presents the results of tree health surveys of the mentioned clones. The study provides data on the vitality and stress tolerance of the tested clones, which will be beneficial in the cultivar certification process.

The main questions of the current study are the following:

1. What is the health status of the studied clones? Are they drought-tolerant? Are there any pests to which any of the clones are susceptible?
2. What is the optimal planting spacing for the tested clones?

2 MATERIALS AND METHODS

2.1 Study sites of clone trials

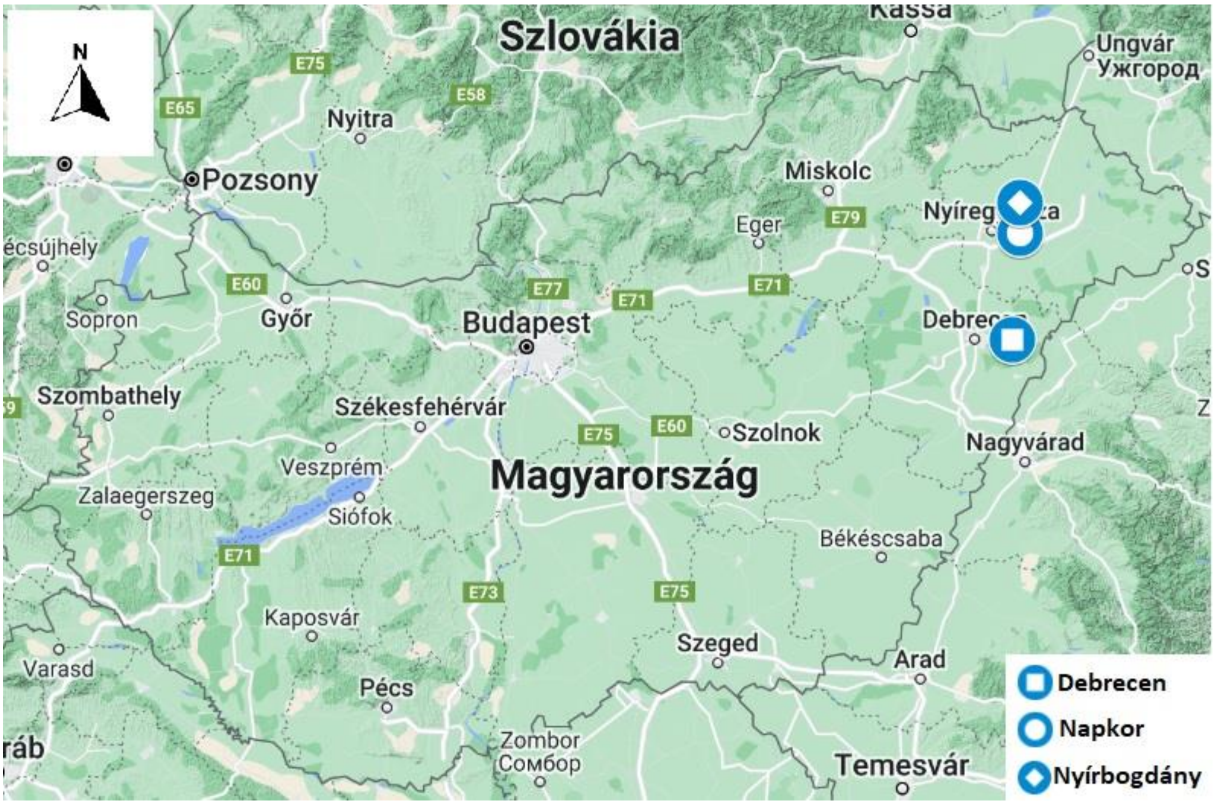

Figure 1. Location of study sites in Eastern Hungary

Napkor and Nyírbogdány

We have two experiments in the Nyírség region in eastern Hungary (*Figure 1*), the foremost black locust growing area. One of the clone trials is near Napkor, where four clones (Laposi – breeding sign: NK1, Napkori – breeding sign: NK2, Farkasszigeti – breeding sign: PL040, Püspökladányi – breeding sign: PL251) and cultivar Üllői (control) are studied in three different planting spacings (2.5 m ×2.5 m; 3.0 m × 3.0 m; 4.0 m × 4.0 m). The trial was conducted in 15 plots in total (Ábri et al., 2022, 2023a). The other is Nyírbogdány, where the Hajdúsági (breeding sign: PL035), Farkasszigeti, Püspökladányi, and Napkori clones are tested and compared with 'Ópályi' black locust (control). The clones were planted in three planting spacings, as in the Napkor experiment. Both clone trials were established in 2020. The study sites are acidic sandy soil with low humus content (1% > Hu%) (Ábri et al. 2023a).

The mean annual temperature is 10.6 °C in this area, and the mean annual precipitation is 537 mm based on long-term data (1991–2020) of the nearest Hungarian Meteorological Service station in Napkor. In the years of our tree health surveys, the mean temperature was higher by 1.1 °C (2022) and 1.6 °C (2023), and precipitation was 120 mm less in 2022 and 156 mm more in 2023 (Ábri et al. 2023a, HMS, 2024).

Debrecen – subcompartment Debrecen 189V

In subcompartment Debrecen 189V (*Figure 1*), the tested clones (NK1, NK2, PL035, PL040, PL251, and common black locust as control) were planted in 2.5 m × 1.5 m planting spacing. The experiment started in 2022. Our soil analysis results indicate that the humous content is low, and the soil pH was slightly acidic in the topsoil and increased with soil depth. In Debrecen, the mean annual temperature is 11.0 °C, and the mean annual precipitation is 543 mm (Gombos et al. 2023). In 2023, the health status investigation year, the mean temperature was higher by 1.6 °C, and precipitation was 121.5 mm higher. It is worth mentioning the extreme heat and drought in the planting year. In 2022, the mean temperature was higher by 1.1 °C, and precipitation was 101 mm less. In the period from May to August, the amount of precipitation was 69.5 mm, which is considerably below the 30-year average (240 mm) (*Figure 2*) (HMS 2024).

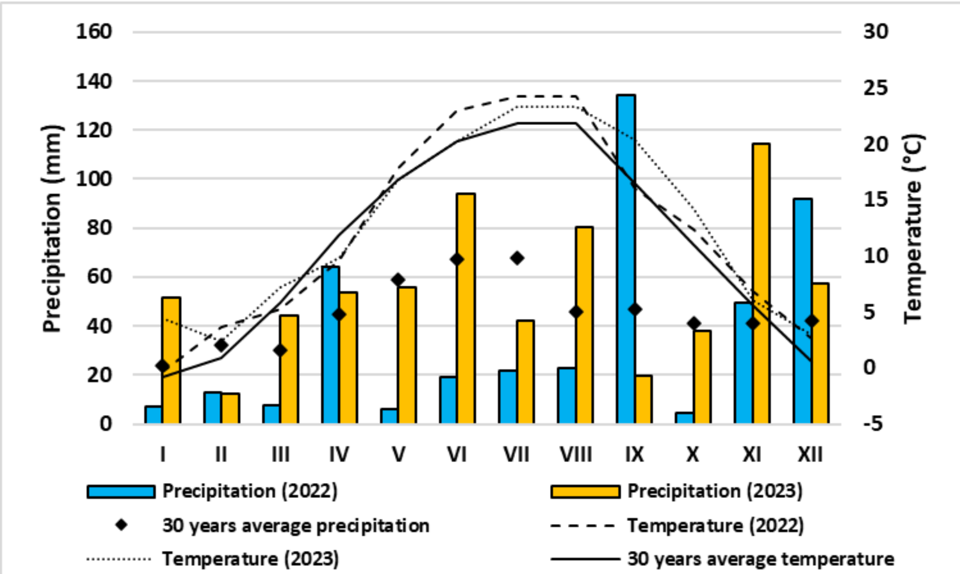

Figure 2. Monthly precipitation sums and temperature averages (Debrecen, 2022 and 2023). Numbers in the bars: monthly sum precipitation. Note: The 30-year averages are based on Gombos et al. 2023, and the 2022-2023 meteorological data are from HMS 2024.

2.2 Method

The tree health surveys were performed on 30 randomly selected individuals per clone in September 2022 (Napkor) and at the end of August 2023 (Nyírbogdány, Debrecen) after the cycle of main pests. For the investigation, we used an etalon tree, which was chosen locally. The ages of the studied clones are two (Debrecen), three (Napkor), and four (Nyírbogdány) years old. The average defoliation per individual was estimated in each experimental plot (and each planting spacing), as were the extent and causes of damage to the crown (canopy), branches, and trunk.

The average defoliation value represents the actual physical foliage loss relative to the total canopy area, which can occur due to several biotic and abiotic causes. The cumulative foliage loss value due to these causes provides the average foliage loss for a given clone.

Biotically caused leaf loss was also determined according to the emerging pests and pathogens. The frequency of occurrence (% of leaflets affected by the damage) and damage intensity (average percentage of leaf area affected) were recorded for the different foliage damage types. These two data are complementary and provide an accurate picture of the significance of a damage type. For example, in an extreme case, if all leaves show symptoms of fungal infection (frequency 100%) but only 1% of the leaf area is affected, then the intensity is 1%.

Abiotic defoliation is foliage loss due to drought and other abiotic factors (e.g., windbreak, frost, etc.) and is usually determined by the number of damaged, symptomatic leaves still present in the crown and by the number of fallen, discolored leaves, not including foliage loss due to crown breaks. Crown damages are in a separate category with a % value, which indicates crown break intensity, i.e., the percentage of the broken crown part of the total crown.

Pathogen incidence and intensity on trunks — in most cases (*Phomopsis petiolorum*) — is also expressed as a percentage. The frequency value indicates the % of the individuals tested that displayed fungal infection on the trunk, while the intensity % indicates the % of the trunk perimeter exhibiting bark necrosis caused by the fungus. Infection frequency, i.e., the number of individuals infected, is of greater importance for the analysis and data evaluation. The latter indicates the susceptibility of the clone to fungal infection. Intensity is of secondary importance in this case, as necrosis extension after fungal colonization is inevitable.

In Debrecen, we performed Normalized Difference Vegetation Index (NDVI)(Tucker 1979) measurements with a Trimble GreenSeeker handheld crop sensor. The sensor emits brief bursts of red and infrared light and then measures the amount of each light type reflected from the plant. The NDVI values range from 0.00 to 0.99 (Trimble 2024). We measured 30 trees/clones. Before the comparison, the homogeneity of variances was tested with the Levene test, and the normal distributions in the groups were tested with the Shapiro-Wilk tests. As the measured NDVI data met the parametric test conditions, we used one-way ANOVA and Fisher's LSD post hoc test for pairwise comparison. Statistical analyses were performed with IBM SPSS 25.0 statistical software.

3 RESULTS AND DISCUSSION

3.1 Defoliation

Napkor

The average defoliation rate was the lowest in the densest planting spacing (2.5×2.5 m), while the other two spacings had slightly higher values, but none reached 25 %. The two wider planting spacings showed broadly similar values. However, when evaluating the results by clone, we discovered that clones PL251 and NK1 showed significantly less defoliation than the other clones in all three planting spacings (*Figure 3*).

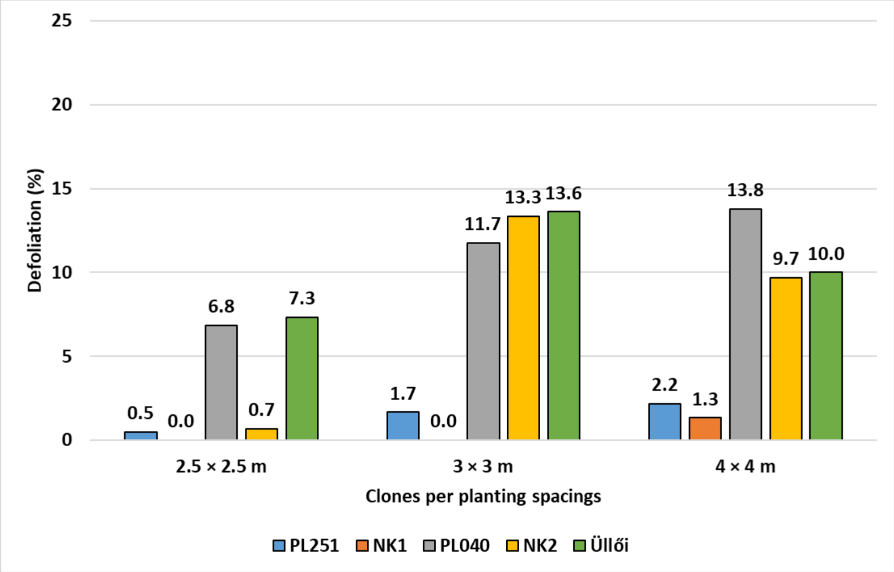

Figure 3. Average defoliation (%) of the clones (n = 30) in 3 different planting spacings (Napkor, 12/09/2022)

Debrecen
The average defoliation rate for the different clones did not exceed 25 % in any of the cases. The highest value, 24.3 %, was observed for clone PL040, but clone PL251 displayed a similar 24 % value. This value remained below 2 0% for the other clones. Clone NK2 had the lowest average defoliation at 9.8 % (*Figure 4*).

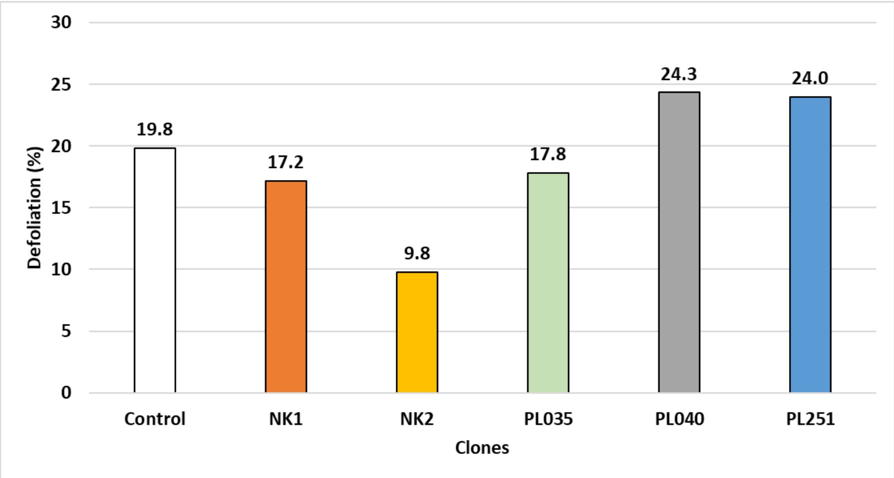

Figure 4. Average defoliation (%) of the clones (n = 30) (Debrecen, 21/08/2023)

3.2 Abiotic damages

Napkor
In this category, we mainly summed up the defoliation caused by drought and windthrow. The data showed relatively low % values for all clones. Perhaps the most notable was clone NK1, which had an abiotic leaf loss of 0 % in the 2.5×2.5 m and 3×3 m planting spacings but only 10% in the widest one (4×4 m). No outliers were observed for the other clones despite a severe drought in the area in the investigation year (2022), but the impact was relatively moderate. However, it is difficult to determine whether good site factors or the drought tolerance of the clones resulted in these values (possibly a combination of both).

Nyírbogdány

Relatively low percentages were observed for all clones in the Nyírbogdány experiment. The lowest values were in the widest planting spacing (4×4 m) with 0–4%. The values were similar in the other two spacings, usually between 4–6 %.

Debrecen

Data from Debrecen also showed relatively low % values for all clones. Perhaps NK2 was the clone with the lowest abiotic leaf loss, at only 2.5 %. The highest value was 15.7 % for PL251, which is still insignificant. The average drought-induced defoliation of the other clones ranged from 6–12 %. The NDVI measurement results in the experimental plantation in Debrecen are also reported. A considerable difference (p = 0.05) was found between the mean (± standard error) NDVI values of the studied clones. PL040 (0.78±0.0071) was the best, and PL251 (0.74±0.0067) was the weakest, while no significant differences were observed between the latter and the control, common black locust (0.75±0.0063), nor between clones NK1 (0.76±0.0072) and PL040 (*Figure 5*).

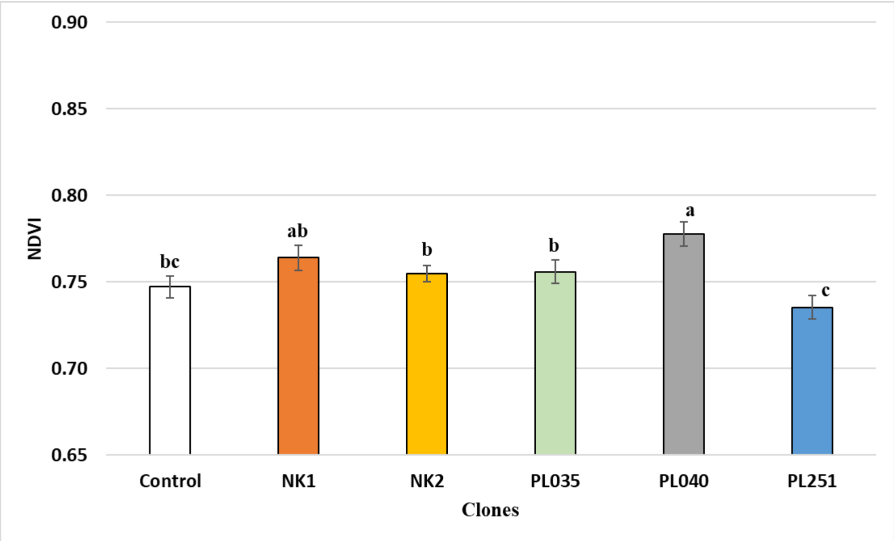

Figure 5. Comparison of the studied clones (n = 30) by their NDVI values using Fisher's LSD post hoc test, ±standard error (Debrecen, 21/08/2023)

3.3 Biotic damages – insect and game damage

We observed damage caused by leaf-mining moths, *Sitona* spp., and black locust gall midge in Nyírbogdány and Debrecen in the survey years, while in Napkor, we only observed symptoms caused by leaf miners. Overall, insect damage was negligible at all three sites. There were no notable differences in clone susceptibility or planting spacings in terms of damage extent. The differences observed can be considered rather random. However, the damage of the recently introduced black locust gall midge (Csóka, 2006; Csóka et al., 2017) is worth monitoring to determine whether there are differences in damage in narrower and wider planting spacings.

Game damage was only observed in Debrecen because that experimental plantation was not fenced. Damage varied from 10–27 %, mainly at the shoot tips, with an average intensity. The experiment results may be affected by chewing damage to the extent that tree height growth in the initial period (until the game reaches them) may be lower than that of the unaffected individuals due to the chewed shoots. The differences in individual clones were presumably not due to differences in susceptibility but to random feeding by the game.

3.4 Biotic damages – fungal diseases

In contrast to insect damage, pest susceptibility of the different cultivars and clones is not typical, but a clear difference in pathogen susceptibility did emerge. There are many examples of this, especially in the case of hybrid poplars, where there are significant differences in susceptibility to fungal diseases between the various cultivars (Tóth, 2006).

Our clone trials detected two pathogens: *Phomopsis petiolorum* in the Napkor and Nyírbogdány plantations and *Phloeospora robiniae* exclusively in the Napkor plantation.

Concerning the infection intensity of *Phloeospora robiniae*, clone PL040 showed a higher value than the other clones, and the difference was detectable in all three planting spacings, indicating that clone PL040 is more susceptible to *Phloeospora robiniae* infection. Another important finding is that higher planting spacing density (2.5×2.5 m) showed higher infestation rates. The probable reason for this is that the microclimatic conditions in the denser stand were more favorable for the pathogen. In addition, PL251 and NK1 clones were practically uninfected or only insignificantly infected (*Figure 6*).

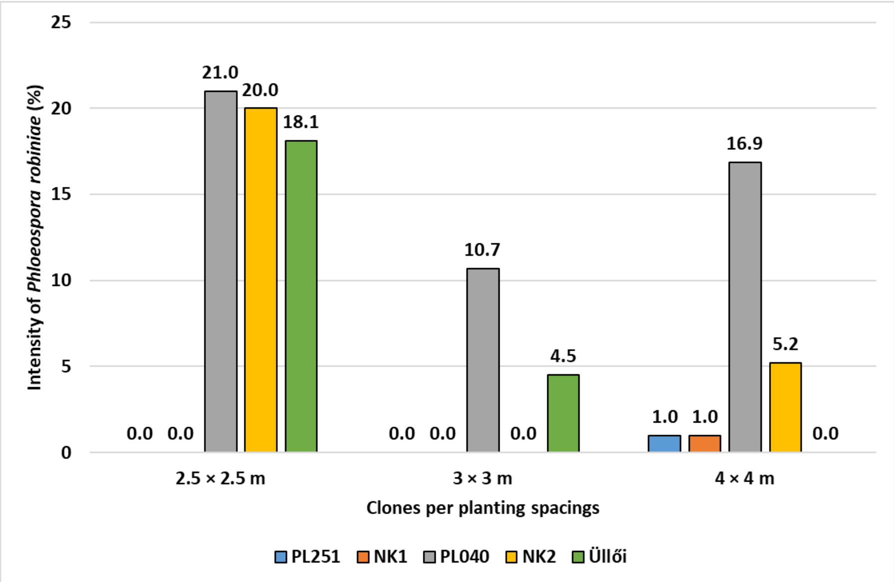

Figure 6. Intensity of Phloeospora robiniae fungal disease on the studied clones (n = 30) in 3 different planting spacings (Napkor, 12/09/2022)

The recording data indicates that the NK2 clone displays high susceptibility to *Phomopsis petiolorum* infection in all three planting spacings in Napkor. A moderate or high (30–50 % of the studied trees had the pathogen) infection. Also, the NK2 clone was highly susceptible to the mentioned disease in the experimental plantation in Nyírbogdány. Infestation also varied between planting spacings, with a relatively low infection rate of 13.3 % in the 2.5×2.5 m, 46.7 % in the 3×3 m, and 80 % in 4×4 m, which is very high. In addition, we observed *Phomopsis petiolorum* symptoms on sample trees of clone PL251 at a slightly lower rate and with increasing intensity in the wider planting spacings. The other clones displayed no such lesions (*Figure 7*).

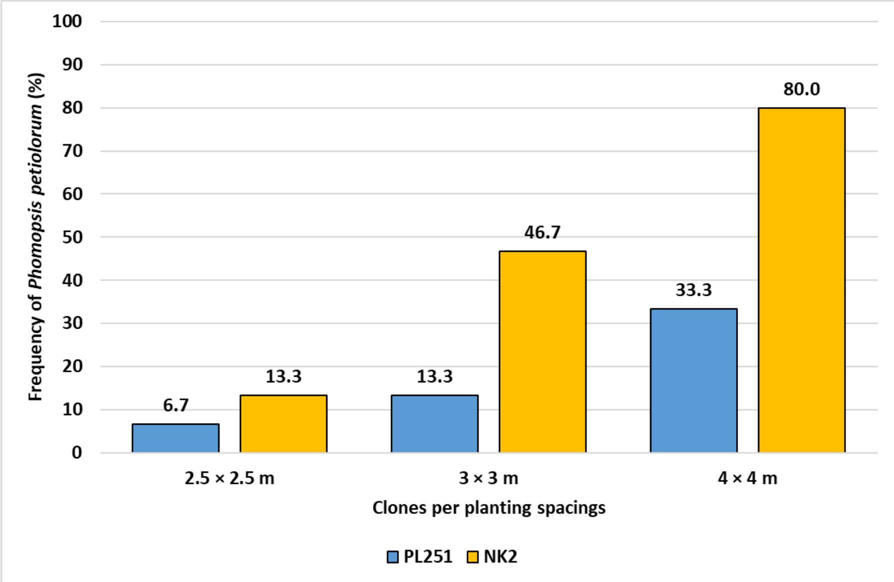

Figure 7. Frequency of Phomopsis petiolorum fungal disease on the studied clones (n = 30) in 3 different planting spacings (Nyírbogdány, 22/08/2023)

The high pathogen incidence was likely due to cultivation errors in the experimental plantations at Napkor and Nyírbogdány. Damage caused by inappropriately selected cultivators during interrow cultivation and late pruning creates favorable conditions for *Phomopsis petiolorum*, a wound parasite (Tóth, 2002). The above is confirmed by the fact that no signs of fungal disease were found in the two-year-old black locust plantation in Debrecen, where no pruning or late pruning had been done. However, care should be taken when growing the Napkori (NK2) and Püspökladányi cultivars (PL251).

3.5 Crown breaking

The crown break results of the current study are discussed separately. Major storms hit the Napkor experimental plantation in 2022, resulting in frequent crown breakage, especially in the more intensively pruned stands. Examining crown breaks by planting spacings detected no significant differences in the 2.5×2.5 m and 3×3 m, while a higher proportion occurred in the widest (4×4 m), obviously due to the freer stance. The data per clone reveals that the NK1 clone had a much higher rate of crown break than the other clones (33.3 % in planting spacings 2.5×2.5 m; 46.7 % in 3×3 m and 66.7 % in 4×4 m), which may be related to crown structure or tissue structure and strength indices. Studying the mechanical properties of the clone more closely from this point of view would be worthwhile (*Figure 8*).

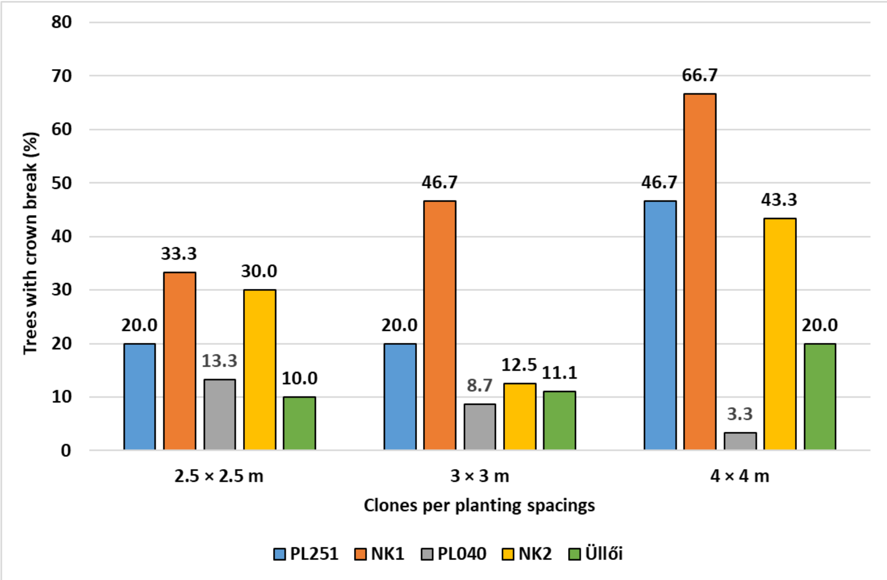

Figure 8. Trees with crown breaks per clone (n = 30) in three different planting spacings (Napkor, 12/09/2022)

In addition to the above, it would be worthwhile to establish different pruning experiments. Leaving the top third part of the trees intact is preferable to vigorous pruning.

3.6 Summary of the results

Based on Koltay (2009), we summarized the results of the plant health surveys of the three clone trials (Napkor, Nyírbogdány, and Debrecen) in *Table 1*.

Table 1. Results summary of the plant health test on the studied clones

Napkor									
Planting spacings	Clones	Defoliation	Abiotic defoliation	*Parectopa robiniella*	*Macrosaccus robiniella*	Obolodiplosis robiniae	*Phloeospora robiniae.*	*Phomopsis petiolorum*	Crown break
2.5×2.5 m	PL251								*
	NK1								**
	PL040		*				*		*
	NK2		*				*	**	**
	Control		*				*		
3.0×3.0 m	PL251								*
	NK1								**
	PL040	*	*				*		
	NK2	*						**	*
	Control	*	*						*
4.0×4.0 m	PL251		*						**
	NK1								***
	PL040	*	*				*		
	NK2		*					**	**
	Control		*						*

Nyírbogdány									
Planting spacings	Clones	Defoliation	*Abiotic defoliation*	*Parectopa robiniella*	*Macrosaccus robiniella*	*Obolodiplosis robiniae*	*Sitona* spp.	*Phomopsis petiolorum*	Crown break
2.5×2.5 m	PL251								
	PL035								
	PL040								
	NK2							*	
	Control								
3.0×3.0 m	PL251							*	
	PL035	*	*						
	PL040								
	NK2							**	
	Control								
4.0×4.0 m	PL251							**	
	PL035								
	PL040								
	NK2							***	
	Control								

Debrecen									
Planting spacings	Clones	Defoliation	Abiotic defoliation	*Parectopa robiniella*	*Macrosaccus robiniella*	*Obolodiplosis robiniae*	*Phloeospora robiniae.*	*Phomopsis petiolorum*	Crown break
2.5×1.5 m	PL251	*	*						
	PL035	*	*						
	PL040	*							
	NK1	*							
	NK2								
	Control	*	*						

The controls are Üllői (Napkor), Ópályi (Nyírbogdány), and common black locust (Debrecen). *The * means the effect of the factors on the clone: * - weak (11–25 %); ** - medium (26–60 %); *** - strong (61 % <).*

Black locust was once a relatively healthy tree species but exhibits a clear downward leaf loss trend. According to the latest forest protection report (NLC 2023), only about a quarter of all Hungarian black locust trees were asymptomatic. Furthermore, several species-specific pests have appeared and spread in recent decades. *Parectopa robiniella* and *Obolodiplosis robiniae* should be made a priority species for controlling invasions of Robinia-specialist insects in Europe and Hungary (Zhang et al., 2024).

We concentrated on these pests and forest protection because the black locust is among the most commonly planted tree species in Hungary (covering approximately 23 % of the forested area).

Although the clones possess good drought tolerance, the NDVI measurement results reveal differences in this parameter. Minimal NDVI variation may highlight subtle genetic differences in traits such as water-use efficiency, photosynthetic activity, and adaptation to site conditions. In the context of tree health, NDVI values help indicate the general vitality of trees. High NDVI (0,7<) generally suggests healthy, dense foliage with active photosynthesis, while lower values (<0,6) can signify stress due to factors like drought, disease, pest infestation, or nutrient deficiencies. NDVI works well at sites where vegetation species are homogeneous (Maselli, 2004; Xiao and McPherson, 2005; Bahe et al., 2021).

4 CONCLUSIONS

The health status of the candidate cultivars under examination is essential for the variety certification procedure. Our study estimated and assessed the average defoliation and the extent and causes of damage to the canopy, branches, and trunk of five newly selected black locust candidate varieties. NDVI measurement is a useful supportive tool for assessing the general vitality of trees. In terms of pests and diseases, our results indicate that candidate cultivar Napkori (NK2) is susceptible to the fungal disease *Phomopsis petiolorum*, which we detected in two of the three black locust clone trials (Napkor and Nyírbogdány). Since no pruning had been done in the Debrecen experiment before our study, we assume that this is why we did not encounter diseased individuals here. Furthermore, late pruning in the Napkor and Nyírbogdány plantations also played a key role in the emergence of the disease. Even though we found *O. robiniae* damage, considered a dangerous invasive pest since the mid-2000s, in two experimental plantations (Nyírbogdány and Debrecen), the extent of the damage and other insect damage was negligible.

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Contents and Abstracts of the Bulletin of Forest Science

Bulletin of Forest Science (Erdészettudományi Közlemények) is a journal supported by the Forest Research Institute of the Faculty of Forestry of the University of Sopron. The papers are in Hungarian, with English summaries. The recent issue (Vol. 13, 2023) contains the following papers. The full papers can be found and downloaded in *pdf* format from the journal's webpage (www.erdtudkoz.hu).

Vol. 13, Nr. 1, 2023

Abstract – Numerous recent studies report an alarming decrease in diversity, biomass, or abundance of arthropods in various habitats. Given that they are important food for other organisms, the ecological consequences of such a decline could be severe. We used data from the Hungarian Forestry Light Trap Network to examine whether the spring caterpillar biomass showed any long term (23-58 years) declining trend in oak-dominated forests. Light trap data for 43 selected macrolepidopteran species (suitable bird food in the larval stage) from six different locations were used for the estimation of the total available caterpillar biomass. Time series analyses showed strong year-toyear fluctuations, and over all locations and time windows there was an increasing rather than decreasing trend. The increase found at some locations may suggest increasing herbivore pressure and negative impacts on forest health. We conclude that foliage-feeding macrolepidopteran species with spring-developing larvae did not show a drastic decrease in recent decades. The estimated biomass increase of the caterpillars of some species may have a negative effect on forest health, but a positive effect on the nesting success of birds. This article is based on the original publication by Eötvös et al. 2021 (No Long-Term Decrease in Caterpillar Availability for Invertivorous Birds in Deciduous Forests in Hungary).
https://dx.doi.org/10.17164/EK.2023.01

Abstract – Mycorrhiza is a symbiosis between the roots of plants and fungi, in which mutual nutrient transfer occurs. In forestry aspect, ectomycorrhiza is the most significant of its seven types of mycorrhiza, because the most of forest trees live in such root connections. In our work we review the Hungarian literature of mycorrhizal research of forest importance from the 19th century to the present. Several researchers have been examined the artificial grafting of fungi on trees and have positive results in almost all cases. Overall, artificial mycorrhization can greatly help the nutrient uptake and so the resistance and growth of trees. However, due to demand the high precision, professional and expensive work, it has not yet

become widespread in Hungary despite the good results. Due to the effects of climate change, forest mycorrhization may be important in the future, currently it is used only in truffle cultivation. In the future, mycorrhization may have a importance in the fight against climate change and in order to create more resistance forests.
https://dx.doi.org/10.17164/EK.2023.02

Fanni FODOR and Tamás MERTL:

The current state and potential of the common hornbeam (*Carpinus betulus* L.) in forestry and in wood industry …35–53

Abstract – – In present paper, an overview of common hornbeam was provided, which is a native wood species with many favorable characteristics and significant logging opportunities, however it is less utilized in the wood industry. Although its wood is not durable in natural form, it is one of the densest, hardest and most wear-resistant wood species in Europe. Due to its unfavorable properties, it is mostly used as firewood. Its areas of use indoors can be expanded with new utensils, interior panelling, and decorative elements. In addition, with various environmentally-friendly wood modification processes, a more durable and resistant wood material can be obtained, the color of which can be adjusted to the user's needs by varying the process parameters. This material can be used for outdoor wood products, but also for architectural applications. Hornbeam is stably available in Hungary in medium-term and can provide opportunity for the production of durable wood products, if there is a manufacturer and effective demand for it within the effective transportation distance. At the end of this article, the findings were summarized with a Strength-Weakness-Opportunity-Threat Analysis.
https://dx.doi.org/10.17164/EK.2023.03

Ferenc SZMORAD and Tibor STANDOVÁR:

Regional analysis of wild game effects on natural regeneration in the Nnorth Hungarian Mountains …55–73

Abstract – This study investigates the relationship between wild ungulates impact and regeneration characteristics in three landscape units of the North Hungarian Mountains (Börzsöny, Mátra, Aggtelek Karst), covering an area of about 50 000 ha. The analyses, based on forest condition surveys of nearly 60 000 points, also cover forest areas not under active management and, in addition to the basic indicators used in forestry practice (cover, browsing), also address the extent of and causes for lack of regeneration. The results show the strong impact of ungulate species in all three landscape units, significantly reducing the viability and amount of regeneration. Heavy browsing was observed in 58.17-76.23% of the samples, while the proportion of samples with less than 1% cover was 46.59-54.23% in the low (0-0.5 m) and 61.31-83.91% in the high (0.5-2.5 m) regeneration. Nonparametric correlation analysis revealed a negative significant relationship between the amount of soil disturbance caused by wild game and regeneration cover. The reduction of wild ungulates impact is essential not only for successful regeneration in age-class forestry, but also for the expansion of continuous cover forestry and the long-term survival of forests not affected by timber production.
https://dx.doi.org/10.17164/EK.2023.04

Vol. 13 Nr. 2

Tamás KOLLÁR:

Forest yield function and table of turkey oak (*Quercus cerris*) stands by the fri's long duration research network database …77–101

Abstract – Yield table of Turkey oak by the Forest Research Institute's long duration research network was publicised in 1974 by Gábor Hajdú, and later in 1983 by Ferenc Kovács. Since then, a great amount of data was accumulated from the University of Sopron – Forest Research Institute's (UOS – FRI) long duration forest yield and silvicultural research network by continuous recordings. From that database new yield functions and yield tables were made in favour of more accurate estimation of Turkey oak yield. 958 digitalised records from 343 parcels were processed, from that great differences were noticed compared to the previous tables. Besides making the traditional yield table, the methods of calculations were given in detail, from which a forest stand's individual growth trends can be calculated. The tables were made assuming a 100% Turkey oak mixture ratio, closure and density.
https://dx.doi.org/10.17164/EK.2023.05

Dániel SÉLLEI, Viktória TÓTH and Dániel WINKLER:

Study on springtail communities of dead wood microhabitats …103–122

Abstract – Our study aimed to investigate the Collembola communities inhabiting dead wood-related microhabitats. The study was carried out in the old remnant floodplain forest (Csáfordi-forest, Northwest Hungary) owing to the massive amount of dead wood in its area. For the survey, we selected 11 microhabitats, including lying dead wood of different stages of decay, dendrotelmata, peeling moss and bark, decaying wood material taken from tree hollows etc. A total of 1309 Collembola individuals belonging to 40 species were collected, three of them (*Anurida granaria*, *Folsomia martynovae*, F. cf. similis) are new to the Hungarian fauna. The most diverse microhabitats were the lying dead trees in a more advanced stadium of decay. The family Entomobryidae represented the largest proportion of species (25%). The number of species varied between 1 and 21 in the microhabitats studied. The communities with higher species numbers were associated with lying dead wood, including dead wood at a more advanced stage of decay. Fewer species were found in the dry wood decay of the tree's base hole, while special microhabitats (detached bark of living trees, dendrotelmata) provided suitable habitats for only one or two species.
https://dx.doi.org/10.17164/EK.2023.06

Dénes HORVÁTH and Sándor FEHÉR:

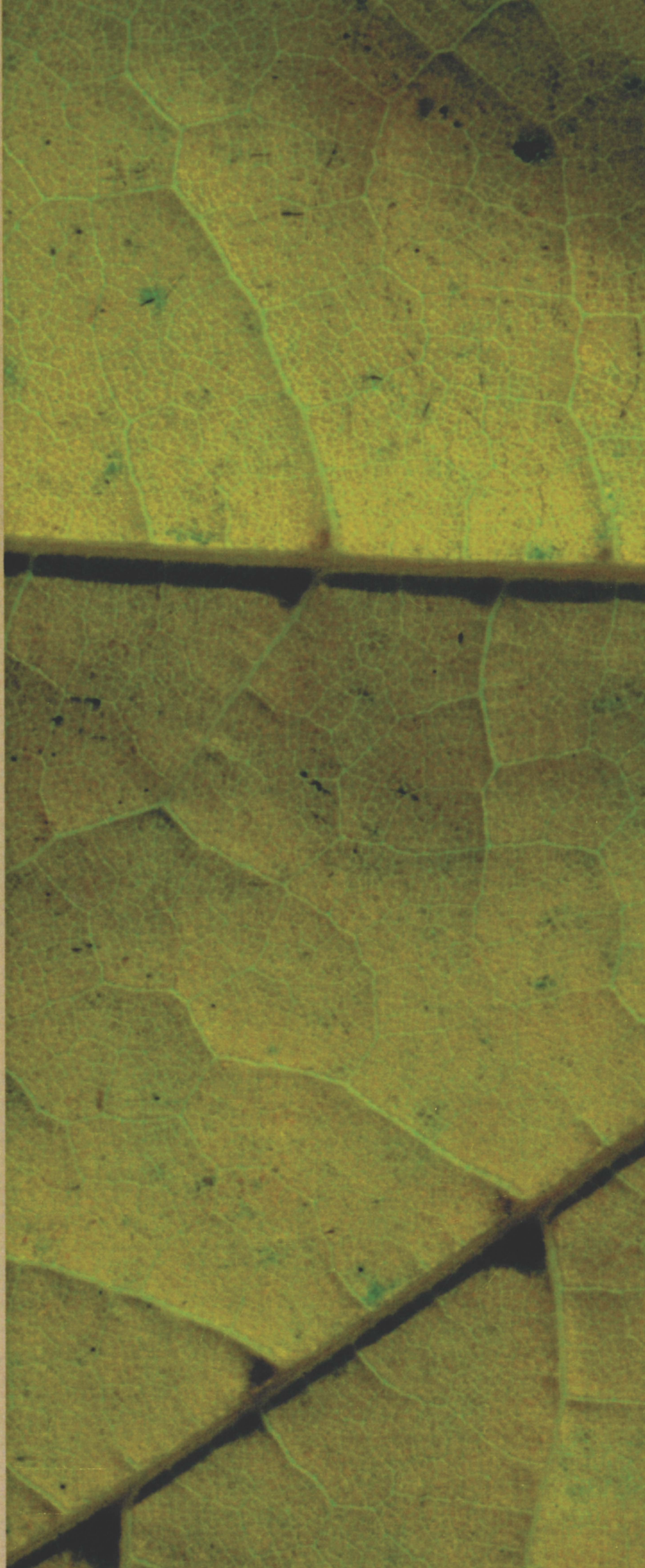
Amount of lamellae derived from low-quality oak logs …123–129

Abstract – The subject of this paper is the quantitative analysis of defect-free lamellae derived from low-quality logs. The noble oak logs included in the study were used to produce boards with a thickness of 30 mm, of which 50 pieces were analysed, representing the typical material quality that can be obtained from low-quality sawlogs. Based on image analysis, 18% of the surface area of these timber could be classified as class 1 lamellae. The remainder of the board surface area either contained some wood defects or the defect-free part was too small for lamella production. While the length of the majority of the lamellae was between 0.25 and 0.50 m, the width of the majority of the lamellae was in the middle category (50 mm). However, there has been little demand for these high quality lamellae on the market for

decades or they would be used for parquet production at very low prices. It would be advisable to find alternative uses for this significant quantity of material in the future, such as glued-laminated structural timber. This would increase the amount of wood used in industrial production and would allow the production of high added value products from a currently unused assortment.
https://dx.doi.org/10.17164/EK.2023.07

Béla Csaba EÖTVÖS, Máté TÓTH, Anikó HIRKA, Ágnes FÜRJES-MIKÓ, Csaba GÁSPÁR, Márton PAULIN, Ferenc LAKATOS and György CSÓKA:

Abstract – The extremely high abundance of the oak lace bug in our oak forests can have significant impacts on the health, productivity, fecundity of oaks and the communities associated with oaks as well. Its long-distance spread is mainly facilitated by road and rail traffic, whereas it can spread shorter distances both actively and passively. Factors influencing its spread may include distance from the source of infestation, the degree of tree mixture or the prevailing wind direction. Specialist herbivores (particularly those searching food plant actively) tend to find their food plants more difficult in mixed forests, so their dispersal is slower and/or limited. Our results show that initially higher infestations occur along roadsides, from where the infestation penetrates into the forest. The mixed forests are not able to slow down significantly the invasion of *C. arcuata*, and the species is able to spread even in the opposite direction to the prevailing wind direction.
https://dx.doi.org/10.17164/EK.2023.08



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