# Biodiversity of linden forests (*Tilia cordata* Mill.) in Western Siberia

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**Abstract.** At the eastern border of small-leaved linden (*Tilia cordata* Mill.) dispersal, in the subzone of small-leaved forests of Western Siberia, 5 main types of linden forests were identified: fern, horsetail, reedgrass, broad-grass, forb-herbs. The taxonomic list of linden vascular plants includes 74 species, from 64 genera and 31 families. Forb-herbs linden forest is characterized by the widest species diversity, while fern forest is characterized by the smallest. The floristic similarity between different types of linden forests ranges from 43.3 to 63.2 %. In the whole floristic complex of linden forests, 35 % is accounted for the nemoral group, which includes associated linden relicts of the tertiary flora of broad-leaved forests. In linden-containing forests, 77 species of xylotrophic fungi from 26 families and 7 orders were observed.

## 1 Introduction

Small-leaved linden (*Tilia cordata* Mill.) is the only representative of broad-leaved tree species naturally growing within the West Siberian Plain. Here lies the eastern boundary of its range, which extends into Western Siberia with a small cline up to the right bank of the lower course of the Irtysh River [1, 2]. Here linden is a relic of the tertiary broad-leaved flora. It is a part of coniferous and deciduous forests, most often as an understory. Pure linden forests are rare, mostly found in the south of the region, within the subzone of indigenous small-leaved forests (hemiboreal zone). Recently, there has been an expansion of the Linden range in the Trans-Ural part of its range. This is likely to be caused by climatic shifts that affect the state and structure of the vegetation cover [3]. Acting as an edificator, linden brings diversity to the vegetation cover of the forest due to the development of the accompanying nemoral element of the flora, as well as contributes to the overall floristic richness and the formation of biodiversity of the studied area as a whole.

The role of linden in the formation of forest biodiversity is also demonstrated in the diversity of xylotrophic basidium fungi which develop on its wood. These fungi are most strongly associated with the presence of linden as a determinant of its trophic consortium.

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This study aims to investigate the biodiversity of vegetation cover and mycobiota of linden forests near the eastern border of their spread.

## 2 Material and methods

Field studies of linden forest floristic diversity were conducted during summer 2020-2021 in the Tyumen and Nizhnetavdinsky districts of the Tyumen Oblast, in the subzone of small-leaved forests (hemiboreal zone) of the West Siberian Plain [4]. Twelve forest areas were studied, where linden forms the upper level of the forest and represents between 70 and 100% of the total number of trees. Based on the dominant composition of the living ground cover, we identified 5 main types of linden forests: I – fern (w/ *Pteridium aquilinum* (L.) Kuhn, *Matteuccia struthiopteris* (L.) Tod.); II – horsetail (w/ *Equisetum sylvaticum* L.; *E. hyemale* L.); III – reedgrass (w/ *Calamagrostis arundinacea* (L.) Roth); IV – broad-leaved (w/ *Aegopodium podagraria* L., *Rubus saxatilis* L. *Lathyrus vernus* (L.) Bernh.); V – forb-herbs (w/ *Vicia cracca* L., *Melica nutans* L., *Maianthemum bifolium* (L.) F.W. Schmidt). Within each type, a 25x25m sample unit (SU) was established for a more detailed study of vegetation biodiversity. All vascular plant species were recorded thoroughly at every SU with an assessment of their quantitative representation (abundance). The abundance of herbaceous plants was estimated through their projective coverage of the sample unit, in %. This information was used to calculate Shannon's species diversity index (H) and Simpson's dominance index (D), which were calculated using the following formulas [5]:

$$H = \Sigma pi * lnpi \qquad (1)$$

$$D = \Sigma\, pi^2 \qquad (2)$$

where: pi – a relative abundance of the i-th species in the community, expressed through its share in the total projective plant coverage of the sample unit.

The floristic similarity of areas was assessed pairwise, in %, using the Sørensen-Czekanowski coefficient (Ks):

$$Ks = 2c/(a + b) * 100 \qquad (3),$$

where: a - number of species in the first SU, b - number of species in the second SU, c - number of species common to the 1st and 2nd SUs.

In addition, the floristic complex species distribution of linden forests by the types of latitudinal range was analyzed.

The composition of xylotrophic fungi in linden forests of the region was studied within the territory of Tyumen, Nizhnetavdinsky, as well as Yarkovsky, Tobolsky, Vikulovsky districts of Tyumen Oblast and Kondinsky district of Khanty-Mansiysk Autonomous District - Yugra. In the course of the study, quantitative mushroom counts were conducted on shuttle routes in 12 forest areas with linden trees. The systematics of fungi is provided by [6].

## 3 Results and discussion

Overall, 74 species of vascular plants belonging to 64 genera and 31 families, including 3 woody, 6 shrubby, 65 herbaceous species, were observed during the study of linden forests.

The dominant families are Asteraceae, Poaceae, Rosaceae, Fabaceae, Ranunculaceae and Apiaceae; together they account for more than 45% of the total floristic list.

The highest indicators of taxonomic richness and species diversity (H) were observed in forb-herbs linden forest (SU-5) (Table 1). It is characterized by the most uniform quantitative distribution of species in the community, as indicated by a low dominance index (D). The lowest diversity and the highest dominance index were observed in the fern linden forest (SU-1). Here *Pteridium aquilinum* grows densely, suppressing the development of other plant species.

**Table 1.** Taxonomic richness and species diversity of vascular plants of forest live cover at SU

| SU No. | Linden forest type | The number of taxa | | | H | D |
|---|---|---|---|---|---|---|
| | | species | genera | families | | |
| SU-1 | Fern | 16 | 16 | 13 | 1.29 | 0.31 |
| SU-2 | Horsetail | 27 | 23 | 16 | 1.93 | 0.21 |
| SU-3 | Reedgrass | 23 | 22 | 17 | 1.77 | 0.26 |
| SU-4 | Broad-herbs | 24 | 18 | 16 | 2.16 | 0.16 |
| SU-5 | Forb-herbs | 33 | 26 | 16 | 2.57 | 0.10 |

Note: Indexes: H - Shannon's species diversity index, D - Simpson's dominance index.

The floristic composition of communities of the different linden forest types is quite specific. Only 9 species were observed across all areas. The floristic similarity coefficients (Ks) between SUs fall within the average values (Table 2). The highest floristic similarity is observed in broad-herbs and forb-herbs linden forests. They share 18 species in common. The least similar are broad-herbs and horsetail linden forests (13 species in common).

**Table 2.** Floristic similarity matrix of SUs based on the Sørensen-Czekanowski coefficient (Ks), %.

| | SU-1 | SU-2 | SU-3 | SU-4 | SU-5 |
|---|---|---|---|---|---|
| SU-1 | - | 46.5 | 51.3 | 55.0 | 44.9 |
| SU-2 | | - | 60.0 | 51.0 | 43.3 |
| SU-3 | | | - | 59.6 | 50.0 |
| SU-4 | | | | - | 63.2 |

The analysis of linden forests' floristic complex distribution by latitudinal range types showed that zonal vegetation of the boreal group dominates in the studied area. However, the share of the nemoral element that has a genetic association with broadleaved forests is also very significant (fig.1). The nemoral plant group includes relicts of the tertiary flora of broadleaved forests, concomitant with linden: *Daphne mezereum* L., *Viola mirabilis* L., *Galium triflorum* Michx., *Actaea spicata* L., *Dryopteris filix-mas* (L.) Schott. The last two species, like the linden itself, are listed in the Red Data Book of the Tyumen Oblast under the "rare" status [7].

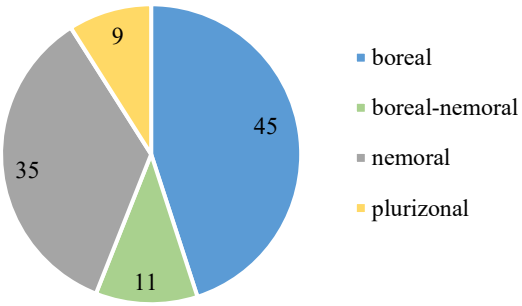


**Fig. 1**. Distribution of floristic complex species of linden trees by latitudinal range types, %.

The relatively small share of plurizonal species can be explained by insignificant anthropogenic impact on linden forests due to their remoteness from populated areas. This group is usually dominated by synanthropic plant species characterized by high ecological plasticity.

In the course of research and literature analysis [8, 9], 77 species of xylotrophic fungi belonging to 26 families of 7 orders were observed in the West Siberian linden range. The order Polyporales is absolutely dominant (43 species of 9 families), represented by specific forms of polypores that have undergone the longest coevolution with woody plants. It includes a fungus that is commonly found on the linden *Bjerkandera adusta* (Willd.) P. Karst. (fam. Phanerochaetaceae), which destroys mechanically damaged trunks, less common are fungi of the genus *Trametes* (Polyporaceae). Fomes fomentarius (L.) Fr. (Polyporaceae) and *Fomitopsis pinicola* (Sw.) P. Karst. (Fomitopsidaceae)., the distinctive wood destroyers of large trunks are also less common than on other deciduous trees. The second in taxonomic diversity on linden is the order Agaricales (15 species, 8 families), whose species have mainly retained the form of ground pileate fungus. These include the most common fungi found on linden, *Schizophyllum commune* Fr. (fam. Schizophyllaceae); *Pleurotus pulmonarius* (Fr.) Quél. (Pleurotaceae). The hollows of old linden trees are more likely to grow *Flammulina velutipes* (Curtis) Singer (Physalacriaceae) and *Pholiota aurivella* (Batsch) P. Kumm. (Batsch) P. Kumm. (Strophariaceae), that cause heart rot of growing trunks and persist as deadwood destroyers. The orders Russulales and Hymenochaetales (7 species, 3 families each) are next in taxonomic diversity. Representatives of the order Russulales of the genus *Penoiphora – P. cinerea* (Pers.) Cooke et al. (Peniophoraceae) are common on thin branches and bark of linden trees. Species of the order Hymenochaetales are rarely found on linden. Among them are common pathogens of stem rots in growing trees.

In Western Siberia, some rare species of fungi have also been recorded on linden trees. For example, the only find in the region of the species *Hyphoderma cremeoalbum* (Höhn. & Litsch.) Jülich (Polyporales, Hyphodermataceae) [10] was made on a linden tree. On the grounds of the national park "Pripyshminskiye Bory" a rather rare polypore *Pappia fissilis* (Berk. & M.A. Curtis) Zmitr. was found throughout the area. Curtis) Zmitr. Two species observed on linden are listed as rare in the Red Data Book of the Tyumen Oblast (2020): *Sarcodontia spumea* (Sowerby) Spirin (Polyporales, Meruliaceae) and *Ganoderma lucidum* (Curtis) P. Karst. (Polyporales, Polyporacea). While the first species can be categorized as nemoral, the second is a multiregional ubiquitously rare fungus.

The majority of fungi found on linden in Western Siberia are widespread in the region (especially in its southern part) and are found on other deciduous trees and shrubs. There are no species for which linden is a substrate preferendum or a formational endemic, which

was noted by V.A. Mukhin [9]. If we compare the species diversity of fungi on linden based on the data of this author, it (55 species) is less than in any other forest-forming species except larch. A similar situation has been observed in Finland [10], in the south of the European part of Russia and Russia's Far East [11], where linden trees, unlike in Western Siberia, grow in their native range.

The relatively poor composition of xylotrophic fungi typical of linden is combined with their low abundance revealed by route census. This is attributed to the rarity of the fungi fruit body formation on the rotting wood of linden trees. At the same time, the overall species diversity and abundance of xylotrophic fungi in forest stands containing linden trees are usually significantly higher than in forest stands without linden trees. Thus, at the northeastern limit of linden spread in Khanty-Mansiysk Autonomous District - Yugra, even the presence of linden in the undergrowth is associated with an increase in the total index of species diversity of xylotrophic fungi up to maximum values for the region (the average Shannon diversity index (H) for the southern boreal subzone of the region is 3.57) (Table 3).

**Table 3.** The indicators of species diversity of xylotrophic fungi in forests with and without linden trees (Kondinsky district of Khanty-Mansiysk Autonomous District - Yugra, southern boreal subzone)

| Forest stand composition | Forest type | Number of species | H |
|---|---|---|---|
| 4S3F2B1A+L,C,P | gr-gm | 33 | 4.08 |
| 3B3A2P2S+F,L | gm-gr-be | 27 | 4.06 |
| 3P3S2A2B+F,C | gm | 25 | 3.71 |
| 6A3B1S | gr-gm | 20 | 3.24 |

Note: S - spruce, F - fir, B - birch, A - aspen, L - linden, C - cedar, P - pine. Species ratio in the forest stand in total = 10; "+" indicates that the proportion of species is less than 1. Forest type: gm - green moss forest, gr - grass forest, be - berry forest; H - Shannon's species diversity index.

For the subzone of small-leaved forests (hemiboreal zone), the average value of the H index = 3.31 (20 species per 100 mushroom-occupied trunks on average). But for forests containing linden trees, the H index is usually higher, and in a forb-herbs forest with 4B3P2A1L the H index reaches the maximum value of 4.26 (27 mushroom species).

## 4 Conclusions

At the eastern borders of its range in Western Siberia, the small-leaved linden forms forests of different types, which differ from each other in taxonomic composition and species diversity. In the whole floristic complex of linden forests, the species of zonal boreal flora dominate. However, at the same time, the share of nemoral element, which includes endemics of tertiary broad-leaved forests, is rather high. The composition of xylotrophic fungi growing on linden trees does not demonstrate its significant role as a determinant of the species diversity of mycobiota and the distribution of nemoral species. It characterizes linden as an indicator of high species diversity in its vegetation area.

## Acknowledgements

The research was carried within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (theme No. FWRZ-2021-0006).

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