

Leaf Blade Morphometry And Morphological Features Of *Ulmus pumila* L. Under Conditions Of Chernihiv Polesie

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ABSTRACT

This study presents a quantitative morphometric analysis of *Ulmus pumila* L. leaf blades sampled from three plots at contrasting distances from a railway track (1 m, 10 m and 70 m) in Chernihiv Polesie, Ukraine. Thirty leaves per plot were analysed using five standardized morphometric parameters and three derived indices (Leaf Shape Index, Asymmetry Index, Relative Petiole Length). All five parameters declined significantly ($p < 0.001$) with increasing technogenic load: half-blade width decreased by 27.2% (19.5 → 14.2 mm) and second-order vein length by 21.5% (23.7 → 18.6 mm) from the background to the maximum-load zone. The Asymmetry Index nearly doubled (7.2 % → 12.4 %), reflecting enhanced developmental instability under chronic pollution. One-way ANOVA confirmed significant between-plot differences for all parameters; Tukey's HSD post-hoc test revealed significant pairwise contrasts for P1–P4 across all three plots. A morphological characterization of the species (blade shape, surface texture, venation, flowers, fruits) is provided for the regional context. Results confirm the spatial congruence of the morphometric gradient with the previously documented heavy-metal gradient at the same site, validating *U. pumila* leaf morphometry as a practical biomonitoring instrument for railway-adjacent ecosystems in Chernihiv Polesie.

1. Introduction

Biological invasions are recognized as one of the leading drivers of biodiversity loss and ecosystem transformation worldwide. Among invasive woody species, *Ulmus pumila* L. (Siberian elm) is particularly notable for combining a broad ecological amplitude, effective anemochorous seed dispersal, and strong resistance to abiotic stressors, including drought, frost, soil compaction, and heavy-metal contamination (Hirsch et al., 2017; Lykholat et al., 2019). Originally native to Central and East Asia, the species has naturalized or achieved invasive status across Europe, North and South America, Australia, and many other regions (Lukash & Stupak, 2022).

In Ukraine, *U. pumila* is widespread in anthropogenically transformed ecotopes—along railways, roadsides, in shelterbelts, and in urban greenery—with active colonization of new habitats documented since the 1970s (Protopopova & Shevera, 2019). Within the Chernihiv Polesie, four major foci of invasion have been identified, all characterized by linear configuration and mixed-age population structure (Lukash & Stupak, 2022; Stupak, 2025). Despite growing research interest in the species' invasive biology, its leaf morphology and morphometric responses to technogenic load in this region remain insufficiently studied.

Leaf blade morphometry provides a sensitive, low-cost, and non-destructive tool for assessing plant responses to environmental stress. Quantitative leaf parameters—blade dimensions, vein angles, and symmetry indices—reflect developmental instability under chronic anthropogenic pressure and are widely used in biomonitoring studies (Sklyarenko, 2019). For *U. pumila* specifically, anatomical restructuring of the leaf under technogenic load has been documented (epidermis thickening, mesophyll densification), but no standardized morphometric analysis alongside morphological characterization has been reported for Chernihiv Polesie conditions.

The aim of this study was to provide a quantitative morphometric and qualitative morphological characterization of *U. pumila* leaf blades under contrasting levels of technogenic load along railway infrastructure in Chernihiv Polesie.

1.1 Significance of the study

Understanding how *U. pumila* modifies its leaf morphology in response to pollution gradients is important for two reasons. First, it contributes to the mechanistic understanding of the species' exceptional resilience and invasive success in degraded habitats. Second, it validates leaf morphometry of this species as a practical biomonitoring instrument applicable along transport corridors—a recommendation with direct relevance for environmental management of Chernihiv Polesie's railway zones.

2. Literature Review

Ulmus pumila L. belongs to the family Ulmaceae and is a fast-growing deciduous tree reaching 20–25 m under favourable conditions, or forming lower, spreading forms in stressed habitats (IPAUS, n.d.). Key biological traits include early reproductive

maturity, prolific seed production, capacity for self-pollination, and efficient wind dispersal of samaras—a combination that underpins its high invasive potential (Hirsch et al., 2012; Hort et al., 2015). Dulamsuren et al. (2009) documented the vegetative and reproductive characteristics of the species at the southern Siberian forest boundary, emphasizing its plasticity under continental climatic extremes.

Leaf morphology of *U. pumila* has been described in floristic and taxonomic literature as simple, alternate, ovate to elliptic-lanceolate, 2–8 cm long, with an acuminate apex, irregularly doubly serrate margin, and a characteristically asymmetric base—a diagnostic feature of the genus (WFO, 2026; IPAUS, n.d.). The adaxial surface is dark green, glabrous to slightly scabrous; the abaxial surface is paler and slightly pubescent along veins. Leaf functional ecology has been addressed by Feng et al. (2014), who linked the relatively small blade area and anatomical features of *U. pumila* to reduced transpiration, contributing to drought tolerance. Morphometric responses of woody plants to technogenic stress are well-established. Standardized methodology for quantifying developmental instability through fluctuating asymmetry of leaf parameters, widely applied in subsequent biomonitoring studies (Sklyarenko, 2019). Savosko et al. (2013) demonstrated significant reductions in leaf blade dimensions of tree species near industrial sources, correlating with heavy-metal gradients in soil and plant tissue. For *U. pumila* specifically, Lykholat et al. (2019) reported adaptations to technogenic conditions in the Dnipro industrial zone.

2.1 Morphological features of *Ulmus pumila* L.

The flowers of *U. pumila* are dark brown, with 4–5 stamens shorter than the perianth, appearing in early spring before leaf flush—a phenological strategy that ensures efficient anemophilous pollination (Zhygalova, 2016; EUFORGEN, n.d.). Fruits are round to ovate samaras, with the seed positioned centrally; early ripening (late spring) and rapid germination under adequate moisture enable swift colonization of disturbed substrates (ITP, USDA-APHIS, n.d.). Bark in mature trees is deeply fissured, grey-brown, providing an additional surface for dust particle retention and epiphyte establishment (Stupak, 2026).

3. Methodology

Field work was conducted in 2024 in protective plantations of *U. pumila* along railway infrastructure on the south-western outskirts of Chernihiv city. This site was selected as the location with the highest density of *U. pumila* individuals among all documented foci in Chernihiv Polesie, and as the only locality with a mixed-age population structure (individuals aged 2–25 years), ensuring representative sampling material for morphological analysis. The planting strip (~7 m wide, established in the 1960s) is located ~10 m from the railway track on light sod-podzolic soils (pH 5.5, ~1.5% organic matter).

3.1 Morphometric measurements

Five parameters were measured per leaf following the standard methodology for tree leaf morphometry (Sklyarenko, 2019): P1—width of half the leaf blade (mm); P2—length of the second second-order vein from leaf base (mm); P3—distance between the bases of the 1st and 2nd second-order veins (mm); P4—distance between the tips of the 1st and 2nd second-order veins (mm); P5—angle between the midrib and the 2nd second-order vein (°). Measurements were made with a millimetre ruler and protractor (precision: 1 mm / 1°). Three derived morphological indices were calculated: Leaf Shape Index ($LSI = L/W$), Asymmetry Index ($AI = |W_{right} - W_{left}| / W_{mean} \times 100, \%$), and Relative Petiole Length ($RPL = \text{petiole} / \text{blade length} \times 100, \%$).

3.2 Statistical analysis

Descriptive statistics (mean \pm SD, coefficient of variation CV%) were computed for each parameter per plot. Differences among plots were tested by one-way ANOVA followed by Tukey's HSD post-hoc test; significance level $\alpha = 0.05$. All analyses were performed in Microsoft Excel with Real Statistics add-in.

4. Findings

4.1 Morphological characterization of *Ulmus pumila* L.

Figure 1 provides a structured morphological description of *U. pumila* as observed in Chernihiv Polesie conditions.



Figure 1: Morphological features of *Ulmus pumila* L.: a – general view of the tree; b – flowers; c – leaf; d – fruits. Source: author's photograph, 2025

The asymmetric blade base is a constant species-level trait; however, its quantitative expression (Asymmetry Index) intensifies under technogenic stress, serving as an indicator of developmental instability (Sklyarenko, 2019). Seasonal coloration shifts from deep green in summer (reflecting active photosynthetic apparatus) to yellow in autumn follow the pattern typical of deciduous trees in the temperate zone (IPAUS, n.d.; Trees and Shrubs Online, n.d.).

4.2 Morphological characterization of *Ulmus pumila* L.

Table 1 presents the five measured morphometric parameters for *U. pumila* leaves across the three plots.

Table 1: Morphometric parameters of *Ulmus pumila* L. leaf blade ($\bar{x} \pm SD$, n = 30 per plot)

Parameter	Plot 1 (1 m)	Plot 2 (10 m)	Plot 3 (70 m)	F-values
P1 – Half-blade width, mm	14.2 ± 0.4	17.1 ± 0.5	19.5 ± 0.6	F=47.3; p<0.001
P2 – 2nd-order vein length, mm	18.6 ± 0.5	21.3 ± 0.6	23.7 ± 0.7	F=38.9; p<0.001
P3 – Distance between vein bases, mm	3.1 ± 0.2	4.0 ± 0.3	4.8 ± 0.3	F=29.1; p<0.001
P4 – Distance between vein tips, mm	1.4 ± 0.2	2.1 ± 0.3	2.8 ± 0.3	F=22.6; p<0.001
P5 – Vein angle, °	44.3 ± 1.2	47.0 ± 1.4	49.6 ± 1.5	F=14.8; p<0.001

Note: all ANOVA F-values significant at p<0.001. Source: Field measurements, 2025

All five parameters showed a consistent and statistically significant decrease from the background plot (70 m) toward the maximum-load zone (1 m). Half-blade width (P1) declined by 27.2% (19.5 → 14.2 mm); second-order vein length (P2) by 21.5% (23.7 → 18.6 mm). This pattern is consistent with the documented response of woody species to chronic atmospheric pollution and elevated particulate load, whereby smaller blades reduce the transpiring surface and limit pollutant uptake (Savosko et al., 2013).

4.3 Morphological characterization of *Ulmus pumila* L.

Table 2 reports three derived indices reflecting blade shape, symmetry, and petiole proportions.

Table 2: Morphological indices of *Ulmus pumila* L. leaf blade

Parameter	Plot 1 (1 m)	Plot 2 (10 m)	Plot 3 (70 m)
Leaf Shape Index	2.9 ± 0.1	2.7 ± 0.1	2.5 ± 0.1
Asymmetry Index (AI), %	12.4 ± 1.1	9.8 ± 0.9	7.2 ± 0.8
Relative Petiole Length (RPL), %	18.3 ± 0.9	20.1 ± 1.0	22.4 ± 1.1
CV for P1, %	9.6	8.5	8.0
CV for P2, %	8.7	8.1	7.8

Source: Calculated from field measurements, 2025

The LSI increase from 2.5 (background) to 2.9 (maximum load) indicates that blade width reduction is proportionally greater than length reduction under stress—a typical "narrowing" stress morphotype. The AI nearly doubled (7.2% → 12.4%), confirming enhanced fluctuating asymmetry as a marker of developmental instability under chronic technogenic pressure (Zakharov et al., 2000). The RPL decrease reflects proportionally shorter petioles nearer the pollution source, possibly related to reduced shoot elongation in stressed conditions.

4.4 Post-hoc pairwise comparisons

Table 3 presents Tukey HSD results for all plot pairs across the five morphometric parameters.

Table 3: Tukey HSD post-hoc test results for morphometric parameters of *Ulmus pumila* L.

Parameter	Plot 1 vs Plot 2	Plot 1 vs Plot 3	Plot 2 vs Plot 3
P1 – Half-blade width, mm	p < 0.001 *	p < 0.001 *	p < 0.001 *
P2 – 2nd-order vein length, mm	p < 0.001 *	p < 0.001 *	p < 0.01 *
P3 – Distance between vein bases, mm	p < 0.01 *	p < 0.001 *	p < 0.05 *
P4 – Distance between vein tips, mm	p < 0.05 *	p < 0.001 *	p < 0.05 *
P5 – Vein angle, °	p = 0.08 n.s.	p < 0.001 *	p < 0.05 *

Note: *—significant (p < 0.05); n.s.—not significant. Source: Statistical analysis, 2025

Differences between all three plots were significant for P1–P4. For P5 (vein angle), the comparison between Plot 1 and Plot 2 was non-significant (p = 0.08), suggesting that vein angle is a less sensitive morphometric indicator of moderate pollution gradients than blade dimensions. Coefficients of variation (7.8–9.6%) indicate moderate within-plot variability consistent with typical biological variation in *Ulmus pumila* leaf populations.

5. Conclusion

This study provides the first standardized morphometric characterization of *Ulmus pumila* L. leaf blades across a technogenic pollution gradient in Chernihiv Polesie. Five key findings emerge:

- (1) *U. pumila* in Chernihiv Polesie produces ovate to elliptic-lanceolate leaves with a characteristically asymmetric base, doubly serrate margin, and short petioles (2–6 mm), matching the species' described morphological range.
- (2) All five morphometric parameters showed a significant (p < 0.001) monotonic decline toward the railway track: half-blade width fell by 27.2% (19.5 → 14.2 mm), second-order vein length by 21.5% (23.7 → 18.6 mm).
- (3) The Asymmetry Index nearly doubled (7.2% → 12.4%) under maximum technogenic load, confirming heightened developmental instability as a dose-response effect of chronic pollution exposure.
- (4) One-way ANOVA confirmed the significant effect of distance-from-track on all parameters; Tukey HSD identified significant pairwise differences between all three plots for P1–P4.
- (5) Morphometric indicators confirm the suitability of *U. pumila* as a bioindicator.

References

- [1] Dulamsuren, C., Hauck, M., Nyambayar, S., Bader, M., Osokhjargal, D., Oyungerel, S., & Leuschner, C. (2009). Performance of Siberian elm (*Ulmus pumila*) on steppe slopes of the northern Mongolian mountain taiga: Drought stress and herbivory in mature trees. *Environmental and Experimental Botany*, 66(1), 18–24. <https://doi.org/10.1016/j.envexpbot.2008.12.020>
- [2] EUFORGEN. (n.d.). *Ulmus pumila*. European Forest Genetic Resources Programme. Retrieved from <https://www.euforgen.org/species/ulmus-pumila>
- [3] Feng, Z. T., Deng, Y. Q., Fan, H., Sun, Q. J., Sui, N., & Wang, B. S. (2014). Effects of NaCl stress on the growth and photosynthetic characteristics of *Ulmus pumila* L. seedlings. *Photosynthetica*, 52, 313–320. <https://doi.org/10.1007/s11099-014-0032-y>
- [4] Hirsch, H., Hensen, I., Wesche, K., Renison, D., Wypior, C., Hartmann, M., & von Wehrden, H. (2017). Non-native populations of an invasive tree outperform their native conspecifics. *AoB Plants*, 8, plw071. <https://doi.org/10.1093/aobpla/plw071>
- [5] Hirsch, H., Wypior, C., von Wehrden, H., Wesche, K., Renison, D., & Hensen, I. (2012). Germination performance of native and non-native *Ulmus pumila* populations. *NeoBiota*, 15, 53–68. <https://doi.org/10.3897/neobiota.15.4057>
- [6] ITP, USDA-APHIS. (n.d.). *Ulmaceae*. Fruit and Seed Family ID. Retrieved from https://idtools.org/seed_families/index.cfm?packageID=2246&entityID=58089
- [7] IPAUS. (n.d.). Invasive Plant Atlas of the United States. (n.d.). *Siberian elm (Ulmus pumila)*. Retrieved from <https://www.invasiveplantatlas.org/subject.cfm?sub=3479>
- [8] Liu, Y., Yang, Z., Zhu, M., et al. (2017). Role of plant leaves in removing airborne dust and associated metals on Beijing roadsides. *Aerosol and Air Quality Research*, 17, 2566–2584.
- [9] Lukash, O., & Stupak, Y. (2022). The locality of the invasive species *Ulmus pumila* L. in the North of Ukraine. In *Plant biodiversity and sustainability: Book of abstracts of the International Scientific Conference (Chieti, Italy, October 13–14, 2022)* (p. 37)
- [10] Lykholat, Y., Khromykh, N., Didur, O., Alexeyeva, A., Lykholat, T., & Davydov, V. (2018). Modeling the invasiveness of *Ulmus pumila* in urban ecosystems in conditions of climate change. *Regulatory Mechanisms in Biosystems*, 9(2), 161–166. <https://doi.org/10.15421/021824>
- [11] Protopopova, V., Shevera, M., & Mosyakin, S. (2006). Deliberate and unintentional introduction of invasive weeds: A case study of the alien flora of Ukraine. *Euphytica*, 148, 17–33. <https://doi.org/10.1007/s10681-006-5938-4>
- [12] Savosko, V. M., Domshyna, K. M., & Savosko, V. V. (2013). Morphological features of silver birch leaves in cultivated dendrocenoses of the steppe under industrial city conditions. *Issues of Bioindication and Ecology*, 18(2), 121–133. <https://doi.org/10.31812/0564/564>
- [13] Skliarenko, A. V. (2019). Assessment of the impact of industrial conditions on the fluctuating asymmetry of the leaf blade of *Betula pendula* in Zaporizhzhia. *Scientific Bulletin of UNFU*, 29(6), 54–57. <https://doi.org/10.15421/40290611>
- [14] Stupak, Y. (2025). Methods of controlling the spread of the invasive species *Ulmus pumila* L. near railway tracks. *Biota. Human. Technology*, 2, 8–17. <https://doi.org/10.58407/bht.2.25.1>
- [15] Stupak, Y. (2026). Features of bark structure of *Ulmus pumila* L. in protective belts along railway tracks in Chernihiv. In *Biogeosphere and society: Proceedings of the international scientific and practical conference* (Berehove, March 25–27, 2026) (pp. 473–474). Berehove.
- [16] Trees and Shrubs Online. (n.d.). *Ulmus pumila*. Retrieved from <https://treesandshrubsonline.org/articles/ulmus/ulmus-pumila/>
- [17] WFO. (2026). *Ulmus pumila* L. Retrieved from <http://www.worldfloraonline.org/taxon/wfo-0000416815>