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BIODIVERSITY ENHANCEMENT IN ORNAMENTAL LANDSCAPES: INTEGRATING NATIVE AND POLLINATOR-FRIENDLY SPECIES FOR SUSTAINABLE URBAN GREENING

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Abstract

Urban green spaces are increasingly recognized not only as aesthetic elements of city infrastructure but as vital components of ecological networks that support biodiversity and deliver essential ecosystem services. However, conventional ornamental landscaping often relies on non-native, low-diversity plantings with limited ecological value, contributing to biotic homogenization and pollinator decline. This study investigates the integration of native and pollinator-friendly plant species into urban ornamental landscapes as a strategy for enhancing functional biodiversity and strengthening ecological resilience. Based on multi-year field trials in Moscow and satellite cities, the research evaluates the performance of 42 native and adapted perennial species—such as Echinacea purpurea, Allium spp., Filipendula ulmaria, Stachys officinalis, and Sanguisorba officinalis—in designed urban plantings. The study assesses their ornamental value, phenological stability, drought tolerance, and attractiveness to pollinating insects, including bees (Apoidea), hoverflies (Syrphidae), and butterflies (Lepidoptera). Results demonstrate that well-designed native-rich plantings increase pollinator abundance by up to 3.8 times and species richness by 2.5 times compared to traditional horticultural schemes. Moreover, native species exhibited higher survival rates under urban stressors (compacted soils, air pollution, irregular watering) and required 30–50% less maintenance.

Keywords: urban biodiversity, native plants, pollinator-friendly landscaping, ornamental horticulture, ecosystem services, sustainable cities, green infrastructure, plant–pollinator interactions

I. Introduction

Urbanization is one of the most significant drivers of global environmental change, with over 56% of the world's population now residing in cities—a figure projected to rise to 60% by 2030 (UN-Habitat, 2022). As natural habitats are replaced by impervious surfaces, urban green spaces have become critical refuges for biodiversity and essential providers of ecosystem services, including air purification, temperature regulation, carbon sequestration, and psychological well-being (Haase et al., 2014; Gaston, 2019). Among these green spaces, ornamental landscapes—parks, roadside plantings, public squares, and private gardens—constitute a major component of urban vegetation. Yet, despite their extensive coverage, they are often ecologically impoverished, dominated by non-native, highly cultivated species selected primarily for aesthetic appeal rather than ecological function.

This conventional approach to ornamental landscaping has contributed to biotic homogenization—the process by which urban floras become increasingly similar across regions—and has played a role in the alarming decline of pollinator populations worldwide (Aronson et al., 2017; IPBES, 2016). Pollinators, particularly bees, hoverflies, and butterflies, are indispensable for both natural ecosystems and agricultural productivity, yet they face mounting pressures from habitat loss, pesticide exposure, and climate change. In cities, where floral resources can be scarce and fragmented, the design of green spaces directly influences pollinator survival and community composition.

In recent years, a paradigm shift has emerged in urban horticulture: from viewing green spaces as purely decorative to recognizing their potential as functional ecological infrastructure. This shift is embodied in the concept of ecological landscaping—the intentional use of plant species and community structures that support biodiversity, enhance ecosystem resilience, and provide multiple benefits to urban dwellers (Nassauer, 2021). Central to this approach is the integration of native plant species and pollinator-friendly perennials into ornamental designs. Native plants, co-evolved with local fauna, offer superior resources for indigenous pollinators, including nectar, pollen, and nesting sites (Baldwin et al., 2019). Moreover, they are typically better adapted to local edaphic and climatic conditions, requiring fewer inputs and demonstrating greater resilience under urban stressors.

Despite growing evidence of their benefits, native and pollinator-supportive species remain underutilized in mainstream urban landscaping, particularly in Northern European and post-Soviet cities, where horticultural traditions favor formal, non-native plantings. Municipal regulations, limited availability of planting material, and public perceptions of "wild" aesthetics as untidy further hinder adoption.

This study addresses these challenges by evaluating the ecological and ornamental performance of native and pollinator-friendly plant species in urban ornamental landscapes in the temperate zone, with a focus on the Moscow region. It aims to bridge the gap between ecological science and landscape practice by demonstrating that aesthetic appeal and biodiversity enhancement are not mutually exclusive, but can be synergistically combined. By quantifying the functional role of selected species in supporting pollinator communities and improving ecosystem resilience, this research provides evidence-based guidance for transforming ornamental horticulture into a powerful tool for urban biodiversity conservation.

The findings contribute to the global discourse on sustainable cities and align with international frameworks such as the UN Decade on Ecosystem Restoration (2021–2030) and the EU Biodiversity Strategy for 2030. They offer practical solutions for landscape architects, municipal planners, and policymakers seeking to create green spaces that are not only beautiful but biologically vibrant and ecologically sustainable.

II. Methods

This study employed an integrated field-experimental and observational approach to evaluate the ecological and ornamental performance of native and pollinator-friendly plant species in urban ornamental landscapes. Research was conducted from 2021 to 2023 in the Moscow region (55°45′N, 37°37′E), within the temperate continental climatic zone, characterized by cold winters, warm summers, and average annual precipitation of 600–700 mm.

1. Experimental Design and Plant Material

Twelve experimental plots (each 4 m × 5 m) were established in three urban green zones with varying levels of anthropogenic pressure:

- Botanical Garden of the Russian State Agrarian University (low anthropogenic load)
- Urban Park "Sokolniki" (moderate load)
- Roadside green belt along Leningradskoye Highway (high load)

Each plot was planted with polycultures of 42 native and adapted perennial species selected for their ornamental value, phenological diversity, and documented attractiveness to pollinators. Key species included *Echinacea purpurea*, *Allium giganteum*, *Filipendula ulmaria*, *Stachys officinalis*, *Sanguisorba officinalis*, *Anthriscus sylvestris*, *Campanula latifolia*, and *Melittis melissophyllum*. For comparison, control plots (n = 6) were planted with conventional ornamental mixtures of non-native species such as *Tagetes patula*, *Pelargonium × hortorum*, and *Lobelia erinus*.

All plantings followed a randomized block design with three replications per site. Soil preparation included light tilling and organic amendment (compost, 10 t/ha). No synthetic pesticides were applied; irrigation was limited to establishment phase (first 4 weeks), simulating low-input urban maintenance conditions.

2. Ornamental Quality Assessment

Ornamental performance was evaluated monthly during the growing season (May–September) using a modified version of the Royal Horticultural Society (RHS) Award of Garden Merit (AGM) criteria, adapted for urban conditions. Parameters included:

- Duration and intensity of flowering (0–5 scale);
- Foliage quality and structural stability (0–5);
- Disease and pest resistance (0–5);
- Overall aesthetic impact (0–10).

Assessments were conducted by a panel of five landscape horticulture experts blinded to treatment types.

3. Pollinator Monitoring

Pollinator visitation was recorded via standardized 10-minute visual transect surveys conducted weekly between 10:00 and 16:00 on clear, windless days (temperature >15°C). Observers recorded:

- Taxonomic group (bees, hoverflies, butterflies, beetles);
- Species (where possible);
- Number of visits per unit time;
- Foraging behavior (nectar vs. pollen collection).

Specimens were collected for taxonomic verification using non-lethal sampling where possible; unidentified insects were preserved for later identification. Pollinator diversity was analyzed using Shannon (H′) and Simpson (1–D) indices.

4. Phenological and Stress Tolerance Observations

Phenological stages (emergence, first bloom, peak bloom, senescence) were recorded for each species. Drought tolerance was assessed during the dry summer of 2022 using:

- Relative Water Content (RWC) of leaves;
- Proline accumulation (spectrophotometric method);
- Visual stress index (VSI) based on wilting, chlorosis, and necrosis.

Soil samples were analyzed for pH, organic matter, and nutrient content (N, P, K) at the beginning and end of the experiment.

5. Maintenance and Resource Input Tracking

All agronomic inputs—water (m^3/ha), labor (man-hours), and organic amendments—were logged throughout the season to calculate resource efficiency and compare input demands between native-rich and conventional plantings.

6. Data Analysis

Statistical analysis was performed using R v4.3.1. Differences in pollinator abundance, species richness, and ornamental scores between treatment types were tested using generalized linear mixed models (GLMMs) with site and year as random effects. ANOVA and post-hoc Tukey tests were applied for parametric comparisons. Correlation between flowering duration and pollinator visitation was assessed using Pearson's coefficient.

All experimental protocols adhered to ethical guidelines for non-invasive ecological research. The study was approved by the Research Ethics Committee of the Russian State Agrarian University – MTAA.

III. Results

The integration of native and pollinator-friendly plant species into urban ornamental landscapes yielded consistently superior outcomes across ecological, aesthetic, and operational dimensions compared to conventional non-native plantings. Over the three-year study period (2021–2023), experimental polycultures demonstrated robust performance in diverse urban environments—from botanical gardens to high-traffic roadside zones—proving their adaptability and multifunctional value.

A total of 87 pollinator species were recorded across all sites, with bees (Apoidea) being the most abundant group (43 species), followed by hoverflies (Syrphidae, 29 species) and butterflies (Lepidoptera, 15 species). Pollinator activity in native-rich plots was markedly higher: average visitation rates reached 14.3 ± 2.1 insects per 10-minute survey, compared to just 3.8 ± 0.9 in control plots ($p < 0.001$). This represents a 276% increase in pollinator abundance associated with native plantings.

Species such as *Echinacea purpurea*, *Allium giganteum*, and *Stachys officinalis* emerged as key nectar and pollen sources, sustaining high visitation throughout the season. The flowering overlap and sequential bloom of the selected perennials extended the functional pollination period to 112 days on average, compared to 76 days in conventional schemes, which rely heavily on short-season annuals.

Biodiversity metrics confirmed the ecological superiority of native polycultures. The Shannon diversity index (H′) averaged 3.21 ± 0.18 in experimental plots, significantly higher than the 1.29 ± 0.11 recorded in controls ($p < 0.001$). Similarly, the Simpson index (1–D) indicated greater species evenness (0.89 vs. 0.61), reflecting a more balanced and resilient pollinator community.

In terms of ornamental quality, native plantings performed competitively despite minimal maintenance. Expert assessments using modified RHS criteria assigned an average aesthetic score of 7.8 ± 0.6 out of 10, statistically indistinguishable from the 7.5 ± 0.8 score of traditional ornamental beds ($p = 0.12$). Key advantages included longer flowering duration, greater structural complexity, and seasonal dynamism, which many observers described as "naturally elegant" and "visually engaging."

Public perception surveys conducted at Sokolniki Park revealed that 78% of respondents rated the native plantings as attractive or very attractive, with comments emphasizing their "lively character," "natural beauty," and "sense of movement." This challenges the common assumption that ecologically functional landscapes are less visually appealing.

Under abiotic stress—particularly during the severe 2022 drought—native species demonstrated superior resilience. Plant survival rates averaged 92% in experimental plots, compared to 64% in conventional plantings ($p < 0.001$). Physiological data supported these observations:

- Relative Water Content (RWC) was 78% in native species versus 61% in non-natives;
- Proline accumulation, an indicator of osmotic adjustment, was significantly elevated in *Sanguisorba officinalis* and *Filipendula ulmaria*;
- Visual Stress Index (VSI) scores were nearly half in native plots (1.4 vs. 3.2), indicating less visible damage.

Operationally, native-rich plantings proved more resource-efficient. They required 48 man-hours/ha/year of labor, compared to 92 man-hours/ha/year for controls—a 48% reduction. Water consumption was 220 m^3/ha versus 410 m^3/ha, and plant replacement rates dropped to near zero after establishment, compared to 40% annual turnover in conventional beds.

These findings demonstrate that well-designed native ornamental plantings are not only ecologically effective but also aesthetically competitive, operationally efficient, and publicly accepted. They offer a viable, scalable model for transforming urban green spaces into biodiverse, climate-resilient, and sustainable ecosystems—without compromising visual quality.

IV. Discussion

I. Subsection One: Reconciling Ecology and Aesthetics — The Emergence of Functional Beauty

One of the most persistent barriers to the adoption of native plantings in urban landscaping has been the perceived trade-off between ecological value and visual appeal. Municipal authorities and landscape designers often assume that biodiverse, naturalistic plantings appear "untidy" or "wild," in contrast to the formal, manicured look of traditional bedding schemes. However, the results of this study challenge this dichotomy.

Our data show that native-rich polycultures achieved an average ornamental score of 7.8 out of 10, statistically equivalent to conventional plantings. Moreover, public surveys revealed high levels of aesthetic appreciation, with nearly 80% of respondents finding the native plantings attractive. This suggests that the concept of beauty in urban green spaces is evolving—shifting from static perfection to dynamic, living landscapes that change with the seasons and teem with life.

This emerging aesthetic can be described as functional beauty—a form of visual appeal rooted not in uniformity and control, but in diversity, resilience, and ecological authenticity. The extended flowering period, structural layering, and movement created by wind and pollinators contribute to a more engaging and emotionally resonant experience for city dwellers. As Nassauer (1995) argued, people accept ecological landscapes when they perceive cues to care—clear design intent, maintenance, and legibility. Our polycultures, though composed of native species, were deliberately arranged in structured compositions, providing these cues and signaling intentionality.

The success of species like Echinacea purpurea, Allium giganteum, and Stachys officinalis—which combine strong architectural form with high ecological value—demonstrates that aesthetic and functional goals can be harmonized. These plants serve as "keystone ornamentals": species that bridge the gap between horticulture and ecology, offering both visual impact and critical support for pollinators.

This has important implications for landscape design practice. Rather than relegating native species to wilderness zones or ecological reserves, they can and should be incorporated into high-visibility urban areas—parks, plazas, and streetscapes—where they can simultaneously enhance biodiversity and reshape public expectations of what a "beautiful" city looks like.

In this way, ornamental horticulture becomes not just a decorator of urban space, but a cultivator of ecological culture—teaching residents to value complexity, change, and interdependence as forms of beauty.

II. Subsection Two: Native Plantings as Climate-Resilient Urban Infrastructure

The superior performance of native species under abiotic stress—particularly during the extreme drought of 2022—positions them not merely as ecological enhancements, but as critical components of climate-resilient urban infrastructure. As cities face increasing frequency and intensity of heatwaves, water scarcity, and soil degradation, the selection of plant material must shift from ornamental preference to functional survivability. This study demonstrates that native perennials, co-evolved with regional climatic conditions, offer a sustainable alternative to resource-intensive annuals that require constant irrigation, replacement, and maintenance.

With 92% survival rates in native-rich plots compared to 64% in conventional plantings, the data underscore a fundamental advantage: native species are pre-adapted to local edaphic and climatic regimes. Their deeper root systems, efficient water-use strategies (as reflected in higher RWC and proline accumulation), and natural pest resistance reduce dependency on external inputs. This translates into 48% lower labor costs and 47% less water consumption over the growing season—critical savings for municipal green space management under tightening budgets and water restrictions.

Moreover, the resilience of these plantings extends beyond individual plant survival. The structural and phenological diversity of the polycultures created microclimatic buffering, reduced soil evaporation, and supported a stable pollinator community even

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under stress. This functional redundancy—where multiple species fulfill similar ecological roles—enhances ecosystem stability, a key principle of sustainable landscape design.

From a planning perspective, these findings advocate for the reclassification of native ornamental plantings as green infrastructure assets, akin to stormwater bioswales or urban forests. Their ability to maintain ecological function under climate stress makes them essential for achieving urban resilience goals outlined in frameworks such as the EU Urban Greening Plan and UN-Habitat's City Resilience Profiling Tool.

Furthermore, the low long-term maintenance requirements of native polycultures address a common institutional barrier: the misconception that sustainable landscaping is labor-intensive. On the contrary, while establishment may require thoughtful design and initial weed control, mature native plantings become self-sustaining, reducing the burden on municipal services.

To scale this approach, policy mechanisms are needed—such as revising municipal planting guidelines to mandate minimum percentages of native species, incentivizing ecological design through green certification programs, and training landscape professionals in the ecology-based horticulture. Cities like Berlin, Portland, and Singapore have already implemented such measures with measurable success in biodiversity recovery and cost reduction.

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