PLANTS
IN URBAN AREAS AND LANDSCAPE

THE PERFORMANCE OF UNDERSTOREY HERBACEOUS PERENNIALS IN LOW MAINTAINED URBAN PARKS

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Designing and establishment of rich herbaceous layer is an essential part of recreating urban woodland and urban parks. Efficient methods for active restoration of the herbaceous layer are therefore needed. The 9-yr-long-time observation of understorey mixture under the different forest stand structures has showed more divergent changes in herb layer establishment success and plant vitality. The worst field layer according to the evaluated parameters (abundance, ground cover, vitality) was observed in a woodland edge dominated by *Tilia cordata* and *Tilia platyphila*. The most perspective plants of the herbaceous layer in forest stands were *Aruncus dioicus* and *Primula veris* ´Cabrilo´ with enormous expanding growth, and *Lysimachia cletroides*, *Alchemilla mollis* ´Auslese´ and *Geranium macrorrhizum* ´Spersard´ with stable growth effects.

Keywords: reintroduction, woodland, herbaceous, survival, planting, vitality

1 Introduction

The stylized naturalistic herbaceous perennial planting is the most innovative approach in the urban landscape (Dunnett and Hitchmough, 2007; Oudolf and Kingsbury, 2014; Rainer and West, 2015). The characteristic beautiful prairies and meadows ecosystem (Schmithals and Kuhn, 2017; Hitchmough, 2017), as well as the herbaceous understory vegetation (Martinek, 2004; Hillová, 2010; Schulte, 2017) became the most frequent sources of inspiration for landscape designers around the world. The enrichment of herbaceous layers is an essential part of recreation of urban woodland and urban parks in last decades (Gilbert and Anderson, 2004; Brunet, 2007). Enhancement of attractive field layer species has been possible by natural succession processes (Gilbert and Anderson, 2004; Brunet, 2007; Onaindia et al., 2013) or management interventions (Martinek, 2004; Riedel et al., 2007). Natural colonization was found out to be very poor and slow and should build out from cores of ancient woodland for optimal ground vegetation development. However, many typical forest species are not able to disperse across open fields (Brunet, 2007) and are not able to persist through competitive aggressive ruderal weed species (Francis, 1998; Hill, 2002). Without effective control of these competitive species, any attempts to either encourage or actively introduce other less competitive ground layer species (by sowing or planting) are likely to be unsuccessful (Hill, 2002). The successful herbaceous plant introduction by direct enhancement techniques to increase species diversity and additional correct management may be a long-term benefit in the appearance, use, ecology and provision of wildlife habitat (Woodland, 2005). Mixed planting is the simplest way to establish a multipurpose and dynamic perennial community in low maintained urban parks. The affordable perennial mixes which combine attractiveness with low maintenance were developed under the auspices of the German Federation of Plant Nurseries (BdS) (Riedel et al., 2007; Schulte, 2017). This has become an excellent tool for practitioners who may be possible to ensure quality and functional introduction of semi-shade and shade tolerant herb layers into low maintained urban parks. The aim of this research project was to investigate the performance of diverse herbaceous perennials mixtures in low maintained urban woodland edges. The key research questions were as follows:

- What effects does the structure of woody plant species have on the establishment success of understorey planting mixtures?
- What effects does the structure of woody plant species have on the vitality of understorey planting mixtures?

2 Material and Methods

2.1 Experimental site

The investigation of naturalistic herbaceous planting was carried out in the experimental part of the

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Botanical garden located in the campus of the Slovak University of Agriculture in Nitra, Western Slovakia. The experimental plot was established on former agricultural land at specific transition zone between open land and diverse woodland edge. The long-term average rainfall per year is 596.4 mm. The original soil at this area is fertile loamy clay with low organic matter content. The two weed treatments were applied before experiment initiation: chemical weed control (Roundup application, requiring a second treatment) and hand weeding. After clearing, the site was rototilled to 30 cm in early 2008. The experiment was performed during 2008/2009 and repeated independently for the second time in 2017.

2.2 Experimental design

In May 2008, the total of 15 treatment main plots of 10 m^2 (4 × 2.5 m) in split-plot design of experiment was set up. Five plots were allocated at woodland edge dominated by *Acer platanoides* (A), another five plots were allocated at woodland edge dominated by *Acer platanoides* and *Prunus domestica* (AP), and remaining five plots were allocated at woodland edge dominated by *Tilia cordata* and *Tilia platyphila* (TT). Every main plot was then planted by 5 diverse planting mixtures, based on diverse number of plant genera (the mix of 3, 5, 7, 10, 13 species). The experimental mixtures consisted of dominant perennials, companion perennials as well as ground covering perennials. Altogether, 1,050 plants had been planted (Table 1). The ratio between the quantities of species plants in mixture was set up according to their sociability (Hansen and Stahl, 1993). The distribution of perennials was made randomly (Kircher et al., 2017), in planting density 7 species per m^2. The plants were obtained from perennial nursery Victoria, Čab Slovakia, in traditional 9 cm containers.

2.3 Measurements of plant performance

The survival of planted individuals was recorded in late October 2008 (mortality after planting) and May 2017 (mortality caused by ageing of planting). The performance criteria (plant cover, plant survival, vitality) of flowering individuals were recorded from April to July, depending on phenological development in the years 2009 and 2017. The vitality assessment was set up according to the modified scale of Braun and Blanquet (1928) in Krížová (2001) with five determined intervals:

1. very weak; occasionally germinating, but not multiplying,
2. feeble; pronouncedly less vital than normally,
3. normal vitality,
4. pronouncedly more vital than normally,
5. exceptionally luxuriant.

2.4 Data analysis

Statistical analyses of experimental data were performed using the Statistica Advanced, Version: 12.0, License Number: 135-949-814. The analysis of variance (ANOVA) was performed to estimate statistically significant difference in vitality between their mean values at a confidence level of 95% (p-value <0.05). The multiple range test of the least significant difference test (LSD test) was used to analyse the existence of homogenous samples.

Table 1 The composition of understorey planting mixture

Taxonomic diversity	Assortment	The count of taxa					Total
		A	B	C	D	E	
A (3-species mixture)	*Aruncus dioicus*	7	7	7	5	3	29
	Geranium macrorrhizum ´Spersard´	42	21	14	12	8	97
	Helleborus orientalis ´New Hybrids´	21	14	7	5	3	50
B (5- species mixture)	*Ligularia przewalskii*		7	7	4	3	21
	Epimedium pinnatum ssp.colchicum		21	14	12	9	56
C (7- species mixture)	*Campanula persicifolia*			9	6	5	20
	Luzula nivea			12	7	7	26
D (10- species mixture)	*Lysimachia cletroides*				5	5	10
	Alchemilla mollis ´Auslese´				8	8	16
	Primula veris ´Cabrilo´				6	5	11
E (13- species mixture)	*Helleborus argutifolius*					5	5
	Matteuccia struthiopteris					3	3
	Heuchera micrantha ´Palace Purple´					6	6
Grand total		70	70	70	70	70	350

3 Results and discussion

3.1 The impact of the forest stand structure on the establishment success of understorey vegetation (field layer)

The initial clearing of the experimental site had an equable effect on the establishment success of understorey mixture under different forest stand structures. The abundance of a newly established understorey planting mixture in the whole experiment has been between 87.3–87.8% (Table 2). The persistent effect on the establishment success of the understorey mixture has not been affected by the type of the forest stand, but it has been affected by the initial vegetation clearing (Baeten and Verheyen, 2017). *Matteuccia struthioptris*, *Primula veris* ´Cabrilo´ and *Lysimachia cletroides* were significantly more abundant compared to *Ligularia przewalskii*. The 9-yr-long-time observation showed more divergent changes in the percentage abundance of field layer related to difference in dominant tree species. The total population size in the woodland edge (TT) persists almost unchanged compared with the remaining woodland edges (A, AP) that were increased by abundance of field layer (Table 3). Regardless of these differences, there were recorded:

a) initially decline and then full mortality at *Ligularia przewalskii*,
b) the initial persistent establish effect and then full mortality at *Matteuccia struthiopteris* and *Heuchera micrantha* ´Palace Purple´,
c) progressive decline at *Helleborus argutifolius*,
d) long-term (9-yr-long) stable effect at *Lysimachia cletroides*, *Alchemilla mollis* ´Auslese´ and *Geranium macrorrhizum* ´Spersard´,
e) enormous expanding of *Aruncus dioicus* and *Primula veris* ´Cabrilo´.

The most expanding taxa had different adaptive strategies (Grime et al., 2014): C-strategist *Aruncus dioicus* (Pierce et al., 2012) and S/CSR-strategist *Primula veris* (Grime et al., 2014). The remaining taxa showed divergent changes related to differences in dominant tree species (Table 2, Table 3), they were likely to spread or to diminish with time (Kingsbury, 2011). The total ground cover of herbaceous layers was affected by the forest stand structure and the age stage of the planting mixture (Table 4.). The newly established understorey planting mixtures (one year after planting) in woodland edges (A, AP) reached the ground covering 78.8–77.6%; the remaining soil surface was without vegetation. On the other side, the newly established field layer in the woodland edge (TT) reached the lowest values of ground covering (57%). During maturation of field layers in every evaluated woodland edge the increase of their ground covering was equal. The developed mixtures (9 years after planting) in woodland edges (A, AP) reached the ground covering 91.6–93.2%, and in woodland edges (TT) it reached the ground covering of 85.2%. Godefroid et al. (2011), based on an extensive study which used data from literature (1989–2009) combined with a questionnaire survey showed a significant downward trend over time in the survival of reintroduced plants, and indicated three variables for the reintroduction success: material provenance, removing surrounding plants and site protection. The use of seedlings provided higher survival rates than the use of seeds. In our study, we used uniform seedlings which were reproduced by various methods, and put into pure and protected ground (area of botanical garden with fencing). The survival rate can be improved by various planting techniques:

a) using bare roots (Godefroid et al., 2011),
b) using heteromorphic alternation of generations (Gorbunov, 2008),
c) using miniature root-balls (ø 4 cm) (Schmithals and Kühn, 2014; Woodland, 2005; Dixie and Francis, 1996; Gilbert and Anderson, 1998) with peat free composts, planted at a higher density (25 plants/m^2) (Schmithals and Kühn, 2014; Godefroid et al., 2011) and post-planting management:
   a) composting (10 cm thick layer of garden waste compost) (Richnau et al., 2016),
   b) mowing during vegetation (Kircher et al., 2010) coupled with maintenance of species-richness.

Godefroid and Vanderborght (2011) emphasized that successful plant reintroduction needs a global centralized database for rapid and effective broadcasting of information in a standardized and accessible form.

3.2 The impact of the forest stand structure on vitality of understorey planting mixtures

Vitality values of understorey planting mixtures changed significantly according to the forest stand structure and age stage of the planting mixture (Figure 1). The striking differences could be detected between the vitality values of the newly established understorey planting mixtures (one year after planting) and fully matured and developed mixtures (9 years after planting). The newly established field layer in the woodland edge (A) attained higher values of vitality (3.13) and then during the maturity stage their values decreased (2.72). On the other side, the newly established field layer

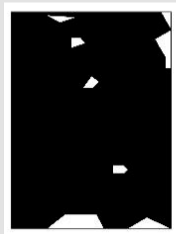
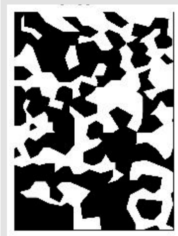
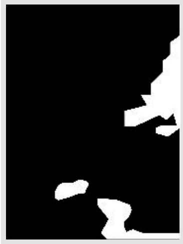
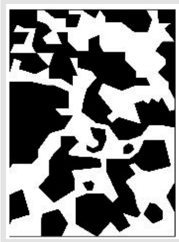
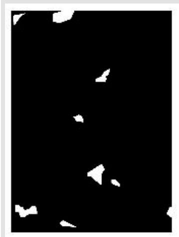
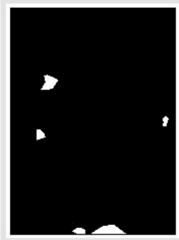
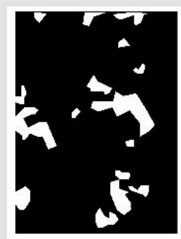
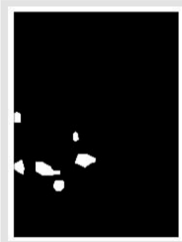
Table 2 The percentage abundance of herbaceous forbs taxa in different woodland edge, one year afterplanting (2008)

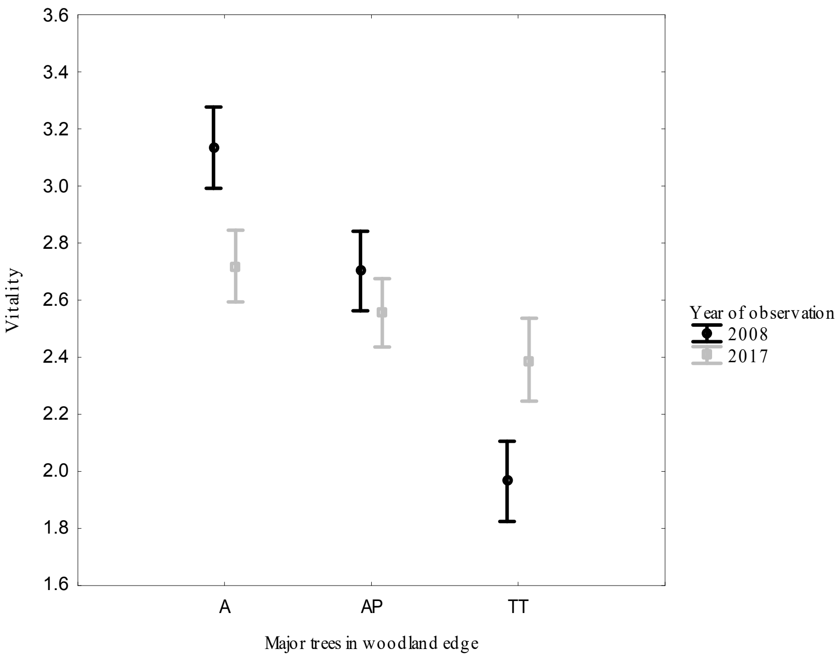
Assortment	Total number of plant in one edge	Woodland edges with different dominance of tree (% abundance)																	
		A						AP						TT					
		3	5	7	10	13	total	3	5	7	10	13	total	3	5	7	10	13	total
Aruncus dioicus	29	85.7	85.7	85.7	40	100	**79.4**	85.7	85.7	85.7	80	100	**87.4**	71.4	85.7	71.4	100	100	**85.7**
***Geranium macrorrhizum* ´Spersard´**	97	100	76.2	100	91.7	87.5	**91.1**	95.2	90.5	85.7	100	100	**94.3**	97.6	95.2	92.9	91.7	100	**95.5**
***Helleborus orientalis* ´New Hybrids´**	50	90.5	71.4	71.4	100	100	**86.7**	90.5	92.9	100	100	66.7	**90.0**	90.5	92.9	85.7	100	100	**93.8**
Ligularia przewalskii	21		100	42.9	75	33.3	**62.8**		57.1	57.1	75	66.7	**64.0**		28.6	71.4	75	100	**68.8**
***Epimedium pinnatum* ssp. colchicum**	56		61.9	64.3	83.3	66.7	**69.1**		66.7	85.7	83.3	77.8	**78.4**		47.6	57.1	83.3	55.6	**60.9**
Campanula persicifolia	20			88.9	83.3	100	**90.7**			88.9	100	100	**96.3**			66.7	100	100	**88.9**
Luzula nivea	26			58.3	85.7	100	**81.3**			91.7	71.4	57.1	**73.4**			50	85.7	100	**78.6**
Lysimachia cletroides	10				100	100	**100.0**				100	100	**100.0**				100	100	**100.0**
***Alchemilla mollis* ´Auslese´**	16				100	100	**100.0**				100	87.5	**93.8**				100	100	**100.0**
***Primula veris* ´Cabrilo´**	11				100	100	**100.0**				100	100	**100.0**				100	100	**100.0**
Helleborus argutifolius	5					80	**80.0**					60	**60.0**					80	**80.0**
Matteuccia struthiopteris	3					100	**100.0**					100	**100.0**					100	**100.0**
***Heuchera micrantha* ´Palace Purple´**	6					100	**100.0**					100	**100.0**					83.3	**83.3**
Total	–	92.1	79.0	73.1	85.9	89.8	**87.8**	90.5	78.6	85.0	91.0	85.8	**87.5**	86.5	70.0	70.7	93.6	93.8	**87.3**

Table 3 The percentage abundance of herbaceous forbs taxa in different woodland edge, 9 years after planting (2017)

Assortment	Total number of plant in one edge	Woodland edges with different dominance of tree (% abundance)																	
		A						AP						TT					
		3	5	7	10	13	total	3	5	7	10	13	total	3	5	7	10	13	total
Aruncus dioicus	29	85,7	157,1	214,3	60,0	133,3	**130,1**	357,0	171,4	257,0	22,0	133,3	**188,1**	142,9	100,0	42,9	140,0	300,0	**145,2**
***Geranium macrorrhizum* ´Spersard´**	97	100,0	100,0	100,0	100,0	100,0	**100,0**	100,0	100,0	100,0	100,0	100,0	**100,0**	100,0	100,0	100,0	100,0	100,0	**100,0**
***Helleborus orientalis* ´New Hybrids´**	50	114,3	100,0	85,7	80,0	100,0	**96,0**	104,8	157,1	114,3	80,0	133,3	**117,9**	95,2	100,0	42,9	100,0	100,0	**87,6**
Ligularia przewalskii	21		0,0	0,0	0,0	0,0	**0,0**		0,0	0,0	0,0	0,0	**0,0**		0,0	0,0	0,0	0,0	**0,0**
***Epimedium pinnatum* ssp. colchicum**	56		66,7	50,0	33,3	133,3	**70,8**		90,5	142,9	75,0	111,1	**104,9**		47,6	42,9	33,3	44,4	**42,1**
Campanula persicifolia	20			166,7	316,7	620,0	**367,8**			155,6	10,0	40,0	**68,5**			166,7	50,0	380,0	**198,9**
Luzula nivea	26			50,0	71,4	100,0	**73,8**			66,7	85,7	114,3	**88,9**			166,7	85,7	71,4	**107,9**
Lysimachia cletroides	10				100,0	100,0	**100,0**				100,0	100,0	**100,0**				100,0	100,0	**100,0**
***Alchemilla mollis* ´Auslese´**	16				100,0	100,0	**100,0**				100,0	100,0	**100,0**				100,0	100,0	**100,0**
***Primula veris* ´Cabrilo´**	11				500,0	400,0	**450,0**				550,0	640,0	**595,0**				167,0	100,0	**133,5**
Helleborus argutifolius	5					40,0	**40,0**					40,0	**40,0**					60,0	**60,0**
Matteuccia struthiopteris	3					0,0	**0,0**					0,0	**0,0**					0,0	**0,0**
***Heuchera micrantha* ´Palace Purple´**	6					0,0	**0,0**					0,0	**0,0**					0,0	**0,0**
Total	–	**100,0**	**84,8**	**95,2**	**136,1**	**140,5**	**117,6**	**187,3**	**103,8**	**119,5**	**112,3**	**116,3**	**115,6**	**112,7**	**69,5**	**80,3**	**87,6**	**104,3**	**82,7**

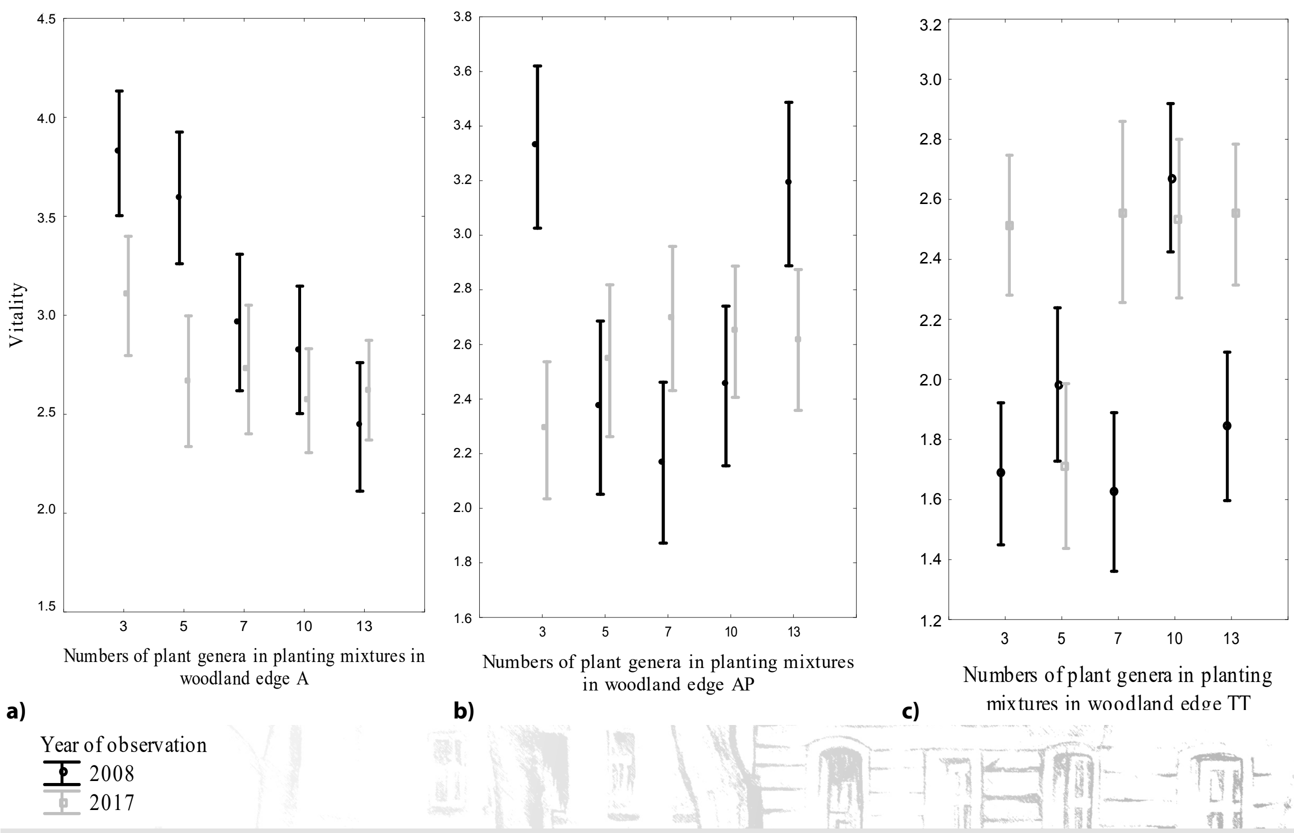
Table 4 The ground cover of compositions understorey planting mixtures in different types of woodland edges

Numbers of plant genera in mixture	Ground cover					
	Woodland edge (A)		Woodland edge (AP)		Woodland edge (TT)	
	2008	2017	2008	2017	2008	2017
3						
	95%	96%	89%	89%	55%	92%
5						
	86%	90%	66%	90%	47%	76%
7						
	70%	80%	69%	91%	49%	78%
10						
	76%	97%	75%	98%	69%	89%
13						
	67%	95%	89%	98%	65%	91%
Totally ground cover	**78,8%**	**91,6%**	**77,6%**	**93,2%**	**57%**	**85,2%**

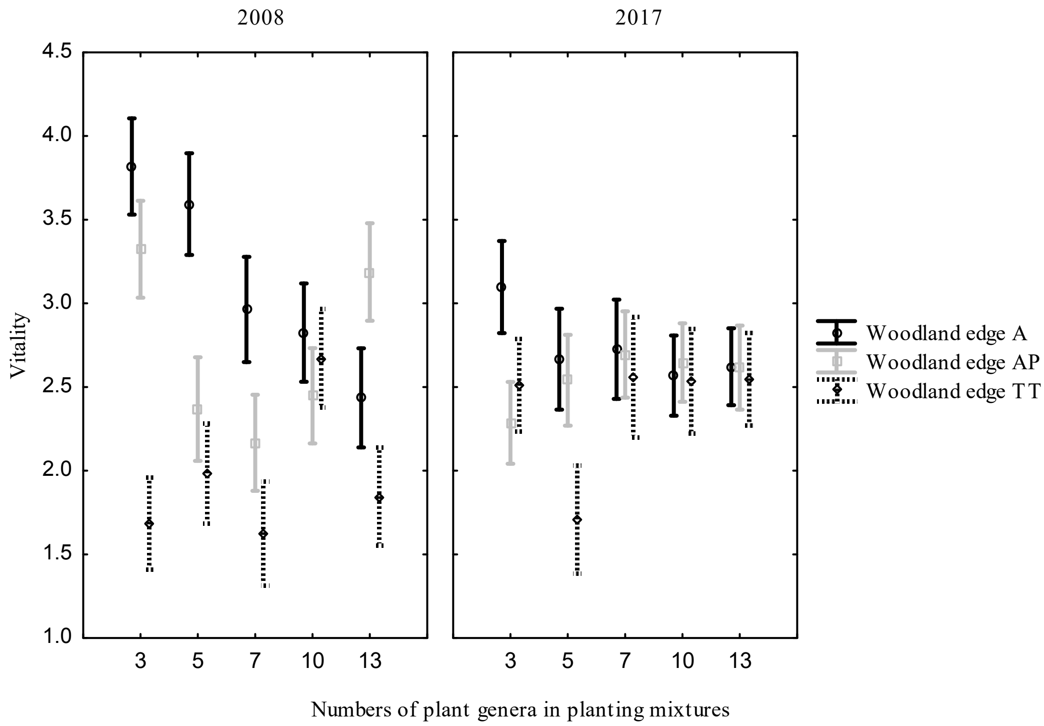


■ **Figure 1:** The average vitality values of understorey planting mixtures in different types of woodland edges

in the woodland edge (TT) attained the lowest values of vitality (1.97) and then during the maturity stage their values increased (2.72), but did not reach the vitality value of the woodland edge (A). The maturation of field layer in the woodland edge (AP) had no effect on vitality values that remained stable (2.56–2.7). The range of vitality values decreased after maturation from 1.97–3.13 in 2008, to the range 2.39–2.72 in 2017 (Figure 1). The assessment of vitality of different understorey planting mixtures in the woodland edge (A) demonstrated a significant decrease only in low taxonomic diversity mixtures (3 and 5 different taxa in mixtures) after maturation. Monocultures and very simple systems of low diversity are vulnerable to environmental fluctuation. The main indicators of ecosystem health and functioning are primarily dictated by the performance of vegetation dominants and these are likely to be relatively few in numbers. The successful combination of different plant species is one the main functions of planting design and



■ **Figure 2:** The average vitality values of understorey planting mixtures in different woodland edges



■ **Figure 3** The average vitality values of understorey planting mixtures in different types of woodland edge and age stage of planting mixture

landscape management (Dunnet and Hitchmough, 2004). Maturation of different understorey planting mixtures in the woodland edge (A) led to a stabilization of vitality values at about 2.57–3.1 (no significant statistical differences) (Figure 2a). The vitality values of the lowest and the highest taxonomic diversity mixtures were also significantly lower in the woodland edge (AP) (Figure 2b), and similarly the maturation of different understorey planting mixtures in the woodland edge (AP) led to a stabilization of vitality values at about 2.29–2.7 (no significant statistical differences). But surprisingly, we noticed a significantly increased vitality level in the woodland edge (TT) in 3 different possibilities (3-, 7-, and 13-different taxa in mixtures) (Figure 2c). Figure 3 confirms stabilisation effect of maturation understorey planting mixtures in different woodland edges, if two years of observation are compared.

The mixtures did not show statistically significant differences in vitality values, except low taxonomic diversity mixtures (3-different taxa in woodland edge (A) and 5-different taxa in woodland edge (TT)). In our study, we used 5 variances of taxonomic diversity, but species-richness in plant community varied from a lowland woodland (may support more than 100 herbaceous species in the field layer, including forbs, grasses, sedges, rushes and ferns), in contrast to the site characterized by dense shade, southern beechwoods (may only have 10 to 15 species in the field layer) (Woodland, 2005). Woodland herbaceous species should be introduced into a new area as a part of well balanced and robust mixtures, both ecologically and visually, 15–20 woodland species with a range of flowering times, colours, heights and structures and growth forms (Woodland, 2005; Kircher et al., 2012).

4 Conclusion

The 9-yr-long-time observation of understorey mixture under different forest stand structures has showed more divergent changes in herb layer establishment success and plant vitality, which can influence setting innovative approaches of the herbaceous perennials planting design. Based on these results we can state the following:

- the total population size of field layer in the first year of establishment has not been affected by the type of a forest stand,
- the total population size in woodland edge was dominated by *Tilia cordata* and *Tilia platyphila* (TT) persists almost unchanged compared with remaining woodland edges dominated by *Acer platanoides* (A), or *Acer platanoides* and *Prunus domestica* (AP),

- the most perspective plants of evaluated mixtures in forest stand were *Aruncus dioicus* and *Primula veris* ´Cabrilo´ with enormous expanding growth, and *Lysimachia cletroides*, *Alchemilla mollis* ´Auslese´ and *Geranium macrorrhizum* ´Spersard´ with stable growth effect,
- the total ground cover of herbaceous layers size in woodland edge was dominated by *Tilia cordata* and *Tilia platyphila* (TT) was lower and gradually increased during maturation, but start level and final level of ground covering was higher in woodland edges dominated by *Acer platanoides* (A), or *Acer platanoides* and *Prunus domestica* (AP),
- the vitality values of field layer were significantly different in the first year of establishment (the best was in woodland edge (A), then in woodland edge (AP) and the lowest values in woodland edge (TT)), and during maturation of field layers (9-yr-old) the differences in vitality levels were not significant.

There is the need to state that the worst field layer according to the evaluated parameters (abundance, ground cover, vitality) was observed in the woodland edge dominated by *Tilia cordata* and *Tilia platyphila* (TT). These results appeal to future research aims based on a) complex herb and tree assortment and b) establishment, maintenance and restoration approaches. The complex view on understorey vegetation may develop the process of guidelining specific parts of herbaceous perennial planting design – low maintained understorey planting design.

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