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DURABILITY OF 28 GROUND-COVERING WOODY SPECIES AND CULTIVARS IN ROAD-SIDE PLANTING IN WARSAW, POLAND

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Shrub species selection for road-side planting should consider their ability to cope with stress factors imposed by road trafic. In our examination we evaluated durability of 28 ground-covering woody species and cultivars in road-side environment in Warsaw. A dendrological inventory of planting beds located along Niepodległości Avenue was carried out 11 years after planting. The survival rate of each planted group of shrubs (a patch) was determined. Electrical conductivity of soil in planting beds was measured in order to determine soil salinity. Planting beds were divided into 3 groups: (1) wide beds at street corners, (2) narrow beds between pavements and interior roads, (3) road-side beds between interior roads and main roads. The results showed that the greatest number of shrubs was lost in the road-side planting beds, but in the wide beds and the narrow beds there were also some plant losses. The most resistant species to road-side environment were *Spiraea* × *cinerea* 'Grefsheim', certain cultivars of *Spiraea japonica*, *Rosa rugosa* and *Ribes alpinum* 'Schmidt'.

Keywords: ground cover shrubs, salt stress, urban environment

The problem of high mortality of urban trees has been widely discussed (Pauleit et al., 2002; Sæbø et al., 2003; Borowski and Pstrągowska, 2010). Harsh environmental conditions, quite different from those from natural stands, i.e. air and soil drought, decreased water deposition in soils, soil contamination and compaction, are considered to be the most important factors responsible for tree damage in cities (Sieghart et al., 2005; Sjöman and Nielsen, 2010; Swoczyna et al., 2015). Accumulation of de-icing salts in road-side soils is the additional stress factor affecting road-side trees in Central and Nothern Europe (Cekstere et al., 2008). The similar problem concerns shrubs, however, mortality of shrubs is not so much emphasised. Shrubs play a key role in urban environments. Planting of ornamental shrubs shifts the aesthetic value of city boulevards, streets and squares. When planted along streets, shrubs accumulate road contaminations due to their short height (Dzierżanowski et al., 2011). Simultaneously, they are affected both by road-side contamination and harmful abiotic factors. Therefore, shrub species and cultivars which are planted along streets should reveal tolerance to road-side conditions, i.e. to a complex of abiotic factors connected directly with close vicinity of roads, especially de-icing salt accumulation in soil.

The objective of our study was to evaluate 28 ground-covering woody species and cultivars durability in road-side environment.

Material and methods

The research was performed along Aleja Niepodległości, a downtown avenue in Warsaw, Poland (52° 12′ 20″ N, 21° 00′ 33″ E), oriented in North-South direction, supporting heavy traffic. Three types of planting beds were established:

1. wide beds of 6.5–10 m width at street corners,
2. narrow beds of 1.6–2.8 m width between pavement and interior roads,
3. road-side beds of 1.5–2.5 m width between interior roads and main roads (Figure 1).

Ground cover shrubs were planted in 2004 in patches consisting of 30 to 120 specimens due to a design made by Agnieszka Matyszczyk, Zarząd Oczyszczania Miasta (ZOM) – Metropolitan Authority of Parks, Greenery and Cleaning, Warsaw. In wide planting beds, shrubs were planted in irregular patches, in narrow and road-side beds, shrub patches formed rows arranged one by one along each planting bed. Due to dendrological inventory performed in 2005 (Królikowska, 2006), the following species and cultivars were used: *Berberis thunbergii* DC. 'Atropurpurea', *B. thunbergii* 'Atropurpurea Nana', *B. thunbergii* 'Green Carpet', *Cotoneaster dammeri* C.K.Schneid. 'Eichholz', *C. dammeri* 'Major', *Cotoneaster horizontalis*, *Cotoneaster* × *suecicus* G. Klotz 'Coral Beauty', *Euonymus fortunei* (Turcz.) Hand.-Mazz. 'Coloratus', Forsythia 'Maree d'Or', *Hedera helix* L., *Mahonia aquifolium* (Push) Nutt., Physocarpus opulifolius (L.)Maxim. 'Diabolo', Ph. opulifolius 'Luteus', Potentilla fruticosa L. 'Goldfinger', *Ribes alpinum* L. 'Schmidt', *Rosa rugosa* Thunb., Rosa 'The Fairy', *Sorbaria sorbifolia* (L.)A. Br., *Spiraea* × *cinerea* Zabel 'Grefsheim', *Spiraea japonica* L. 'Anthony Waterer', *S. japonica* 'Froebelli', *S. japonica* 'Golden Princess', *S. japonica* 'Goldflame', *S. japonica* 'Goldmound', *S. japonica* 'Little Princess', *Stephanandra incisa* (Thunb.) Siebold & Zucc. ex Zabel 'Crispa', *Symphoricarpos* × *chenaulti*

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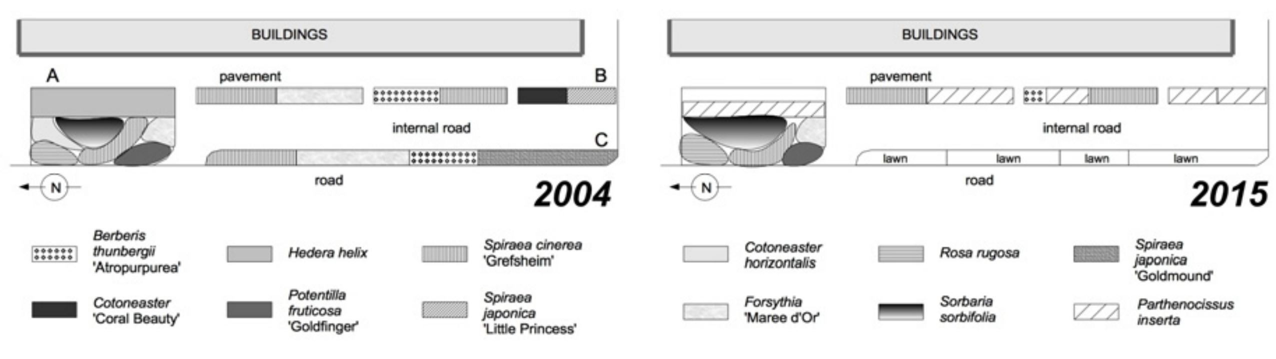

Figure 1 The example of ground cover shrubs' arrangement in Niepodległości Avenue in 2004 and 2015
Source: Drawn by T. Swoczyna
A – wide planting beds, B – narrow planting beds, C – road-side planting beds

Table 1 Scale for evaluation of ground cover shrubs' survival

Class	Degree of survival
0	no specimen survived
1	only single specimens survived
2	less than 75% of total specimens survived
3	more than 75% of total specimens survived

Source: Authors' original work

Rehder 'Hancock', *Weigela florida* (Bunge)A.DC. 'Nana Variegata'. Shrubs were maintained due to procedures accepted by ZOM (watering, fertilising, weeding).

In August 2015, the inventory and evaluation of plant survival was proceeded. Every patch was given a number and for each one the rate of plant survival was evaluated, according to a scale given in Table 1.

In the beginning of September 2015, soil salinity in planting beds was measured. Soil samples were collected from wide beds and road-side beds, 1 m from the road edge, and from the middle line of narrow beds, each at 0–0.2 m depth. Three replications from each type of planting beds and an additional sample from lawn area of a neighbouring park were taken for laboratory analyses. The electrical conductivity of soil was measured using a CX-551 multifunction meter (ELMETRON Sp. j., Zabrze, Poland).

For statistical analysis, Kruskall-Wallis test was performed using STATISTICA 10.0 software (StatSoft, Inc., Tulsa, OK, USA).

Results and discussion

The species arrangement in all planting beds changed during 11 years. In many patches, plants were totally lost, especially in road-side planting beds (Figure 1 and 2). The survival of shrubs in road-side planting beds was significantly lower than in wide and narrow beds ($p = 0.000$ and $p = 0.042$, respectively).

Soil salinity expressed as electrical conductivity (EC) was higher in the close vicinity of the road edge (Table 2). Although the measurements were done in the end of the growing season, the salt deposition in road-side soils still remained very high. This may explain the poor survival of road-side shrubs. According to Marosz and Nowak (2008), EC values exceeding 2 mS cm^{-1} seriously affect young trees. In woody plants, de-icing salts are accumulated in tissues and prove to cause severe injuries after long-term exposition to salt stress (Pracz, 1990; Cekstere et al., 2008). Harmful impact of soil salinity consists both in accumulations of toxic ions in plant tissues and in osmotic limitations to water absorption by roots. Additionally, restricted soil volume supported to urban trees is often responsible for water scarcity which affects urban trees (Sieghart et al., 2005). In our research the restricted soil volume in the road-side planting beds might have precluded

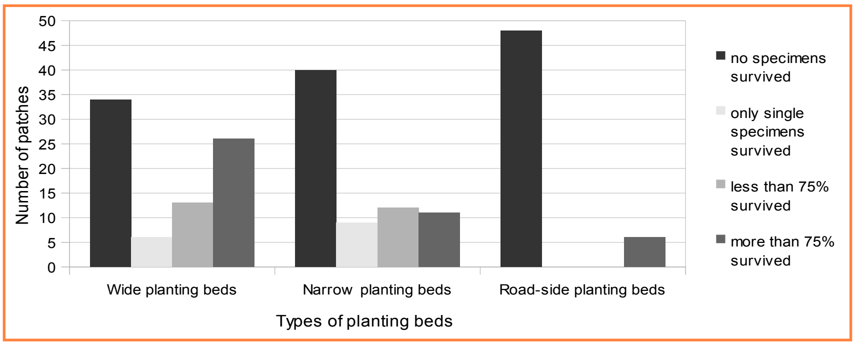

Figure 2 Total ground cover shrubs' survival in three types of planting beds. Survival rate according to table 1
Source: Authors' original work

Table 2 Soil salinity expressed as electrical conductivity (EC) in planting beds and park lawn (control). Means and SE are shown

Site	Control	Narrow beds	Road-side beds	Wide beds
EC (mS cm^{-1})	0.724 (± 0.171)	1.122 (± 0.070)	2.268 (± 0.272)	2.379 (± 0.364)

Source: Authors' original work

Table 3 Survival of cover shrubs planted along Niepodległości Avenue after 11 years. Degrees of survival according to table 1

Species and cultivars	Wide planting beds					Narrow planting beds					Road-side planting beds				
	no. of patches	degree of survival (%)				no. of patches	degree of survival (%)				no. of patches	degree of survival (%)			
		0	1	2	3		0	1	2	3		0	1	2	3
***Berberis thunbergii* 'Atropurpurea Nana'**	2	100	0	0	0	1	100	0	0	0	1	100	0	0	0
***Berberis thunbergii* 'Green Carpet'**	1	100	0	0	0	–	–	–	–	–	1	100	0	0	0
***Cotoneaster dammeri* 'Major'**	4	100	0	0	0	9	100	0	0	0	2	100	0	0	0
Mahonia aquifolium	2	100	0	0	0	3	67	0	0	33	–	–	–	–	–
***Physocarpus opulifolius* 'Luteus'**	1	100	0	0	0	1	100	0	0	0	–	–	–	–	–
***Spiraea japonica* 'Golden Princess'**	1	100	0	0	0	2	100	0	0	0	–	–	–	–	–
***Spiraea japonica* 'Goldflame'**	2	100	0	0	0	1	0	100	0	0	1	100	0	0	0
***Stephanandra incisa* 'Crispa'**	1	100	0	0	0	–	–	–	–	–	3	100	0	0	0
***Cotoneaster* × *suecicus* 'Coral Beauty'**	4	75	0	25	0	6	83	0	17	0	1	100	0	0	0
Cotoneaster horizontalis	3	67	0	33	0	2	50	50	0	0	2	100	0	0	0
***Spiraea japonica* 'Little Princess'**	3	67	33	0	0	2	100	0	0	0	2	100	0	0	0
Hedera helix	7	58	14	29	0	5	20	20	60	0	–	–	–	–	–
***Symphoricarpos* × *chenaulti* 'Hancock'**	7	57	0	0	43	9	22	11	33	33	2	0	0	0	100
***Euonymus fortunei* 'Coloratus'**	2	50	50	0	0	–	–	–	–	–	–	–	–	–	–
***Potentilla fruticosa* 'Goldfinger'**	6	50	17	33	0	3	100	0	0	0	4	100	0	0	0
***Spiraea japonica* 'Froebelli'**	2	50	0	0	50	1	100	0	0	0	3	33	0	0	67
***Cotoneaster dammeri* 'Eichholz'**	–	–	–	–	–	–	–	–	–	–	4	100	0	0	0
***Rosa* 'The Fairy'**	–	–	–	–	–	4	25	0	0	75	1	100	0	0	0
***Weigela florida* 'Nana Variegata'**	–	–	–	–	–	–	–	–	–	–	2	100	0	0	0
***Physocarpus opulifolius* 'Diabolo'**	–	–	–	–	–	1	100	0	0	0	–	–	–	–	–
***Berberis thunbergii* 'Atropurpurea'**	2	0	50	50	0	1	0	100	0	0	3	100	0	0	0
***Forsythia* 'Marée d'Or'**	5	0	0	60	40	1	100	0	0	0	1	100	0	0	0
***Spiraea* × *cinerea* 'Grefsheim'**	6	0	0	33	67	4	0	0	50	50	3	100	0	0	0
***Ribes alpinum* 'Schmidt'**	7	0	0	14	86	9	22	22	33	22	7	86	0	0	14
Rosa rugosa	8	0	13	0	88	4	50	50	0	0	4	75	0	0	25
***Spiraea japonica* 'Anthony Waterer'**	1	0	0	0	100	–	–	–	–	–	3	100	0	0	0
***Spiraea japonica* 'Goldmound'**	1	0	0	0	100	3	100	0	0	0	4	100	0	0	0
Sorbaria sorbifolia	1	0	0	0	100	–	–	–	–	–	–	–	–	–	–

Source: Authors' original work

water storage in soil and, consequently, could have shifted detrimental effect of soil salinity. Although the soil salinity in the wide planting beds was similar compared to the road-side beds, the shrub survival rates in wide beds were higher. Presumably, the enlarged area of planting beds enabled better water accumulation in soil and this could have moderated the effect of the high soil salinity.

The survival rates of particular species and cultivars show some differences between the taxa. The number of experimental plots, i.e. patches, does not allow conducting successful statistical analysis. However, the insight into species-specific survival rates gives some suggestions on individual species durability in road-side environment. The results showed that the most resistant species were *Spiraea* × *cinerea* 'Grefsheim', certain cultivars of *Spiraea japonica*, *Rosa rugosa* and *Ribes alpinum* 'Schmidt' (Table 3). Salt tolerance of *Spiraea* × *cinerea* 'Grefsheim' was confirmed by Marosz (2004). He also found Potentilla fruticosa and *Cotoneaster horizontalis* to be salt resistant, however, in our examination no specimens of these species survived in road-side planting beds. Taking into account drought stress, Percival & Sheriffs (2002) classified *Spiraea japonica* 'Shirobana' as a drought-sensitive taxon. On the contrary, they found *Hedera helix* and *Mahonia aquifolium* to be tolerant. The discrepancy between Marosz's, Percival & Sheriffs's and our results indicates that in road-side environments a complex of abiotic stress factors creates a specific pattern of plants' reactions. Laboratory experiments may indicate the resistance to some particular stress factors applied in a given time. Observations *in situ* allow evaluating plant ability to cope with a complex of stress factors affecting plants during their whole life span. This ability includes also recovery potential which is connected with the type of growth, for example, the ability to sucker. In our examination *Sorbaria sorbifolia* was the only species with markedly enlarged area (Figure 1), however, there was the only patch filled with *Sorbaria sorbifolia*. Thus, we cannot conclude whether this species is able to cope with road-side stress.

The opinions on the tolerance of shrub species to urban and road-side conditions are mostly based on individual observations. Therefore, scarce publications give only some general information on taxa which are appropriate for urban planting (Borowski & Latocha, 2006). This examination confirms some of Borowski & Latocha's opinions on Cotoneaster ssp. susceptability. Contrary to that, *Symphoricarpos* × *chenaulti* 'Hancock' appeared to be tolerant enough in road-side conditions. Surprisingly, *Berberis thunbergii* which is considered to be tolerant enough to drought revealed to be susceptible in road-side environment.

Conclusions

Road-side environments harmfully affect ground-covering shrubs. The list of species which can cope with environmental stress caused by heavy traffic is limited and includes *Spiraea* × *cinerea* 'Grefsheim', some cultivars of *Spiraea japonica*, *Rosa rugosa* and *Ribes alpinum* 'Schmidt'. The highest mortality of shrubs occurs in planting beds situated in close proximity to roads. In order to increase the durability of ground cover shrubs the designed and established planting beds along streets should have greater area (exceeding 3 m width).

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