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ROAD-SIDE HERBACEOUS VEGETATION: LIFE HISTORY GROUPS AND HABITAT PREFERENCES

ABSTRACT: The study examines the vegetation diversity (235 herbaceous species) in variable road-site types in terms of life history components (life traits) like life form, type of pollination, seed dispersal, spreading ability, life strategy according to Grime's classification, and in terms of habitat preferences using Ellenberg's indicator value (in relation to light, temperature, moisture, nitrogen, soil pH and soil salinity). Plants registered as alien species were evaluated also according to invasive status, level of abundance, introduction mode and land use habitat. Study localities (9 sites) were situated in the Českomoravská highlands and the South Bohemian regions (Czech Republic). The plant species were recorded in the bands (width in range of 1.5–3.0 m) along the verge of two types of roads (motorways with median stripes) and secondary roads (II and III classes). In total – road length of about 15 km and the total area of road-side vegetation of about 8 ha were surveyed.

The annual/therophyte species with a tendency to seed dispersed by wind, preferring a light and dry habitat, and having the RC (competitive-ruderal) life strategy were mainly found along the motorways. It means that road verges along motorways are quite insolated and constitute the dry habitats, probably suitable for ruderal, weedy, non-native, and invasive species. On the contrary, species with a tendency to vegetative reproduction and the C (competitive) strategy occur mainly along the secondary roads. It seems that the secondary roads are alternative habitats for grassland flora. Species occurred on the verges of the secondary roads do not belong to the particular group of the life traits. The salt tolerant species *Puccinellia distans* (Jacq.) Parl. was found along all types of roads. Almost 24% of all recorded herbaceous species growing in road-sites were alien species.

KEY WORDS: road-side vegetation, road ecology, life form, life history, habitat preference, alien species

1. INTRODUCTION

Road-side vegetation plays an important role in the integration of the road network with the natural landscape. It fulfils many functions in the ecological stabilization of a landscape (Spellerberg 1998). Vegetation accompaniments of roads (tree lines, green belt, road embankment, road-side ditches, verges, vegetation of divider strip) are usually studied for biodiversity, species richness, plant dispersal, and the occurrence of alien species.

Roads and motorways are man-made constructions in a landscape, connected with vehicle transport and specific maintenance. The plant communities along a road network are first of all affected by road construction

(Rentch *et al.* 2005), dust deposition (Farmer 1993), road sediment (Bernhardt-Romermann *et al.* 2006), disturbance from road maintenance (Truscot *et al.* 2005), man activities at the road (Jantunen *et al.* 2006, Wrobel 2006).

The presented study deals with the life history of plants and their habitat preferences (indicated by Ellenberg's indicator values) that are connected with the close vicinity of roads. The grouping of plant species (according to life span, growth form, etc.) are derived from traits based on species morphology, physiology and life history. These plant functional groups can be applied to study the ecological processes (Blomberg *et al.* 2003), such as stability and succession of road-side vegetation communities (Valladares *et al.* 2008) and to detect and predict the vegetation responses of the environmental changes of the roadscape.

Two research questions are raised up in the paper: 1. To analyse the vegetation diversity in terms of the life history groups in order to identify the main trends. 2. To identify the influence of road type on vegetation structure.

2. STUDY SITES

Two study areas were chosen along roads of two general classes (motorways, and secondary roads of class II and III, according to http://rsd.cz) and selected in open landscape, outside the settlements and outside the protected areas. Both areas are situated in southern region of Czech Republic. Both territories belong to hilly, agricultural-forest landscape with mosaics of forest patches of the different tree species composition, fields and grasslands (Anonymous 1992). The natural vegetation has been originally the woodrush-beech woodland (*Luzulo-Fagion*) in the first area and woodrush-oak woodland (*Luzulo albida-Quercetum petraeae*) in the second one; recently they have been succeeded by the herb-poor communities of pinewood (Neuhäuselová *et al.* 1998). Average annual temperature is 7.5–8.5°C and yearly precipitation ranged 700–900 mm in both research areas. The areas are characterized by a short, moderate to moderately-cold and moderately-dry summer, with a moderate spring and autumn, and with a normally long winter (Quitt 1971). Annual traffic volume amounted around 17 000 heavy vehicles and 38 000 all vehicles in the investigated motorways and about 3000 heavy vehicles and 7 400 all vehicles in the secondary roads (Anonymous 1992).

Nine research sites were selected in research areas (Table 1). The first area included the vegetation bands (up to 3.0 wide) and median stripes of the D1 motorway from

Table 1. Size and natural characteristics of research sites.

Site number	Site lenght (km)	Site width (m)	Site area (ha)	Roads type	Elevation (m a.s.l.)	Geological substrate	Soil type	Surrounding area
1	2.1	3	1.47	Motorway	550	granite, gneiss	cambisol, gley	grassland
2	4.3	3	3.01	Motorway	630	gneiss	cambisol	coniferous forest
3	1.0	3	0.70	Motorway	310	gneiss	cambisol	agriculture land, grassland
4	1.9	2	0.76	Secondary roads, IInd class	570	gneiss, granite	cambisol	coniferous forest, grassland
5	1.3	2	0.52	Secondary roads, IInd class	580	fault rock, gneiss	pseudogley	coniferous forest
6	1.1	2	0.44	Secondary roads, IInd class	600	gneiss	cambisol	agriculture land, grassland
7	1.4	1.5	0.49	Secondary roads, IIIrd class	590	gneiss	cambisol	agriculture land
8	0.8	1.5	0.28	Secondary roads, IIIrd class	600	gneiss	cambisol	grassland
9	1.0	1.5	0.35	Secondary roads, IIIrd class	560	fault rock	cambisol, gley, sand	agriculture land

Humpolec to Jihlava (sites 1–3 in sections Skorkov–Smrčná; length 7.4 km). The second area included the vegetative bands (also up to 3.0) along the II class E55 road from Česke Budějovice to Horní Dvořiště (sites 4–6 in sections Hubenov–Kaplice and Kaplice–Skoronice; total length 4.3 km) and adjoining the III class road (sites 7–9 in sections Kapice–Stradov, Skoronice–Ježov, and Skoronice–Zdíky; total length 3.2 km).

3. MATERIAL AND METHODS

The vegetation of the above sites was investigated on both sides of road and, in the case of the motorway, also in the median stripe. Floristic investigations were performed in the spring (April to June) and autumn (September, October) from 2002 to 2005. We recorded all species of vascular plants (except trees and mosses) growing about 3 m from the road. This distance was a bit smaller (about 1.5 m) in few instances (e.g. along roads running through a spruce forest). The median stripe was investigated in its full width in most cases 1.50 m. The whole length and area of the sites were 14.9 km and 8.02 ha respectively (Table 1). Plant species nomenclature was taken from Kubát *et al.* (2002).

The survey of 235 recorded species was complemented by grouping the species into several life history (ecological) traits: life span (subgroup: perennial, annual, biennial, monocarpic perennial), life form (subgroup: therophyte, geophyte, hemicryptophyte, chamaephyte), agent of pollination (subgroup: wind, insect, self), agent of seed dispersal (subgroup: wind, gravitation, ant, water, self, exozoochory, endozoochory), and life strategies according to Grime's classification (subgroup: C competitive, S stress tolerant, R ruderal, and mixed types, such as CR, RS, CS, and CSR). These traits have been described in the papers Frank and Klotz (1988) and Grime *et al.* (1987).

The studied plant species were also classified into three types according to the way of lateral spreading: species without lateral spread (0), those with the ability of vegetative propagation to 0.30 m per year (1), and species with the ability of vegetative propagation over 0.31 m per year (2) (rounded to 0.01m; Hejný and Slavík 1988, 1990, 1992, Slavík 1995, 1997, 2000, Slavík and Štěpánková 2004, Kubát *et al.* 2002).

Ellenberg's indicator values were taken from Ellenberg *et al.* (1991), which included: light (available data for 93% of species from roadside vegetation), temperature (50%), moisture (85%), soil pH reaction (50%), soil nitrogen (80%), and soil salinity (7%). The ability to tolerate saline soil conditions is crucial for species growing along roads.

Plants registered as alien species in the Czech Republic (Pyšek *et al.* 2002) were identified from the whole survey (56 species, 24%). This set was complemented with following characteristics: invasive status (casual, naturalized, invasive, post invasive), level of abundance (single locality, rare, scattered, locally abundant, common, extinct, single locality, now extinct), and introduction mode (deliberate, accidental, both means) as classified by Pyšek *et al.* (2002). Also the land-use and habitat typical for recent occurrence of the alien species were provided: natural habitats (natural forest and naturally treeless habitats), semi natural habitats (managed landscape except for settlements, communications, arable land,) and human-made habitats according to Pyšek *et al.* (2002).

The recorded plant species were compared according to the groups and subgroups of the above-mentioned plant traits. Qualitative (life span, life form, type of pollination, etc.) data were recorded using contingency, trait and road percentage ratios. Contingency percentage ratio was a value of a data field from common contingency table (Milton 1992). Trait and road percentage ratios described marginal frequencies of plant species occurrence for all combination in relation to plant trait and to road types respectively. The ratios tested association between classification variables by comparing observed cell frequencies.

All used percentage ratios were calculated using following indices:

Contingency percentage ratio (*CT*):

$$CT_{ij} = \frac{N_{S_iR_j}}{N} \cdot 100 \qquad (1)$$

Trait percentage ratio (*PT*):

$$PT_{ij} = \frac{N_{S_iR_j}}{N_{S_iR}} \cdot 100 \qquad (2)$$

*Road p*ercentage ratio (*PR*):

$$PR_{ij} = \frac{N_{S_iR_j}}{N_{SR_j}} \cdot 100 \qquad (3)$$

Where:
i – index of subgroup,
j – index of road type

$N_{S_iR_j}$ – number of species in subgroup *i* and road type *j*

N_{SR_j} – number of species of all subgroups in given road type *j*

N_{S_iR} – number of species of given subgroup *i* in the whole road type

N – number of all species

$$N_{S_iR} = \sum_j N_{S_iR_j}$$

$$N_{SR_j} = \sum_i N_{S_iR_j}$$

$$N = \sum_j N_{SR_j} = \sum_i N_{S_iR}$$

The data of the qualitative traits i.e. Ellenberg's indicator values in relation to light, temperature, etc. are laying into the quantitative scale and therefore mean values were presented (Sen and Puri 1971). Differences among the traits were tested using one-way ANOVA and Tukey HSD post hoc comparison. Both tests were run at the significant level $\alpha = 0.05$.

4. RESULTS

We recorded 235 plant species from 38 families in the chosen localities during four vegetative seasons (Table 2). The most recorded plant species grown only along secondary road (127 species); 34 species grown only along motorway (including median stripes) and 74 species grown along both road types.

Invasive plant species comprised almost 25% of all species growing along roads (Table 3). The occurrence of invasive species was usually "post invasive", belonging to a common abundant type. The accidental mode of introduction occurred typically in human-made habitats.

The number and percentage of functional traits (as life history and form, lateral spread, etc.) are given in Table 4. Perennial plants dominated along all types of investigated road (70%). Biennials and monocarpic perennials contributed to lesser extent (6 and 0%, respectively). Biennials were found mainly along secondary roads (67%). Hemicryptophytes were the most frequent (56%) life form and the least frequent were chamaephytes (8%). Annuals and plant species without the ability for lateral spread were found mostly along the motorway (38 and 53%, respectively). Almost a half of the plant species growing along all investigated roads was pollinated by insects (47%), regardless of road type. The highest ratio of these species was noted for secondary roads (54%).

Seven subgroups of seed dispersal and CSR strategy were recognized. They are represented by a small number of species occurring. However, certain interesting trends can be noted.

Table 5 shows the mean values of Ellenberg's indicator for plants growing along roads. The plant species growing along the motorway significantly differed from those growing along the other types of roads, in terms of their demands for light and moisture (Tukey HSD test for unequal n, $P < 0.05$). Plant species demanding light (mean of Ellenberg's indicator value = 7.71) and tolerating drought (4.30) grew mainly along the motorway. We had only a limited number of information about Ellenberg's indicator values for temperature, soil reaction and, above all, salt.

5. DISCUSSION

5.1. General family and species composition

Plant species diversity recorded at the investigated sites (235 species) is consistent with road verges from north and west Yorkshire (212 species, Akbar *et al.* 2009). The large number of species recorded on the road verges was connected with Asteraceae (41 species), Poaceae (37 species) and Fabaceae (20 species) families (Table 2). Several interesting species were found, such as the

Table 2. List of the botanical families and number of species (n) found in 9 sites during the spring and autumn seasons 2002–2005, see Table 1.

Family	n	Family	n	Family	n
Apiaceae	12	Euphorbiaceae	1	Poaceae	37
Asteraceae	41	Fabaceae	20	Polygonaceae	7
Boraginaceae	3	Geraniaceae	2	Primulaceae	3
Brassicaceae	8	Hypericaceae	1	Pyrolaceae	1
Campanulaceae	3	Juncaceae	7	Ranunculaceae	3
Caryophyllaceae	10	Lamiaceae	11	Rosaceae	10
Chenopodiaceae	8	Linaceae	1	Rubiaceae	5
Convolvulaceae	2	Lycopodiaceae	1	Scrophulariaceae	7
Cyperaceae	4	Lythraceae	1	Solanaceae	1
Dipsacaceae	1	Onagraceae	4	Urticaceae	1
Dryopteridaceae	2	Orchidaceae	1	Valerianaceae	1
Equisetaceae	2	Papaveraceae	2	Violaceae	5
Ericaceae	3	Plantaginaceae	3		

Table 3. Composition of the invasive species (n = 56) from the lines along roads. Number (and percent) of species are given. Classification were taken from Pyšek *et al.* 2002 (details see in text). *N – natural habitats, S – seminatural habitats, H – human-made habitats.

Invasive plant classification		Total
Invasive status	Post invasive	28 (50)
	Invasive	15 (27)
	Naturalized	9 (16)
	Casual	4 (7)
Land use - habitat*	H	27 (48)
	SH	20 (36)
	NSH	9 (16)
Abundance type	Common	48 (85)
	Scattered	6 (11)
	Locally abundand	1 (2)
	Rare	1 (2)
Introduction mode	Accidental	38 (68)
	Deliberate	9 (16)
	Both means	9 (16)

Table 4. Composition of the flora from the lines along roads in comparision to some ecological traits. NSR number species in individual categories on trait and road, CT contingency percent ratio, PT trait percent ratio, PR road percent ratio, more details see in text.

Ecological trait	Subgroup	Motorway (S_iR_1)				Motorway with secondary roads (S_iR_2)				Secondary roads (S_iR_3)				Road sum (S_iR)			
		N_{SR}	CT (%)	PT (%)	PR (%)	N_{SR}	CT (%)	PT (%)	PR (%)	N_{SR}	CT (%)	PT (%)	PR (%)	N_{SR}	CT (%)	PT (%)	PR (%)
Life history	Perennial (S_1R_j)	19	8	12	56	53	23	32	72	92	39	56	72	164	70	100	–
	Annual (S_2R_j)	13	5	24	38	18	8	33	24	24	10	43	19	55	24	100	–
	Biennial (S_3R_j)	2	1	13	6	3	1	20	4	10	4	67	8	15	6	100	–
	Monocarpic perennial (S_4R_j)	0	0	0	0	0	0	0	0	1	1	100	1	1	0	100	–
	Subgroup sum (SR_j)	34	14	–	100	74	31	–	100	127	54	–	100	235	100	–	–
Life form	Hemicryptophyte (S_1R_j)	19	8	14	56	41	17	31	56	72	31	55	57	132	56	100	–
	Therophyte (S_2R_j)	12	5	22	35	18	8	33	24	24	10	45	19	54	23	100	–
	Geophyte (S_3R_j)	2	1	7	6	9	4	30	12	19	8	63	15	30	13	100	–
	Chamaephyte (S_4R_j)	1	0	5	3	6	3	32	8	12	5	63	9	19	8	100	–
	Subgroup sum (SR_j)	34	14	–	100	74	31	–	100	127	54	–	100	235	100	–	–
Ability to lateral spread	Without (S_1R_j)	18	8	19	53	29	12	31	39	46	19	50	36	93	39	100	–
	<0.30 m per year (S_2R_j)	13	5	15	38	23	10	26	31	53	23	59	42	89	38	100	–
	>/= 0.30 m per year (S_3R_j)	3	1	6	9	22	9	41	30	28	12	53	22	53	23	100	–
	Subgroup sum (SR_j)	34	14	–	100	74	31	–	100	127	54	–	100	235	100	–	–
Pollination agents	Insect (S_1R_j)	14	6	13	41	29	12	26	39	68	29	61	54	111	47	100	–
	Wind (S_2R_j)	11	5	17	32	30	13	47	41	23	10	36	18	64	27	100	–
	Self (S_3R_j)	8	3	15	24	14	6	25	19	33	14	60	26	55	24	100	–
	Without (S_4R_j)	1	0	20	3	1	0	20	1	3	1	60	2	5	2	100	–
	Subgroup sum (SR_j)	34	14	–	100	74	31	–	100	127	54	–	100	235	100	–	–
Seed dispersal	Wind (S_1R_j)	14	6	17	41	33	14	41	45	34	14	42	27	81	34	100	–
	On animal's hair (S_2R_j)	6	2	12	17	15	6	31	21	28	12	57	22	49	21	100	–
	Gravitation (S_3R_j)	7	3	16	21	12	5	27	16	25	11	57	20	44	19	100	–
	Self (S_4R_j)	7	3	27	21	5	2	19	7	14	6	54	11	26	11	100	–
	Ant (S_5R_j)	0	0	0	0	4	2	21	5	15	6	79	12	19	8	100	–
	In animal's digestive tract (S_6R_j)	0	0	0	0	4	2	36	5	7	3	64	5	11	5	100	–
	Water (S_7R_j)	0	0	0	0	1	0	20	1	4	2	80	3	5	2	100	–
	Subgroup sum (SR_j)	34	14	–	100	74	31	–	100	127	54	–	100	235	100	–	–
Strategy	C (S_1R_j)	5	2	8	15	21	9	36	28	33	14	56	26	59	25	100	–
	CSR (S_2R_j)	7	3	14	20	12	5	24	16	31	13	62	25	50	21	100	–
	RC (S_3R_j)	10	4	22	29	14	6	30	19	22	9	48	17	46	20	100	–
	R (S_4R_j)	2	1	8	6	14	6	54	19	10	4	38	8	26	11	100	–
	CS (S_5R_j)	3	1	12	9	5	2	19	7	18	8	69	14	26	11	100	–
	S (S_6R_j)	2	1	13	6	6	3	37	8	8	4	50	6	16	7	100	–
	SR (S_7R_j)	5	2	42	15	2	1	16	3	5	2	42	4	12	5	100	–
	Subgroup sum (SR_j)	34	14	–	100	74	31	–	100	127	54	–	100	235	100	–	–

Table 5. Ecological requirements of plant species from lines along three types of roads. Ellenberg's indicator values were used to express the relation to investigated factors. Number of observation (n), mean of indicator value, and standard deviation (SD) are given. *Means that were significantly different in Tukey HSD test for unequal n are followed by the different letter (HSD). Detailes see in text.

Factor	Total number	Motorway				Motorway with secondary roads				Secondary roads			
		n (%)	mean	SD	HSD	n (%)	mean	SD	HSD	n (%)	mean	SD	HSD
Light*	219	28 (82)	7.71	0.91	a	69 (93)	6.62	1.23	b	122 (96)	6.62	1.27	b
Moisture*	200	27 (79)	4.30	1.29	a	57 (77)	5.48	1.34	ab	116 (91)	5.70	1.71	b
Nitrogen	187	26 (76)	3.96	2.42	a	61 (82)	5.11	1.90	a	100 (79)	5.42	2.26	a
Soil reaction	117	19 (56)	4.00	2.39	a	33 (45)	4.75	1.94	a	65 (51)	5.63	1.96	a
Temperature	118	17 (50)	5.40	0.74	a	22 (30)	5.29	0.47	a	79 (62)	5.22	0.67	a
Salt	16	3 (9)	2.00	1.00	a	10 (14)	1.10	0.32	a	3 (2)	1.00	0.00	a

numerous populations of two club-moss species (*Huperzia selago* (L.) Schrank et C.F.P. Martius, L*ycopodium clavatum* L.), *Epipactis helleborine* (L.) Crantz, *Hypochaeris radicata* L. and *Pyrola minor* L. The occurrence of these species near the motorway is certainly remarkable (embankment; distance about 4 m from the asphalt surface of the motorway running through a forest). In such managed ecosystems, road-side verge is sometimes viewed as safe sites for the native or rare flora (Ullmann and Heindl 1989). Roads in the landscape can serve not only as propagation lines (Tyser and Worley 1992, Hansen and Clevenger 2005, Zwaenepoel *et al.* 2006), but also as refugia in a landscape rich in species composition (Hovd and Skogen 2005). The finding of the above-mentioned species confirms this.

5.2. Invasive plant species

Road verges are affected by construction repairs, road maintenance, and mowing (Forman *et al.* 2002). This suggests that road-sides are suitable habitats for both the occurrence and spread of weed and ruderal species (Ullmann *et al.* 1998, Godefroid and Koedam 2004, Truscott *et al.* 2005). Invasive species distribution was important characteristic for the greenery along roads in this study. Result of our research is in accordance with the literature: road-side verges are often considered as reservoirs for non-native or invasive species (Tyser and Worley 1992, Hansen and Clevenger 2005, Rentch *et al.* 2005, Wrobel 2006).

5.3. Life history, life form, and lateral spread

Vegetation accompaniments of roads differ from surrounding vegetation not only in species composition (Jantunen *et al.* 2006), but also in life form and history of the plant species (Cilliers and Bredenkamp 2000, Šerá 2008). It was found that there are mainly perennials and species proliferating generatively than vegetatively along roads (Table 4). Most species growing along all types of roads showed a characteristic feature: the inability of vegetative spread and low abilities of proliferating less than 0.30 m per year, which means that the number of species was declining with increasing ability of vegetative reproduction. The largest representation of species with a vegetative means of reproduction was recorded along the IInd class roads (Table 4) and a relatively high number of annuals/therophytes were found along the motorway. The road verges have smaller vegetative coverage (and higher species variability) than surrounding localities (Hovd and Skogen 2005). The abundance of annual plants is highest where perennials are sparse (Steinschen *et al.* 1996). This shows that verges are suitable habitat for shortly living species, increasing their chance of survival and probably also for proliferation. This was also confirmed by Skov (2000), who found a close positive correlation between the occurrences of annuals with road habitat. Similar observations were found by Ullmann *et al.* (1998). They confirmed a greater proportion of short-lived species in the verge edge in comparison to the outermost verge.

5.4. Pollination

Our results correspond with the finding of Skov (2000), who noted the occurrence of insect pollinated plant species along roads in Denmark. A large ratio of insect pollinated plant species can be explained by the fact that localities along roads are dominated (in number and cover) by species associated with field habitats or semi-natural grasslands (Jantunen *et al.* 2006), i.e. species dependent on insect pollinators (Hegland and Totland 2005). The number of self-pollinating and anemophilous plant species were only 50 % of the number of insect pollinated ones (Table 4). A relatively high ratio of anemophilous species was found along both the motorway and secondary roads (Table 4). It is generally considered that adaptation to wind pollination is advantageous for all species in unfavorable habitats and unproductive environments (Šerá and Šerý 2004).

5.5. Seed dispersal

Schmidt (1989) stated that almost all plant species growing along roads can be carried by vehicles. We found that anemochorous species (34%) were the most frequently occurring species along the roads and a low number of them (6%) was growing along the motorway (Table 4)). The number of anemochorous plant species along the secondary roads and motorway with secondary roads were equal. Anemochorous species produced the smallest and the most numerous seeds of the plant categories with different types of seed dispersal (Šerá and Šerý 2004). Zwaenepoel *et al.* (2006) found that plants dispersed by vehicles (and by mud on vehicle wheels) consist mostly of species with small, light seeds and a persistent seed bank. Thus, it is likely that road habitats are suitable for species adapted to wind pollination. The second largest category consisted of species which disperse due to various hooks and hairs on mammals´ hair and birds´ feathers (exozoochory; 21%; Table 4). Open habitats (pasture riverbanks, pastures and road verges) significantly differ from tree forest habitats in the higher number of species with fur and feather dispersal (in tropical condition, Mayfield *et al.* 2006). It is, in principle, the same category as exozoochory. Seeds with various protuberances from the canopy part of generative organs will probably „run“ with the wind from their parent plant (“steppe runner“), if they do not stick to an animal carrier. The form of “steppe runner“ is an adaptation to seed dispersal in natural conditions of steppe grass-herbaceous formations (Pijl 1982). The high number of anemochorous plants, and plants with protuberances and hairs, growing along roads is not probably a coincidence. Light seeds or seeds with hooks and protuberances can be very advantageous in the conditions of local turbulences from passing vehicles. Further investigations should confirm or refute this theory.

The total number of myrmecochorous species (ant dispersed) was 8% (Table 4). The secondary roads had the largest percentage of this amount (79%; Table 4). It is known that road verges host amphibian (Orlowski *et al.* 2008), small mammal (Bellamy *et al.* 2000) and a large number of various species of ant (Samways *et al.* 1997). Ants and lizards were repeatedly observed during this project, mainly on sunny locations near the motorway (edges behind the full line, motorway shoulders etc.). Another interesting finding is the absence of myrmecochorous species growing only along the motorway. Thus, ants settled near roads searching primarily for animal food. Accidental collecting of seeds with protein carunculum probably occurs only along secondary roads with more frequently occurring myrmecochorous plant species. On the contrary, a relatively high number of species with the tendency to disperse seeds through gravitation was found along the motorway (21%; Table 4).

The smallest category represents plant species dispersing through animals´ digestive tracts (endozoochorous species) or water (hydrochorous species). These results are predictable. Animals (birds and mammals) usually do not nest in close distance to roads, and so this finding was not surprising. A lot of small mammals can be found along all types of roads (Bellamy *et al*. 2000), mainly voles (field mice) in our conditions. Consumption or seed dispersal by these species have not been recorded along the roads.

5.6. CSR strategy

A striking feature was the very low occurrence of C-strategists along the motorway (8%; Table 4), where RC-strategists dominated (29%; Table 4). The highest occurrence of R-strategists was found in the mixed category of roads (54%) and S-strategists along the secondary road (69%; Table 4). Truscott *et al.* (2005) found that the edges of road verges are covered mainly by ruderal species. Our study dealt with the plants on road verges as such and did not take into account the distances from the road edges. The disclosed trends correspond to the fact that road edges are open habitats with an anthropogenic effect (Ullmann *et al.* 1998, Skov 2000), and offer a suitable place for lawn and pasture species (Jantunen *et al.* 2006, Mayfield *et al.* 2006).

5.7. Light, temperature, and moisture

There grew mainly light demanding species along the motorway (Ellenberg's indicator value 7.71) and those tolerating drought (Ellenberg's indicator value 4.3, Table 5). These data are similar to the demands of plants from large cities. Plant species growing in the central parts of agglomerations are also more light- and drought-demanding than species from the periphery in nature (Kowarik 1990). Jantunen *et al.* (2006) declared that motorways are alternative habitats for grassland flora. Influence of small macroclimate features was proved on the species composition along roads (Godefroid and Tanghe 2000). Plant species composition is significantly affected by moisture level between field margins and roads verges in agricultural landscapes (Hovd and Skogen 2005). In this study, the obtained data confirm that motorways are rather more open habitats with abundant light and dry verges than narrow secondary roads.

5.8. Soil pH reaction, nitrogen, and salinity

The vegetation of roads verges and adjacent localities along roads is affected by traffic emissions and substances added to the road spreading (Bernhardt-Romermann *et al.* 2006). Road verges are covered with salt-tolerant plants, and there is a general decrease of nitrogen demanding species with increasing distance from the roads (Godefroid and Koedam 2004, Truscott *et al.* 2005, Akbar *et al.* 2009). Soil reaction, nitrogen and salinity demands of plants occurring along various types of roads were not significantly different (Table 5). In spite of that, species tolerating higher soil acidity, lower content of nitrogen and a higher concentration of salts in soil grew along the motorway in comparison with secondary roads. The low number of species demanding nitrogen in the soil was probably caused by the fact that the soil along the motorway was sandy.

In total, there were 16 salt-tolerant plant species on the road verges. The most common halophyte on roads is *Puccinellia distans* (Jacq.) Parl. (in central Europe, Beyschlag *et al.* 1996), where salty localities along roads are its secondary habitat. Its occurrence was recorded along all types of investigated roads. It created mono-species compact lines. Along with this species, there occurred also the following species: *Atriplex sagittata* Borkh., *Polygonum aviculare* agg., *Spergularia rubra* (L.) J. Presl et C. Presl, *Cardaria draba* (L.) Desv., *Elytrigia repens* (L.) Nevski and *Digitaria sanguinalis* (L.) Scop. All of these plant species grew in the brim at the asphalt edge, about 0.25 to 0.35 m wide (Truscott *et al.* 2005, Wrobel 2006).

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