Tram tracks as specific anthropogenic habitats for the growth of plants

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Although tramway tracks are found in most cities, their flora is not thoroughly researched. Many more studies relate to railway areas as specific anthropogenic habitats for the development of plants. Both railway and tram tracks represent specific ecological migration corridors for plants. The objective of this study was to determine the relationship between the floristic composition and selected soil parameters of tram tracks. In 2014-2015, floristic studies were carried out along tram tracks in the Upper Silesian conurbation (southern Poland). Depending on the dominant species, five groups of sites with varying floristic composition were distinguished. Five plots with an area of 1 m^2 were randomly selected in each of the sites. The species composition was determined at each plot together with the cover-abundance of all species occurring at a given plot according to Westhoff's and van Maarel's scale. Soil samples were collected from each plot and analysed for pH, the content of biogenic elements and heavy metals. A total of 329 species of vascular plants were identified on the tram tracks of the surveyed area, and 40 species on the plots. The dominant species included: *Amaranthus retroflexus*, *Achillea millefolium, Plantago lanceolata, Hieracium pilosella, Silene vulgaris, Taraxacum sp.* and *Trifolium repens.* Grouping of plots in respect of soil factors largely reflects their species composition. It has been found that the content of nitrate nitrogen, lead and phosphorus has the strongest impact on the floristic diversity of the railway tracks. Based on these parameters, three groups of species were distinguished: nitrophytes, metallophytes and common, i.e. not closely associated with the studied soil properties. Three habitat types of varying plant species composition were distinguished based on the content of nitrate nitrogen and lead: 1) nitrophilous dominated by *Amaranthus retroflexus*, 2) with increased content of heavy metals, dominated by *Silene vulgaris* and 3) mesotrophic dominated by meadow species (*Achillea millefolium*, *Plantago lanceolata*, *Hieracium pilosella, Taraxacum* sp., *Trifolium repens*).

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Abstract

Although tramway tracks are found in most cities, their flora is not thoroughly researched. Many more studies relate to railway areas as specific anthropogenic habitats for the development of plants. Both railway and tram tracks represent specific ecological migration corridors for plants. The objective of this study was to determine the relationship between the floristic composition and selected soil parameters of tram tracks. In 2014-2015, floristic studies were carried out along tram tracks in the Upper Silesian conurbation (southern Poland). Depending on the dominant species, five groups of sites with varying floristic composition were distinguished. Five plots with an area of 1 m^2 were randomly selected in each of the sites. The species composition was determined at each plot together with the cover-abundance of all species occurring at a given plot according to Westhoff's and van Maarel's scale. Soil samples were collected from each plot and analysed for pH, the content of biogenic elements and heavy metals. A total of 329 species of vascular plants were identified on the tram tracks of the surveyed area, and 40 species on the plots. The dominant species included: *Amaranthus retroflexus*, *Achillea millefolium, Plantago lanceolata, Hieracium pilosella, Silene vulgaris, Taraxacum sp.* and *Trifolium repens.* Grouping of plots in respect of soil factors largely reflects their species composition. It has been found that the content of nitrate nitrogen, lead and phosphorus has the strongest impact on the floristic diversity of the railway tracks. Based on these parameters, three groups of species were distinguished: nitrophytes, metallophytes and

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common, i.e. not closely associated with the studied soil properties. Three habitat types of varying plant species composition were distinguished based on the content of nitrate nitrogen and lead: 1) nitrophilous dominated by *Amaranthus retroflexus*, 2) with increased content of heavy metals, dominated by *Silene vulgaris* and 3) mesotrophic dominated by meadow species (*Achillea millefolium*, *Plantago lanceolata*, *Hieracium pilosella,* *Taraxacum* sp., *Trifolium repens*).

Introduction

Anthropogenic habitats, which include urban areas, are characterised by a relatively high species richness which results from the heterogeneity (mosaic) of habitats (Klera & Bacieczko, 2013). Vegetation on urban habitats can develop in peculiar places, very difficult for the growth of plants, such as fissures in buildings or pavement slabs. A specific type of habitat occurring in many cities are tram tracks (Sudnik-Wójcikowska & Galera, 2005). Tram transport is a popular choice by the locals due to the lack of chemical emission in the cities (Klera & Bacieczko, 2013) and its independence from transportation difficulties and traffic by excluding railway tracks from the roadway, which definitely makes travelling in crowded cities easier (Stoeck, 2012).

Areas of tram tracks are very poorly researched in terms of nature. In Poland, only one paper was published on tram tracks in Szczecin (Klera & Bacieczko 2013). The flora of tram tracks in Braunschweig was studied by Brandes (2005). Much more scientific work focused on railway areas, where habitat conditions are often very similar, but in many other cases significantly different (e.g. Gańko, 2005; Fornal-Pieniak & Wysocki, 2010; Filibeck, Cornelini & Petrella, 2012; Altay et al. 2014, Pfeiffenschneider, Gräser & Ries, 2014).

Vegetation growing on tram tracks serves different functions. First of all, it represents a high aesthetic value in the cities, which often determines the land-use planning of a given area towards green railway or tramway tracks (Giedych, Szulczewska & Maksymiuk, 2012; Wagner, Krauze K. & Zalewski, 2013). It also affects the microclimate of habitats (Wagner, Krauze K. & Zalewski, 2013), while dwarf plant species muffle the noise and prevent stray voltage, thus prolonging the life of rails. Due to a significant impact of tram transport, specific vegetation develops on tracks, and most of the species occurring there are characterised by specific adaptations such as durability (hemicryptophytes), xeromorphy, photophilia, resistance to herbicides and mechanical injuries, anemochory. Furthermore, a considerable contribution of seedlings and large fluctuations in the number of species and their abundance can be observed (Brandes, 2005; Sudnik-Wójcikowska & Galera, 2005; Sudnik-Wójcikowska & Galera, 2011).

The flora of tram tracks in the hitherto surveyed towns and cities in Poland is represented by a large number of anthropophytes, especially neophytes, including invasive species (Sudnik-Wójcikowska & Galera, 2005; Klera & Bacieczko, 2013). Due to the linear nature of tracks, they may serve as migration routes for many species, which can quickly spread through air movements (Priemus & Zonneveld, 2003; Hansen & Clevengerg, 2005; Wiłkomirski et al., 2012; Rutkovska et al., 2013). A significant role of railway transport as ecological migration corridors is emphasized among others by Gańko (2005) and Pouteau, Hulme & Duncan (2014). It can therefore be assumed that this function is also fulfilled by tram tracks, even though they have rather local character. Sudnik-Wójcikowska & Galera (2005) point out that not all types of anthropogenic habitats have been sufficiently researched. This should be improved in the context of threats posed by invasions of alien species that penetrate primarily the anthropogenic vegetation (Šilc et al., 2012). The conclusions reached should be taken into account in urban planning, especially planning of green areas. At present, one of the biggest challenges for urban areas, in particular urban agglomerations and conurbations, is to improve the biological conditions and to enrich the ecosystems (Bieske-Matejak, 2005).

The objective of this study was to determine the floristic diversity of tram tracks in relation to selected soil parameters. An attempt was undertaken to answer the following questions: (a) What are the specific features of the dominant species in the flora of tram tracks? (b) What are the main soil parameters determining the composition of flora on these habitats? (c) Are there any other factors (other than soil) with a significant impact on the development of specific vegetation on tram tracks?

Materials & Methods

Study area

The research covered the area of tram infrastructure in the Upper Silesian conurbation, located in the central part of the Silesia Province (southern Poland). In terms of physiographic division, the area is located within the Silesian Upland (Kondracki, 1998). This macroregion is characterised by warm temperate climate with optimum moisture content (Ziernicka-Wojtaszek & Zawora, 2009). Western winds prevail, although the climate is affected both by the oceanic air masses from the west and the continental air masses from the east. The average annual temperature in 2015 was 9.7°C, and the total annual precipitation did not exceed 600 mm (Ustrnul et al. 2015). Urban areas are characterised by local topoclimates resulting from intensive human activities. The interurban tram network in the Upper Silesian conurbation is one of the largest in Europe. It is located within the limits of 13 cities and the total length of tram tracks is 225 km, including 131 km of tracks excluded from the roadway. The infrastructure is owned by Tramwaje Śląskie S.A. (Silesian Trams PLC; approval number of statement: DR / RR – 1498 / 2015). It supports the most urbanized region in Poland, with the highest population density (Budzyński, 2015).

Data collection

In 2014-2015, floristic inventories were carried out along one-kilometre sections of tram tracks. Only tram tracks excluded from the roadway were included in the inventories. Their age varies. Tramway lines running through the centres and main districts of the cities have been upgraded after 2008. One line with a length of ca. 40 km was restored by 2006, while the others have not been renovated since 1980s or the 1990s. Some of the surveyed tram tracks are located far from traffic routes, but most of them run along the routes or within a green belt separating the roadways. Only species occurring up to 2.5 m from the outer rail were taken into account. Two biotopes were distinguished in the area of tram tracks after Bacieczko & Klera (2013): strict tram tracks (the area between rails or tracks up to 0.5 m from the outer rail of tram tracks) and tracksides (a strip of land running from 0.5 m to 2.5 m from the outer rail of tracks). Based on field observations, five repeatable (in terms of species composition) groups were distinguished, predominant in the whole network of the conurbation. Five sites were randomly selected in each of them (Table 1) and a square or rectangular plot with an area of 1 m^2 was delimited at each site. In October 2015, soil samples were collected from each plot (Table 2). The material was collected in the form of bulk samples (from five places within a plot – one in the central part and four in the corners) from up to a 15-cm surface layer of soil. The following analyses were carried out by the Regional Chemical-Agricultural Station in Gliwice, applying the standard PN-EN ISO/IEC 17025:2005: acidity pH in KCl, the content of available forms of phosphorus (P), potassium (K) and magnesium (Mg), the content of nitrate nitrogen (N-NO3) and ammonia nitrogen (N-NH4), the content of heavy metals such as: lead (Pb), cadmium (Cd), zinc (Zn) and copper (Cu). Detailed analysis of the floristic composition was conducted at each plot. The contribution of a given species was expressed using a 10-point cover-abundance scale of Braun-Blanquet modified by van Maarel and Westhof (Maarel, 1979). The percentage cover was assessed for each dominant species. In addition, other factors that may affect the flora were also determined for each plot, including: the presence of moss and their percentage cover, the presence of debris, the biotope (as described above) and the distance from a road to take account of the impact of road traffic.

Furthermore, the characteristic of species noted on floristic inventory was done based on affilation geographical-historical groups affilation (Kornaś 2002, Mirek i in. 1995, Tokarska-Guzik i in. 2012), Raunkiaer plant life forms affilation, type of seed dispersal and syntaxonomic affilation (Ellenberg 1973).

Table 1. Location of plots

Table 2. Average results of soil factors for 25 plots

Statistical analyses

Cluster analysis was applied to identify groups of sites most similar to each other in terms of soil factors. The data were standardized prior to cluster analysis. The Euclidean distance was applied in the formation of clusters and Ward's method was used to calculate distances between clusters. The result of clustering was presented in the form of a dendrogram and the clusters were used in the discriminant analysis to select soil factors that account for the observed division to the greatest extent. Canonical analysis revealed the existence of three statistically significant canonical functions ($p \leq 0.00001$). The stepwise backward procedure was applied to identify the most significant variables. The model took account of partial Wilks' lambda, which specifies the contribution of a variable in the discrimination between groups. The smaller the value, the greater the discriminatory power (Stanisz, 2007 b).

To extend the discriminant analysis and graphical presentation of relationships between species occurrence and soil factors, Canonical Correspondence Analysis (CCA) was performed after DCA analysis showed a gradient of more than 3 SD. The Monte Carlo Test was run with

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999 permutations, and the results were considered statistically significant at $p<0.05$.

To determine the effect of other nominal variables (in addition to soil factors), two-way analysis of variance was used. The percentage cover of a dominant species in a given plot was defined as a dependent variable. The biotope, the distance from a road, the presence of debris and the cover-abundance of moss were used as qualitative factors. The result is a graphical representation of the effect of interaction between two independent (explanatory) variables (Stanisz, 2007 a).

Results

A total of 40 species of vascular plants were identified in 25 plots during floristic inventories. Five groups with different dominant species were distinguished based on the floristic composition of the plots: 1. *Amaranthus retroflexus*, 2. *Achillea millefolium* and *Plantago lanceolata*, 3. *Hieracium pilosella* and *Achillea millefolium*, 4. *Silene vulgaris*, 5. *Taraxacum* sp. and *Trifolium repens*.

Species that dominate on tram tracks are common plants, apophytes (Fig. 1a), hemicryptophytes (Fig. 1b) with a wide range of ecological tolerance. They are heliophilous, anemochorous and tolerate increased salinity and the content of heavy metals in the soil. Most of the plants from the tram tracks represent CSR, C or CR life strategies. The dominant type of dispersal is anemochory and epizoochory (Fig.1c) and dominant syntaxon is a Molinio-Arrhenetheretea (Fig. 1d). The most common species are *Achillea millefolium* (16 plots), *Taraxacum* sp. (15), *Plantago lanceolata* (10) and *Poa annua* (10).

Fig. 1. Percentage of individual species traits in the surveyed plots

The preliminary selected sites with similar species composition largely correspond to five groups obtained as a result of cluster analysis (Fig. 2.). This applies mainly to plots with *Silene vulgaris* (cluster 1) and with *Amaranthus retroflexus* (clusters 3 and 5). The remaining species were included in three different groups (clusters).

Fig. 2. Dendrogram for selected sites – clustering in relation to soil factors (Euclidean distance, Ward’s method). Before the names are nubers of plots

The first, most specific group consists of four plots distinguished by the highest content of lead in the soil. The second group comprises plots with a lower content of this element in the soil. The third group is characterised by the highest values of available forms of nitrogen – nitrate nitrogen. The fourth, most diverse (in terms of the dominant species) group is characterised by the highest content of magnesium. The fifth group, on the other hand, shows much lower content of available forms of phosphorus compared to the other groups (Table 2).

The discriminant analysis, which explains the above clustering of the sites, selected three variables from all the soil data: the content of phosphorus, the content of nitrate nitrogen and the content of lead (Table 1). Partial Wilks' lambda indicates that the variable nitrate nitrogen (partial Wilks' 0.046) is the largest contributor to the overall discrimination. The variable with the smallest, but highly significant contribution is phosphorus (partial Wilks' 0.206). The first discriminant function is affected the most by the content of nitrate nitrogen, while the two other variables have minor effect. The second function is created mainly by the variable lead and, to a lesser extent, phosphorus. The chi-square test confirms the statistical significance of both functions ($p<0.0000001$), and the first two functions explain 89.99% of the discriminatory power, with the largest contribution by the first function (73%).

Table 3. Summary of discriminant function analysis (backward stepwise procedure)

The first discriminant function discriminates mainly between the third group (Fig. 3) and all the other groups. The second function discriminates between the first and the fifth group and the two other groups (i.e. the second and the fourth one) with the common dominant species.

Fig. 3. Scatter plot of canonical discriminant analysis. The numbers in figure correspond to the numbers of plots

The results of Canonical Correspondence Analysis show the significant effect of nitrate nitrogen and lead on the floristic diversity of the tram tracks. The Monte Carlo Test clearly confirms the statistical significance of the two factors are ($p<0.05$) – Table 4.

Table 4. Selected soil factors of Canonical Correspondence Analysis (CCA)

CCA distinguished three main groups of species. The first group includes species associated with the variable heavy metals, including lead (Fig. 3), i.e. *Silene vulgaris* and species such as: *Leontodon hispidus*, *L. autumnalis* and *Rumex acetosa*, which actually occur at the sites with the higher content of lead in the soil covered with debris.

Fig. 4. Results of Canonical Correspondence Analysis (CCA). ***Ac.neg***. – *Acer negundo,* ***Ach.mill***. – *Achillea millefolium,* ***Aeg.pod.*** – *Aegopodium podagraria,* ***Am.ret.*** – *Amaranthus retroflexus,* ***Ar.thal.*** – *Arabidopsis thaliana****,*** ***Arc.lap.*** – *Arctium lappa, Art.vulg. – Artemisia vulgaris,* ***Bel.per.*** – *Bellis perennis,* ***Cer.arv.*** – *Cerastium arvense*, ***Ch.gl.*** – *Chenopodium glaucum,* ***Ch.pol.*** – *Chenopodium polyspermum,* ***Con.arv.*** – *Convolvulus arvensis,* ***Con.can.*** – *Conyza canadensis****,*** ***Cor.can.*** – *Corynephorus canescens,* ***Dau.car.*** – *Daucus carota,* ***Dig.sang***. – *Digitaria sanguinalis*, ***Dip.mur.*** – *Diplotaxis muralis,* ***Ech.c-g.*** – *Echinochloa crus-galli*, ***Fr. exc.*** – *Fraxinus excelsior*, ***Gal.par.*** – *Galinsoga parviflora*, ***Hier.pil.*** – Hieracium pilosella, ***Hyp.rad.*** – *Hypochoeris radicata,* ***Leo.aut.*** – *Leontodon autumnalis,* ***Leo.his.*** – *Leontodon hispidus*, ***Med.lup.*** – *Medicago lupulina*, ***Med.sat.*** – *Medicago sativa,* ***Mel.alb.*** – *Melilotus album,* ***Pl.lan.*** – *Plantago lanceolata*, ***Pl.maj.*** – *Plantago major*, ***Po.ann.*** – *Poa annua*, ***Pol.av.*** – *Polygonum aviculare*, ***Rum. ac.*** – *Rumex acetosa*, ***Sed.acr.*** – *Sedum acre*, ***Set.pum.*** – *Setaria pumila*, ***Set.vir.*** – *Setaria viridis*, ***Sil.vulg.*** – *Silene vulgaris,* ***Sol.can.*** – *Solidago canadensis,* ***Tarax sp.***, – *Taraxacum officinale s.l.,* ***Tr.prat.*** – *Trifolium pratense,****Tr.rep***. – *Trifolium repens.*

The second group consists of species growing on soils with a high content of nitrate nitrogen and phosphorus. Therophytes of alien origin dominate there, including mainly: *Amaranthus retroflexus*, *Setaria viridis*, *Diplotaxis muralis* and *Chenopodium polyspermum*.

The largest, third group is represented by native common species, the occurrence of which is not closely related to any particular soil parameter (Fig. 4), for instance: *Taraxacum* sp., *Achillea millefolium*, *Hieracium pilosella*, *Plantago lanceolata*, *P. major*, *Poa annua*, *Trifolium repens*, *Conyza canadensis*, *Bellis perennis*.

Two-way analysis of variance was applied to assess the impact of other factors such as location in relation to the tracks and the distance from the road in the traffic route on the percentage cover of a given species at a given site. The analysis showed the statistical significance of the joint effect of the location in relation to the tram tracks and the distance from the road on the percentage cover of the dominant species (Fig. 5). In the close proximity of a plot to the road, the percentage cover of a dominant species is higher if a given plot is located on the strict tram tracks, whereas the more distant plots show only a small diversity in both biotopes in respect of a cover-abundance of a dominant species. No statistical correlation was determined for other dependent (response) variables: such as percentage cover of moss and the presence of debris.

Fig. 5. Effect of interaction between biotop and the distance from the road on the percentage cover of the dominant species (ANOVA). P – tracksides, S – strict tramway rails

Discussion

Anthropophytes are an important component of the flora on tram tracks and they represent 27.5% of the total number of species found at the surveyed sites. Almost the same proportion of this group of plants (27.6%) was recorded on tram tracks near Szczecin (Klera & Bacieczko, 2013). In studies related to railway lines, the contribution of species of alien origin varies to a larger extent and depends on the geographic location and the type of vegetation that occurs in areas crossed by tracks. For example, only 8.5% of anthropophytes were observed along the 4.5 km section of the railway line in Italy (Filibeck, Cornelini & Petrella, 2012), and 19.6% at the railway stations in the north-eastern part of Switzerland (Tinner & Schumacher, 2004). In eastern Poland (Powodowo station), the contribution of this group of species was 25.7% (Nowińska & Czarna, 2008), in the railway areas in Pomerania – 27.7% (Lejmbach et al., 1975), and in the vicinity of Pabianice – 36.4% (Warcholińka & Suwara-Szmigielska, 2009).

Usually those are hemicryptophytes – up to 65% of all species identified in the presented study occurred in this life form, while on tracks in Szczecin – about 50%. A very important component of the flora on the described habitats are therophytes – their contribution at the surveyed sites comes to 37.5% of the flora, and in the area of tram infrastructure in Szczecin – less than 30% (Klera & Bacieczko, 2013). Herbaceous chamaephytes are much less common on tracks, while geophytes or phanerophytes occur occasionally. A similar spectrum of life forms was observed by most authors who studied the flora of railway areas (Cornelini & Petrella, 1996; Filibeck, Cornelini & Petrella, 2012). Biennial hemicryptophytes with leaves arranged in rosettes often occur on tracksides (Tinner & Schumacher, 2004; Nowińska & Czarna, 2008). Many authors report on a considerable contribution of alien therophytes in the flora of tram tracks (e.g. Niemi, 1969; Brandes, 1983; Tinner & Schumacher, 2004; Galera et al., 2011). Their contribution at the studied sites was 20%, as in the railway areas of Pomerania – 22.3% (Lejmbach et al., 1975).

The occurrence of a large number of species with a wide range of ecological tolerance, the life strategy C, CR and CSR, as well as species tolerant of increased content of heavy metals indicates a serious degradation of these habitats. In terms of contamination, this area is similar to other types of anthropogenic habitats in the Silesian conurbation. Pollution in this area is connected with the past of this area. The presence of large numbers of zinc ore and lead mines as well as ironworks left the area with huge amounts of wastes in the form of dumps and soil contamination (Dziubanek, Baranowska & Oleksiuk, 2012).

Similar systems of vegetation occur in the whole conurbation. Areas with *Amaranthus retroflexus* are characterised by the increased concentration of nitrate nitrogen and phosphorus in the soil. Other studies also show that this plant is highly nitrophilous (Costea, Weaver & Tardiff, 2004). It is difficult to explain the increased content of this element, especially since the said places are very diverse in terms of location, surroundings and the age of tracks. On the other hand, sites with *Silene vulgaris* are situated on the substrate with increased concentrations of lead and/or other heavy metals. The location of metal processing plants in the vicinity of some of these places may explain the high content of these metals in the soil (Dziubanek, Barabowska & Oleksiuk, 2012). Previous studies proved that *Silene vulgaris* develops ecotypes growing in areas with a high content of heavy metals in the soil (Schat & Vooijs, 1997; Chardonnes et al., 1999; Verkleij et al., 2001). Other systems are formed by dominant species of a large ecological tolerance, common in various types of urban habitats. Their area often extends beyond the strict tracks. They are also more common on several years old tracks where some remains or no debris occur. In this type of habitats, nutrients may have a stronger effect on the occurrence of species.

Among other factors affecting the vegetation growing on tram tracks, the location of tracks in relation to roads and the location of species in relation to tracks appeared to be significant. The demonstrated interaction between the biotope and the distance from the road may indicate that the road transport induces the formation of more homogeneous vegetation patches. In the case of a short distance, the tram tracksides are very narrow or non-existent. The low percentage of cover-abundance by a dominant species on tracksides would indicate a greater diversity of vegetation patches that develop mostly further away from a road (both on a trackside and in a strict tram track) with a well-developed trackside. It should be noted that plots located along tracksides could be located on the other side of tracks relative to the road, which obviously increases their distance from the road.

Conclusions

Mostly common species with a broad ecological tolerance occur on tram tracks. Those are often plants of alien origin – neophytes. The content of nitrate nitrogen, phosphorus and heavy metals (lead) in the soil has the biggest impact on the diversity of flora along tram tracks. At increased values of these parameters, specific species combinations develop, dominated by nitrophytes or metallophytes.

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Table 1(on next page)

Location of plots

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Table 1. Location of plots

No.	Plots	Latitude N	Longitude E
1.	Zabrze Wolności I	50°17.899'	18°50.113'
2.	Zabrze Wolności II	50°18.346'	18°45.941'
3.	Zabrze Makoszowy	50°16.291'	18°46.557'
4.	Bytom Strzelców Bytomskich	50°23.495'	18°52.832'
5.	Bytom Tarnogórska	50°21.480'	18°54.223'
6.	Bytom Zabrzańska	50°20.316'	18°54.156'
7.	Bytom Siemianowicka	50°20.559'	18°55.932'
8.	Ruda Śląska Katowicka	50°16.545'	18°53.887'
9.	Świętochłowice Bytomska	50°18.142'	18°55.124'
10.	Świętochłowice Chorzowska	50°18.357'	18°54.822'
11.	Świętochłowice Lipiny	50°18.383'	18°53.616'
12.	Katowice Brynów I	50°13.689'	18°59.714'
13.	Katowice Brynów II	50°14.206'	19°00.111'
14.	Katowice Wełnowiec	50°17.067'	19°01.102'
15.	Katowice Plac Alfreda I	50°17.542'	19°00.846'
16.	Katowice Plac Alfreda II	50°17.575'	19°00.846'
17.	Katowice Szopienice	50°15.624'	19°06.596'
18.	Mysłowice Poczta	50°14.329'	19°08.552'
19.	Sosnowiec Niwka	50°14.651'	19°09.604'
20.	Sosnowiec Dańdówka	50°16.419'	19°11.316'
21.	Sosnowiec Wawel	50°16.912'	19°08.882'
22.	Dąbrowa Górnicza II	50°19.657'	19°12.535'
23.	Dąbrowa Górnicza I	50°19.342'	19°09.806'
24.	Będzin	50°19.525'	19°07.249'
25.	Czeladź Pętla	50°19.377'	19°06.363'

Table 2(on next page)

Average results of soil factors for 25 plots

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1 Table 2. Average results of soil factors for 25 samples

Groups with dominant species	pH in KCl	P_2O_5 (mg/100 g)	K_2O (mg/100 g)	Mg (mg/100 g)	N-NO_3 (mg/kg d.m.)	H-NH_4 (mg/kg d.m.)	Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
Hieracium pilosella with *Achillea millefolium*	6.94	65.00	70.34	572.54	2.21	6.10	349.38	15.38	1631.65	99.26
Taraxacum officinale with *Trifolium repens*	7.32	29.36	35.44	196.56	6.69	5.12	193.04	5.38	1024.59	287.06
Achillea millefolium with *Plantago lanceolata*	7.00	32.42	38.66	181.46	4.39	4.27	236.01	10.21	1088.68	127.97
Silene vulgaris	7.35	54.44	51.00	1400.90	2.35	2.15	2320.03	65.90	21496.52	625.74
Amaranthus retroflexus	7.32	113.80	66.12	438.88	17.80	4.82	262.48	7.81	1396.98	369.02

2

Figure 1

Percentage of individual species traits in the surveyed plots

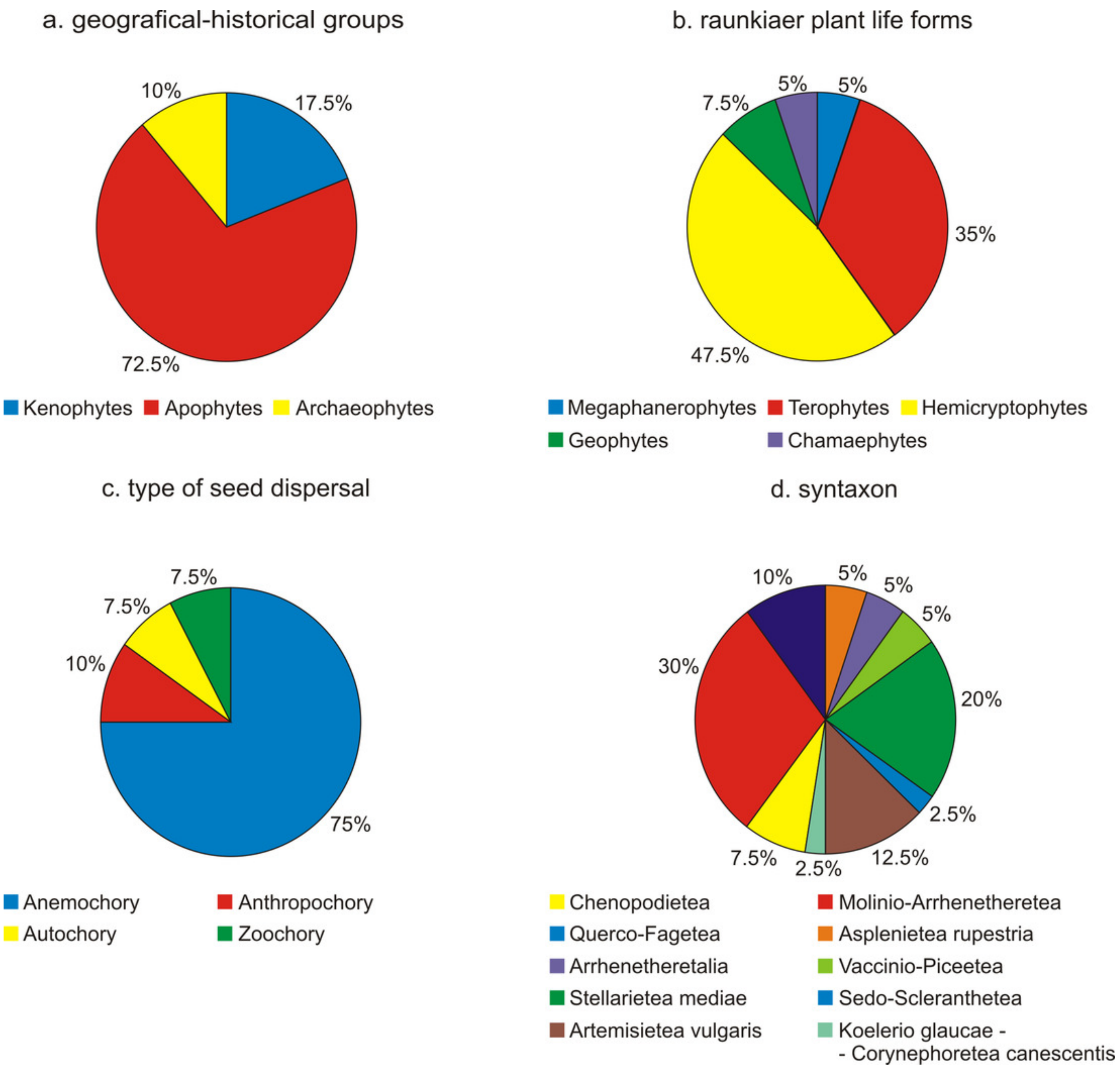

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Figure 2

Dendrogram for selected sites – clustering in relation to soil factors (Euclidean distance, Ward’s method)

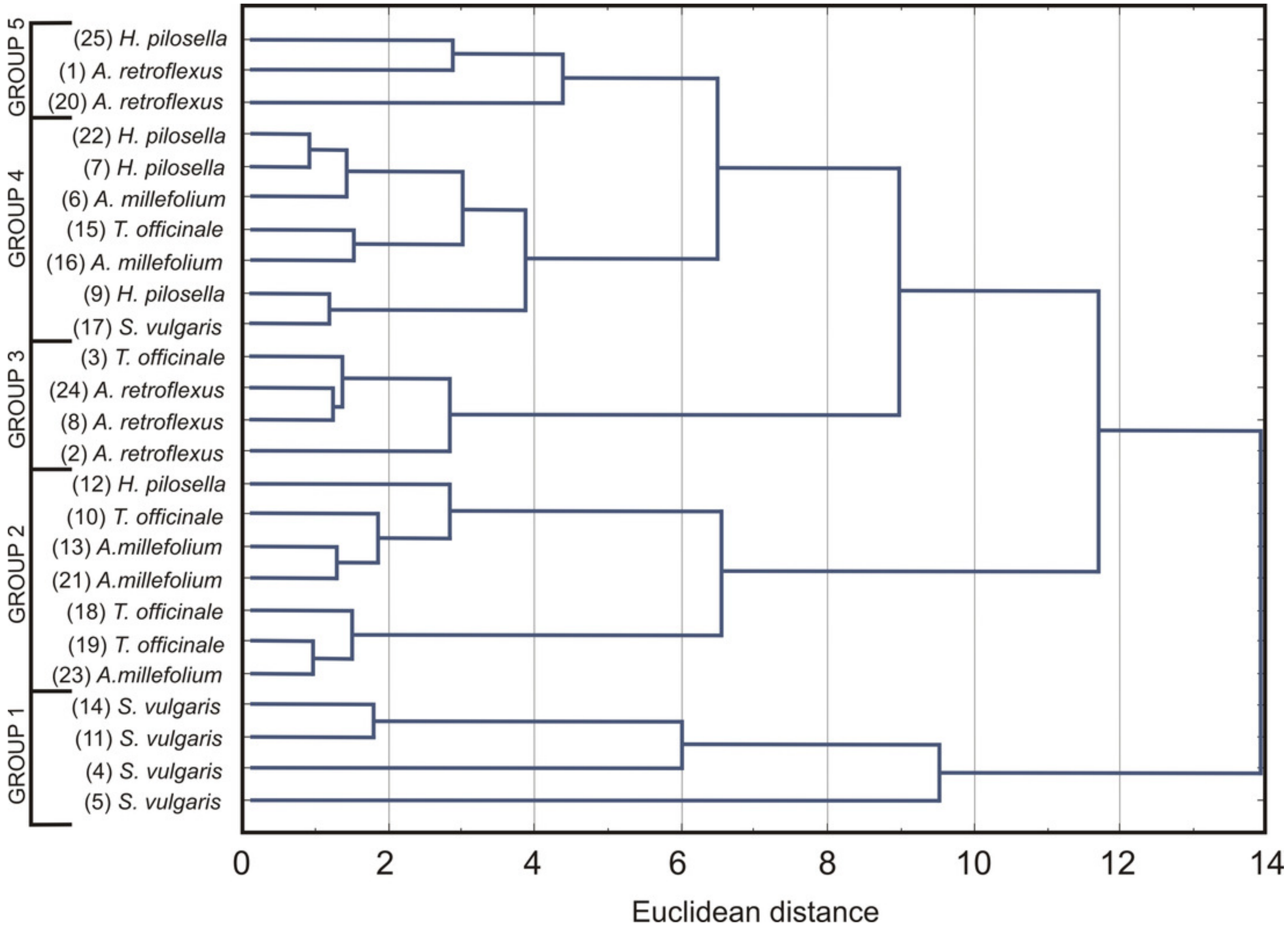

Table 3(on next page)

Summary of discriminant function analysis (backward stepwise procedure)

Table 3. Summary of discriminant function analysis (backward stepwise procedure)

Variables in the model	Wilks' Lambda	Partial Wilks' Lambda	F-to-remove (4.18)	p	Tolerance	1-Tolerance (R-squared)
P_2O_5	0.008	0.206	17.317	0.000	0.880	0.120
$N\text{-}NO_3$	0.035	0.046	93.959	0.000	0.921	0.079
Pb	0.010	0.167	22.465	0.000	0.951	0.049

Figure 3

Scatter plot of canonical discriminant analysis

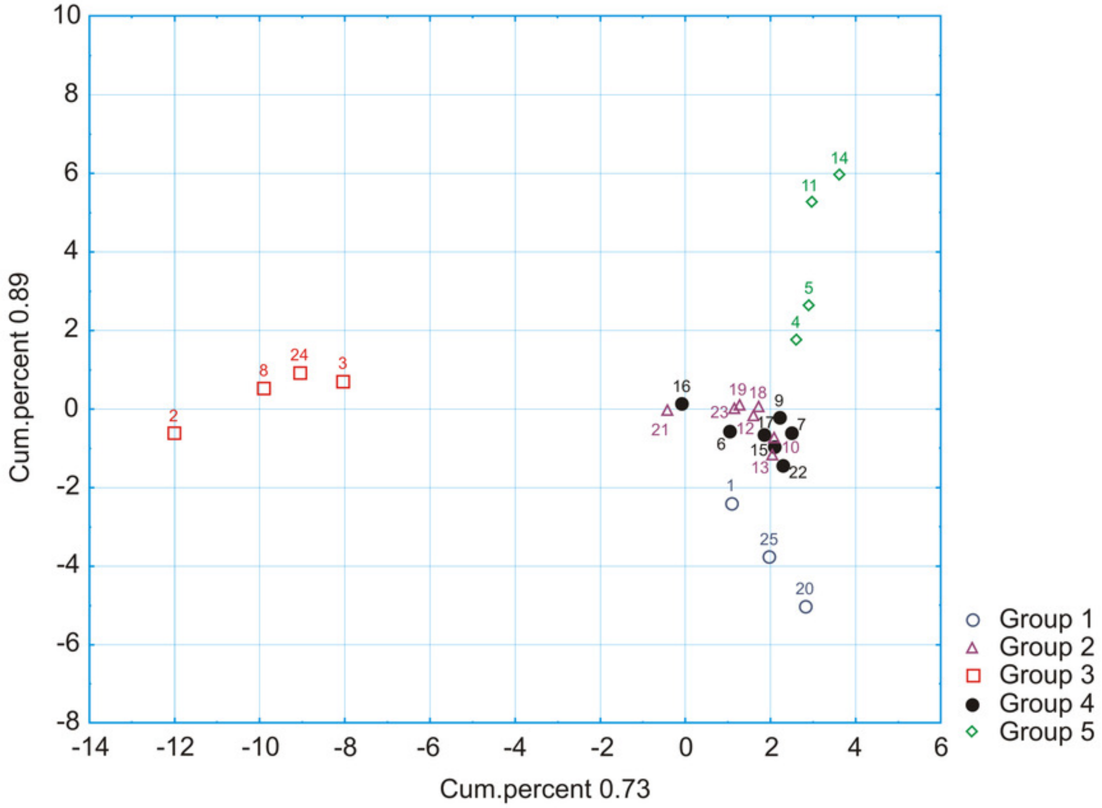

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Table 4(on next page)

Selected soil factors of Canonical Correspondence Analysis (CCA)

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Table 4. Selected soil factors of Canonical Correspondence Analysis

No.	Factor	Lambda	Monte Carlo test	Cumulative variation explained
5	$N\text{-}NO_3$	0.46	P=0.008 F=2.33	0.46
7	Pb	0.34	P=0.025 F=1.75	0.80
2	P_2O_5	0.29	P=0.056 F=1.57	1.09
3	K_2O	0.28	P=0.055 F=1.53	1.37

Figure 4

Results of Canonical Correspondence Analysis (CCA)

Ac.neg. – *Acer negundo*, ***Ach.mill***. – *Achillea millefolium*, ***Aeg.pod.*** – *Aegopodium podagraria*, ***Am.ret.*** – *Amaranthus retroflexus*, ***Ar.thal.*** – *Arabidopsis thaliana****, Arc.lap.*** – *Arctium lappa, Art.vulg. – Artemisia vulgaris*, ***Bel.per.*** – *Bellis perennis*, ***Cer.arv.*** – *Cerastium arvense*, ***Ch.gl.*** – *Chenopodium glaucum*, ***Ch.pol.*** – *Chenopodium polyspermum*, ***Con.arv.*** – *Convolvulus arvensis*, ***Con.can.*** – *Conyza canadensis****, Cor.can.*** – *Corynephorus canescens*, ***Dau.car.*** – *Daucus carota*, ***Dig.sang***. – *Digitaria sanguinalis*, ***Dip.mur.*** – *Diplotaxis muralis*, ***Ech.c-g.*** – *Echinochloa crus-galli*, ***Fr. exc.*** – *Fraxinus excelsior*, ***Gal.par.*** – *Galinsoga parviflora*, ***Hier.pil.*** – Hieracium pilosella, ***Hyp.rad.*** – *Hypochoeris radicata*, ***Leo.aut.*** – *Leontodon autumnalis*, ***Leo.his.*** – *Leontodon hispidus*, ***Med.lup.*** – *Medicago lupulina*, ***Med.sat.*** – *Medicago sativa*, ***Mel.alb.*** – *Melilotus album*, ***Pl.lan.*** – *Plantago lanceolata*, ***Pl.maj.*** – *Plantago major*, ***Po.ann.*** – *Poa annua*, ***Pol.av.*** – *Polygonum aviculare*, ***Rum. ac.*** – *Rumex acetosa*, ***Sed.acr.*** – *Sedum acre*, ***Set.pum.*** – *Setaria pumila*, ***Set.vir.*** – *Setaria viridis*, ***Sil.vulg.*** – *Silene vulgaris*, ***Sol.can.*** – *Solidago canadensis*, ***Tarax sp.***, – *Taraxacum officinale s.l.*, ***Tr.prat.*** – *Trifolium pratense,****Tr.rep***. – *Trifolium repens*

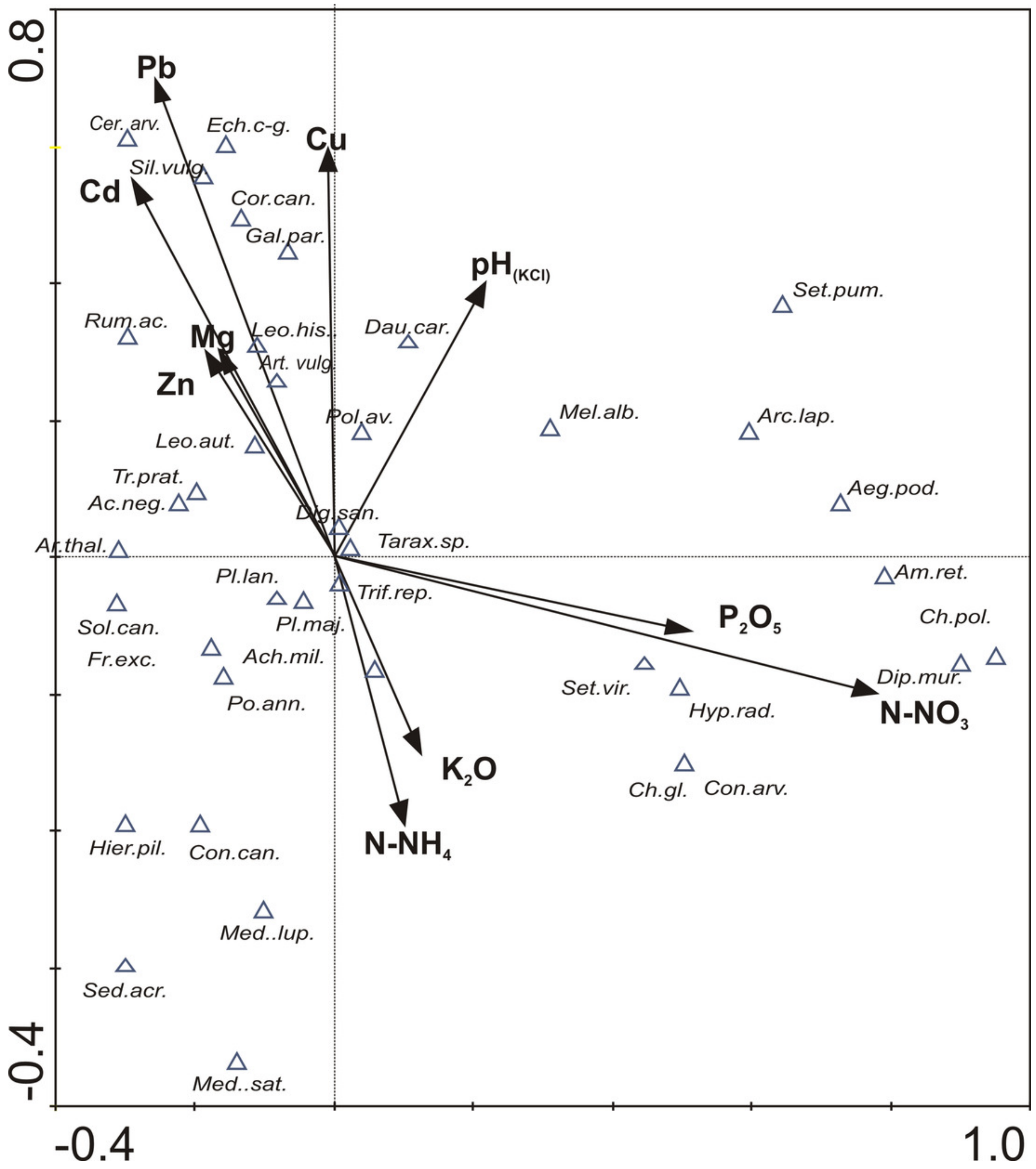
0.8
-0.4
-0.4
1.0
Pb
Cu
Cd
pH$_{(KCl)}$
Mg
Zn
P$_2$O$_5$
N-NO$_3$
K$_2$O
N-NH$_4$
Cer. arv.
Ech.c-g.
Sil.vulg.
Cor.can.
Gal.par.
Set.pum.
Rum.ac.
Leo.his.
Dau.car.
Art. vulg.
Mel.alb.
Arc.lap.
Pol.av.
Leo.aut.
Tr.prat.
Ac.neg.
Aeg.pod.
Dig.san.
Ar.thal.
Tarax.sp.
Am.ret.
Pl.lan.
Trif.rep.
Sol.can.
Pl.maj.
Ch.pol.
Fr.exc.
Ach.mil.
Set.vir.
Dip.mur.
Po.ann.
Hyp.rad.
Ch.gl.
Con.arv.
Hier.pil.
Con.can.
Med..lup.
Sed.acr.
Med..sat.

Figure 5

Effect of interaction between biotop and the distance from the road on the percentage cover of the dominant species (ANOVA)

P – tracksides, S – strict tramway rails