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LAND SNAILS IN THE SLOVAK OPEN- AIR GARDEN CENTRES

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Abstract

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In last decades, the number of non-native land snails increased up to 15 percentages; they create more than eight percent of all the Slovakian species. Trend of newly established snail species corresponds with increases in the average temperatures as well as the intensity of foreign trade, suggesting a synergistic effect of both climatic conditions and socioeconomic factors. The research of the open-air garden centres in Slovakia confirmed both factors. We report here some of the newly established populations of sixteen mollusc species. In the old garden centres, the number of species as well as the number of individuals decreased slightly. Area of the garden centre has a very high impact on both abundance and species diversity. The size and age of garden centre proportionally influences the composition of mollusc assemblages. Two new species *Cornu aspersum* and *Cepaea nemoralis* were noticed for the first time in Slovakia. The recent findings of the introduced populations demonstrate the potential of this snail to colonise new areas.

Key words: Garden centres, mollusc, urban area, Slovakia.

Introduction

Central Europe currently faces an influx of expanding terrestrial invertebrates from more southerly situated regions that are often climate restricted in their distribution. Molluscs are sensitive indicators of environmental conditions, and they constitute a group particularly suited to reconstruction of changes of habitats and ecosystems, occurring as the effect of climate or human activity (Alexandrowicz, 2013). Snails are notoriously known for their limited ability for active dispersal; some spectacular range expansions aided by human activities have been recently observed in Europe (Rabitsch, 2006). A majority of socio-economic changes in Eastern Europe were followed by a dramatic increase in imports, and also in transmit traffic in the last 15 years (Peltanová et al., 2012). Langraf et al. (2016) considered these changes as a demonstration of ecological degradation of ecosystems, which are connected to anthropogenic activities in the country. Problems resulting from the introduction of plant and animal species have become increasingly serious. Ignoring their presence might

lead to impoverishment of native animal and plant communities; economic losses and the process of their spreading may become impossible to stop (Šteffek, 2007).

The open-air garden centres, as the transfer station of the spreads of invasive organisms, are rarely studied areas. The penetration of non-native species into new areas may lead to biotic homogenization, that is, increase in the similarity of species composition between different areas, which may cause the decline of native species, especially. Number of non-native species grows, and more than half of them seem to come from the Mediterranean area. This trend accelerates; seven new species (six from Mediterranean) have appeared during the last two decades. In Slovakia, some of mollusc species were found only in greenhouses, for example, non-native snail *Hawaiia minuscula* (Binney, 1841) was found in two greenhouses in Slovakia (Čiliak et al., 2016); or in the thermal waters (*Helisoma trivolvis, Menetus dilatatus, Melanoides tuberculata, Planorbella duryi*, *Holandriana holandrii, Gulella io, Opeas goodallii, Zonitoides arboreus, Pseudosuccinea columella*) (Šteffek, 2007). Others expand quickly and efficiently to favourable habitats (*Potamopyrgus antipodarum*, *Physella acuta*, *Arion vulgaris, Sinanodonta woodiana, Corbicula fluminea*, *Dreissena polymorpha*) or form the populations there (*Ferrisia clessiniana, Lucilla singleyana, Boettgerilla pallens*) according to Šteffek (2007). In 2015, thanks to an accidental malacological research of the open-air garden centre in Bratislava, there was discovery of viable populations of non-native species for Slovakia - *Hygromia cinctella* (Draparnaud, 1801) and *Cepaea nemoralis* (Linnaeus, 1758), several empty fresh shells of the green garden snail mentioned Čejka (2015a). A viable population of the brown garden snail *Cornu aspersum* (O. F. Müller, 1774) was found in 2015 for the first time (Čejka, 2015b). Čejka, Čačaný (2014) found that *Helix lucorum* in Slovakia came from south-east Mediterranean. Populations of *H. lucorum* were also identified in Prague (Czech Republic) (Peltanová et al., 2012); all the individuals were able to survive the winter condition in Central Europe. These populations were able to live more than four hundred kilometres out of the area of their origin. Similar results were found by Peltanová et al. (2012) and Holienková, Krumpálová (2016) in the Nitra city (Slovakia). Generally, two major driving forces accelerating the global trend of biological invasion are discussed – global climate change (Walther et al., 2009), and human pressure through various socio-economic activities (Pyšek et al., 2010). All these indicate synergic effect of climate conditions and social-economic facts (Peltanová et al., 2012). Horsák et al. (2016) suggest that recent climate warming may foster geographical expansions of many non-native land snail species, as their distributions are controlled mainly by the January temperature. The range expansion of certain gastropod taxa is often correlated with the loss of retreat of many native species. General habitat degradation, fragmentation and loss of habitat connectivity have endangered some native species (Horsák et al., 2010; Hedblom et al., 2017). Extremely important is the elimination of organisms in the initial stages of invasion; the high effect is successful when the populations are small and the reproduction is low (Horsák et al., 2010).

Two ways that are considered in the study of gardens are: i) To specify and qualify the relationship among the age and proportion of garden centres and snail assemblages; and ii) Identification of habitat preferences, which gardens to species living there offer.

Material and methods

The research was carried out in 2016. For research, all potential types of garden centres on the gradient from western to central parts of Slovakia were recognized and considered. Because the molluscs of different urban habitats

cannot be sampled using the standard methods (e.g., square method), we used individual collection per time unit (from 15 min. to 1 hour, depending on the size of garden and microhabitats), which corresponded with similar samplings in the urban environment (e.g., Horsák et al., 2009; Lososová et al., 2011, 2012a,b; Clergeau et al., 2001). Specimens were determined following Ložek (1956) and Horsák et al. (2013a).

According to Horsák et al. (2009), we used a similar method to compare the impact of habitat disturbance and isolation of the site. Each garden centre was categorised, we considered its age and size (Appendix 1, Map). We ranked the species according to Horsák (in verb) to the slightly modified ecological groups sensu Lisický (1991).

Using multidimensional statistic method (Hammer et al., 2001), we evaluated the effect of size and age of gardens on the transfer of new species. We also described similarity, equitability, species diversity and species richness of mollusc assemblages.

Study sites

We sampled garden centres in twenty cities that were chosen in the western part of Slovakia (Appendix 1, Map). The garden centres were categorised according to the age of the building: new - 1 (established among 2010–2016), older - 2 (2000–2010) and old (before the year 2000); and according to the area size: small - 1 (size under 0.5 ha); medium - 2 (up to one ha); and large - 3 (more than one ha).

Results

In the twenty open-air gardens, we found 543 individuals belonging to 16 mollusc species (Table 1); no specimens were found in the four newly established gardens. All the data were tested by Friedman test ($p = 0.006$; DF = 16). Species diversity was low; the highest species diversity (Shannon index) was confirmed in large older garden as the highest value of Margalef's index and equitability (Table 1).

Most of the species were found in the old and large gardens. The highest number of individuals was found in the large gardens with pre-dominance of *Succinea putris* (up to 251 individuals) or with high dominance of *Discus rotundatus* (30 individuals) (Table 1).

Succinea putris was dominant in the seven open-air gardens, with a dominance of nearly 60% and even more (Table 1). Constant occurrence of three species was recorded – *Oxychilus draparnaudi* - 69%, *Cepaea hortensis* - 63% and *Deroceras agreste* - 50% in all the studied gardens; three species had accessorial and ten species occasional occurrence. Frequent eco-elements in gardens were agricolae, sivicolae agricols and praticolae silvicols (Fig. 1).

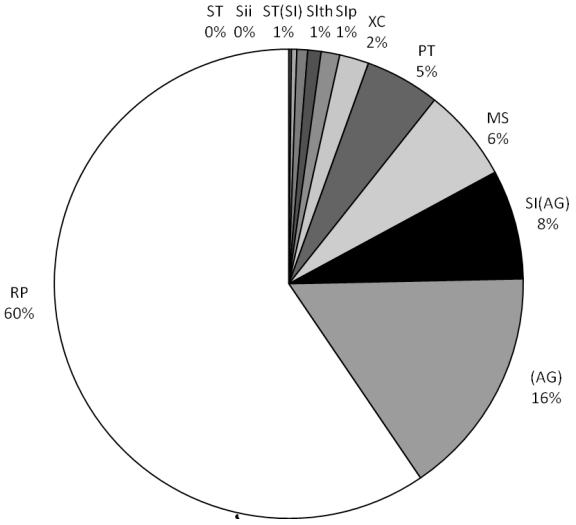

Fig. 1. Percentage of individuals representing eco-elements in open-air gardens.
Notes: AG – agricolae, RP – ripicolae, SI – silvicolae, SI(AG) – silvicolae agricols, MS – euryvalent species, PT – praticolae, XC – xericolae, ST – stepicolae, Sii – silvicols of inundations, ST (SI) – stepicoles of deciduous forests, SIth – silvicols in brushes, SIp – agricols at stones (according to Lisický 1991).

T a b l e 1. Land snails in open-air gardens in Western Slovakia (L1 - L20).

Taxa	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20	Eco elements
Succinea putris (Linnaeus, 1758)	53		2							2	14	251	1								RP
Lacinaria plicata (Draparnaud, 181)																				1	SIp
Arion fuscus (O. F. Müller, 1774)			1							1											Sii
Arion vulgaris Moquin-Tandon, 1855	15	5							3	6						6					MS
Discus rotundatus (O. F. Müller, 1774)		15																			SI(AG)
Cepaea hortensis (O. F. Müller, 1774)	4	2	2		2	2	2		4		1		3		2						SI(AG)
Cepaea nemoralis (Linnaeus, 1758)		1											1								SI(AG)
Cepaea vindobonensis (Férussac, 1821)							1					1	3								ST(SI)
Cornu aspersum (O. F. Müller, 1774)	4	2			3																AG
Helix pomatia (Linnaeus, 1758)	1						1		1						1						Slth
Monacha cartusiana (O. F. Müller, 1774)	1					1							9								XC
Xerolenta obvia (Menke, 1828)																				1	ST
Oxychilus draparnaudi (Beck, 1837)	46		4	4	2	6			1	1	2				3	3				3	AG
Limax maximus Linnaeus, 1758	4										1		1								SIp
Deroceras agreste (Linnaeus, 1758)	6	5			3	2	2				6		2	2							PT
Deroceras reticulatum (O. F. Müller, 1774)			1		1																AG
number of individuals	134	30	10	4	11	11	6		9	10	24	252	20	2	6	9				5	
number of species	9	6	5	1	5	4	4		4	4	5	2	7	1	3	2				3	
Shannon H´	1.5	1.4	1.4	0	1.5	1.2	1.3		1.2	1.1	1.1	0.1	1.6		1.0	0.6				0.9	
Margalef	1.6	1.4	1.7	0	1.7	1.3	1.7		1.4	1.3	1.3	0.2	2.0		1.1	0.5				1.2	
Equitability_J	0.7	0.8	0.9	0	1.0	0.8	1.0		0.9	0.8	0.7	0	0.8		0.9	0.9				0.9	

The age of gardens proportionally influences the composition of mollusc assemblages. A decrease of species spectrum and number of individuals was recorded in the oldest and large garden centres (Fig. 2). On the other hand, in the new garden centres, we found sites without individuals, or numerous. In addition, we observed a huge predominance of some species, namely *Succinea putris*, in the new and middle-aged garden centres. In most of the middle-aged and old gardens, the assemblages were more stable with balanced species spectrum (Fig. 2).

The size of area of the open-air garden centre seems to have a huge impact on both abundance and species diversity (Table 1, Fig. 3). In small and medium sized gardens, the number of species and number of specimens were similar; on the contrary, with increase in the size of gardens, the number of species and individuals increased. Large garden centres give them plenty of potential shelters and living conditions.

Based on the qualitative and quantitative similarity (Bray-Curtis single linkage cluster analysis), a set of snails coenoses were divided into branch and four separate lines at a low level of similarity (0.25). Separately, the lines belong to the old and large gardens detached on the basis of a higher number of species and a high number of collected individuals (Fig. 4). The molluscs' assemblages in large gardens were separately allocated based on the predominance of *Succinea putris* and occurrence of *Limax maximus*. Coenoses of large and old garden (L2) was self-allocated due to the dominance of *Discus rotundatus*, which was found only in this garden. High similarity was between the largest gardens due to the same number of individuals and with the dominance of *Oxychilus draparnaudi*, or between the snail assemblages with higher dominance of *Cepaea hortensis*. The highest similarity was between coenoses in large sized gardens based on the occurrence of *Arion vulgaris* at both sites.

Coenoses of gardens, which differed in age and size, have been characterized by the occurrence typically introduced snails to the environment by human, such as *Monarcha cartusiana*, *Cepaea nemoralis* and *C. vindobonensis*. Presence of *Arion vulgaris* in five gardens signalizes the appropriate conditions there for spreading of this non-native species.

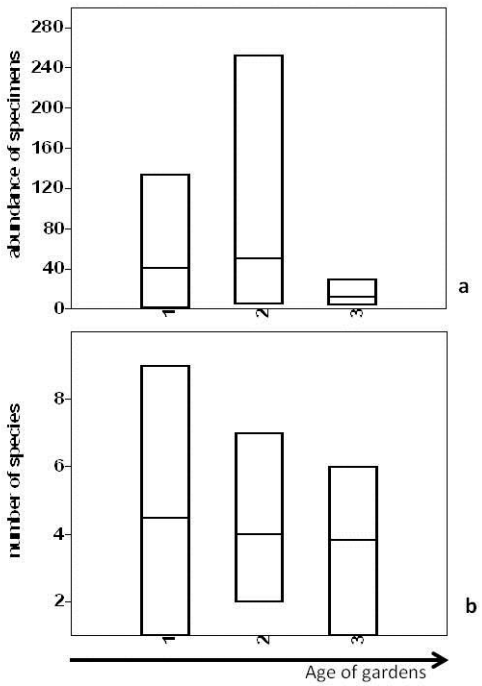

Fig. 2. Box - plot (mean, min-max, 95% confidence limit, $p \leq 0.005$), number of individuals (a) and species (b) in open-air gardens of different ages.
Notes: 1 - new (2010 - 2016), 2 - older (2000-2010), 3 - old (before the year 2000).

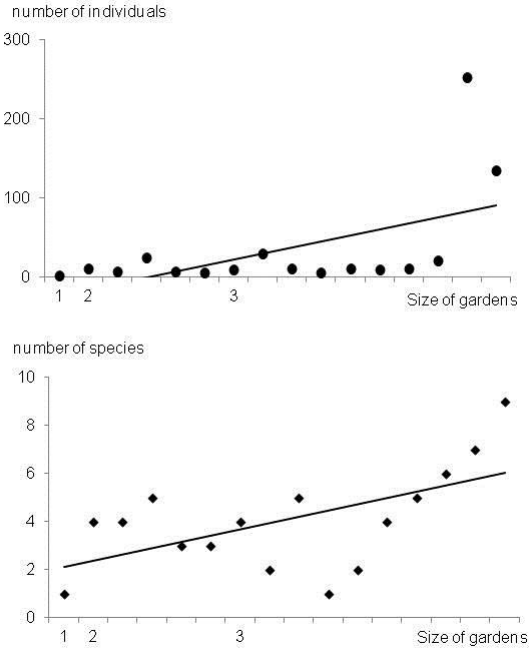

Fig. 3. Trend line of number of individuals and species in different size of gardens.
Notes: 1 - small, 2 - medium, 3 – large garden.

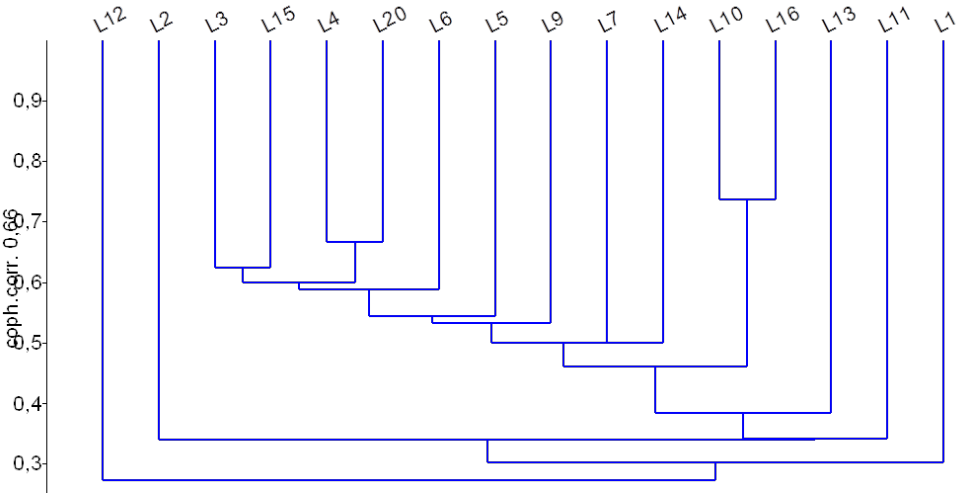

Fig. 4. Bray-Curtis similarity of land snail assemblages in open-air garden centres (Euclidean distance, paired-group; *coph. corr.*: 0.66).

Discussion

In the twenty gardens studied, we recorded two new species for Slovakia – *Cepaea nemoralis* (two gardens) and *Cornu aspersum* (three gardens). *C. nemoralis*, the West European species, was recorded in the Czech Republic for the first time at the end of the 19th century; there was only a slow increase in numbers (Peltanová et al., 2012). It occurs in urban areas, gardens, parks and abandoned urban areas. We found it in two old and large gardens (Bratislava and Zvolen cities); in both we noticed one living exemplar, only. Contrary to the findings of Peltanová et al. (2012), the assumed dispersal mode may result in successful colonization by numerous individuals of even relatively large-shelled in a single event, for example, nearly fifty individuals travelling on the outer surface of a car boot in Prague. The relationship between climbing, traffic intensity, and snail dispersal is now well documented (Aubry et al., 2006). *Cornu aspersum* is a native species common in the Mediterranean region (including Egypt) and Western Europe, from northwest Africa and Iberia, eastwards to Asia Minor, and northwards to the British Isles. In the Czech Republic, *C. aspersum* was for the first time recorded in 2009 (Juřičková, Kapounek, 2009) in two sites in Prague. In Slovakia, it was found in 2015 (Čejka, 2015a). We confirmed its occurrence in three gardens in the Bratislava city; the records were in the old and large open air gardens (Table 1), in which there were found empty shells and living specimens. Based on the number of empty shells and living individuals, we can suppose that its survival in this type of habitat is probable. In agreement with Peltanová et al. (2012), the spreading is supported by an increase of local traffic, the abundance of disturbed sites enriched with nutrients (especially calcium), and microclimatic conditions that facilitate invader survival. Horsák et al. (2013b) found that the number of non-native land snail species in urban habitats was significantly greater in more humid climates. However, for both native and non-native species, the effect of climate on the number of species in the individual habitat types was much less pronounced than the effect of habitat management and disturbance regimes (Horsák et al., 2013b).

The species richness of the garden centres is comparable with the species richness of the urban habitats in Slovakia (Lososová et al., 2011; Čejka 2015a,b; Holienková, Krumpálová, 2016; Mesárošová, Holienková, 2016). Eleven species (from 16) found in the garden centres were confirmed in the cities too. Indeed, there are considerable similarities between the urban biotopes and garden centres. Specific similarity was found between the old and large gardens and city parks or grasslands near apartments. As in open-air gardens and in urban habitat, we found occurrence of typical undemanding synanthropic species such as *Oxychilus draparnadii* or *Deroceras agreste*. Some gastropod species, including ubiquitous species from more southerly European regions, benefit from the ruderalisation of open areas and replace sensitive species. Habitat type explained higher proportions of the total variation in snail species composition than did climate (Lososová et al., 2011). In the near future, we may expect a further increase in the number of non-native species well adapted to human-impacted environments. Newly established urban environments might help alien species to leave their original ranges and to adapt to the new conditions. It is likely that there are general differences in the levels of invasion of cities in different climatic regions, and in the effects of the factors (land-use type and its spatial structure, climatic, edaphic and socio-economic condi-

tions, disturbance and other stochastic processes) on species of different origin (Horsák et al., 2016). Climatic and socio-economic factors separately would not lead to such a high number of successful land snail expansions, but together constitute suitable conditions for spreading (Pyšek et al., 2010; Hedblom et al., 2017; Ružička, Mišovičová, 2013). Assemblages of snails in old garden centres were characterised by a decrease in the number of species and in the number of individuals. On the other hand, the size of the open-air garden centres seems to have a huge impact on both, on the abundance and the species spectrum. The garden conditions are appropriate refugee for the spreading of non-native species.

Conclusion

We report here some of the newly established population of sixteen Land snail species in the Slovak open-air garden centres. In the old garden centres, the number of species as well as the number of individuals decreased slightly. Area of the garden centre has a very high impact on both the abundance and the species diversity. The size and age of garden centre proportionally influences the composition of mollusc assemblages. Coenoses of gardens, which differed in age and size, have been characterized by the occurrence typically introduced snails to the environment by human, such as *Monarcha cartusiana*, *Cepaea nemoralis* and *C. vindobonensis*. Presence of *Arion vulgaris* in five gardens signalizes the appropriate conditions there for spreading of this non-native species. The recent findings of the introduced populations demonstrate the potential of the snail to colonise new surrounding areas.

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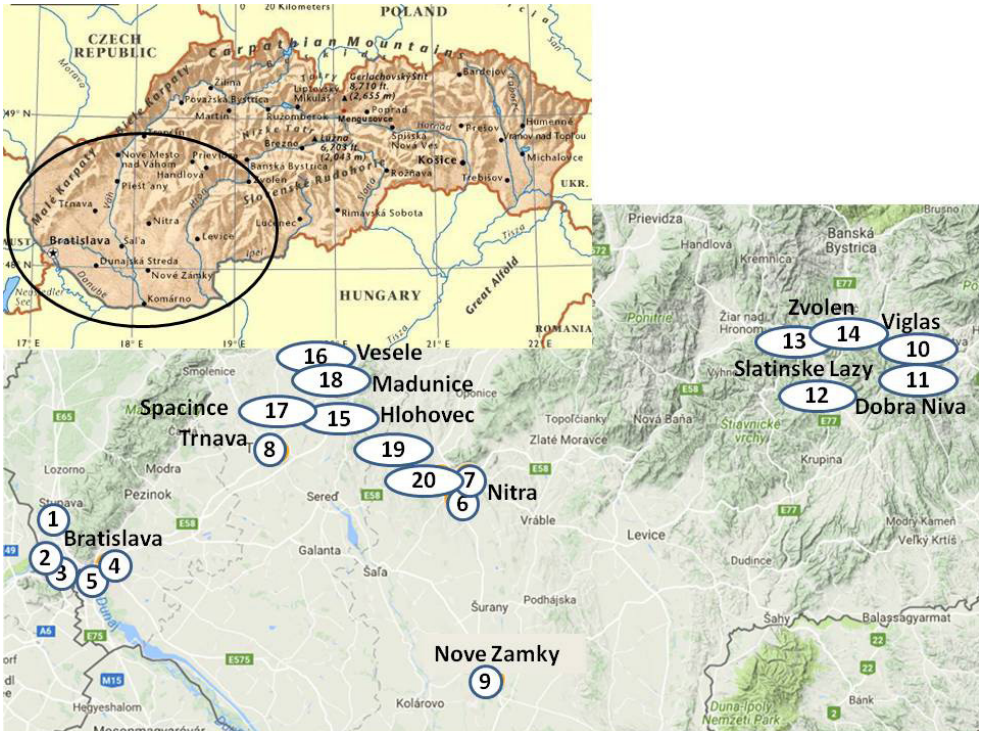
Appendix 1. Map of study sites, the open-air garden centres in western part of the Slovakia.



Notes: L1. Siky Gardens, Bratislava, altitudes: 48.24662, 17.02331, date of establishment: 2004, area 3, age 1. Date of collection: 28 September 2016.
L2. Agapé Bratislava, altitudes: 48.15159, 17.03142, date of establishment: 1996, area 3, age 3. Date of collection: 28 September 2016.
L3. Zreuz, Bratislava, altitudes: 48.15676, 17.01348, date of establishment: 1998, area 3, age 3. Date of collection: 28 September 2016.
L4. Kulla, Bratislava, altitudes: 48.16398, 17.15914, date of establishment: 1992, area 3, age 3. Date of collection: 28 September 2016.
L5. Atelier Duma ltd., Bratislava, altitudes: 48.1425, 17.13391, date of establishment: 1999, area 3, age 3. Date of collection: 28 September 2016
L6. Agapé plus ltd., Nitra, altitudes: 48.28133, 18.09111, date of establishment: 2012, area 2, age 2. Date of collection: 27 September 2016.
L7. Top Garden, Nitra, altitudes: 48.32160, 18.12070, date of establishment: 1998, area 2, age 2. Date of collection: 27 September 2016.
L8. Oazis Lestra & Co ltd., Trnava, altitudes: 48.36601, 17.6101, date of establishment: 2016, area 1, age 1. Date of collection: 27 September 2016.
L9. Grandiflora, Nové Zámky, altitudes: 47.96021, 18.18909, date of establishment: 1991, area 3, age 3. Date of collection: 20 August 2016.
L10. Garden centre, Vígľaš, altitudes: 48.54906, 19.3032, date of establishment: 2010, area 3, age 2. Date of collection: 10 August 2016.
L11. Gardens, Slatinské Lazy, altitudes: 48.50157, 19.3022, date of establishment: 2012, area 2, age 1. Date of collection: 12 August 2016.

L12. Gardens, Dobrá Niva, altitudes: 48.46605, 19.10039, date of establishment: 2000, area 3, age 2. Date of collection: 12 August 2016.
L13. Tília, Zvolen, altitudes: 48.56698, 19.16046, date of establishment: 2000, area 3, age 2. Date of collection: 8 August 2016.
L14. Siki gardens, Zvolen, altitudes: 48.57126, 19.10972, date of establishment: 2012, area 1, age 1. Date of collection: 8 August 2016.
L15. Garden design, Hlohovec, altitudes: 48.42486, 17.8148, date of establishment: 2002, area 2, age 2. Date of collection: 27 September 2016.
L16. Plantex, Veselé, altitudes: 48.55128, 17.73267, date of establishment: 1996, area 3, age 3. Date of collection: 28 September 2016.
L17. Hadzima plant, Špačince, altitudes: 48.43654, 17.60881 39, date of establishment: 2010, area 3, age 1. Date of collection: 28 September 2016.
L18. Smaragd gardens, Madunice, altitudes: 48.48191, 17.78345, date of establishment: 2013, area 1, age 1. Date of collection: 28 September 2016.
L19. Garden centre, Rišňovce, altitudes: 48.36774, 17.896, date of establishment: 2008, area 1, age 1. Date of collection: 28 September 2016.
20. Garden centre Terra design, Nitra, altitudes: 48.31901, 18.05128, date of establishment: 2013, area 2, age 1. Date of collection: 27 September 2016.