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Comparison of invasive woody plant species presence in the Botanical garden of P.J. Šafárik University in Košice from the viewpoint of time and management of sanitation measures

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Abstract: In the year 2012 we have compared the occurrence of invasive woody plant species within the area of Botanical Garden of PJŠU in Košice with their occurrence in the year 2008. It was connected with application of the series of sanation measures to suppress the spread of invasive woody plant species. Following taxa were the subject of the research: *Robinia pseudoacacia* L.*, Ailanthus altisima* (Mill.) Swingle*, Negundo aceroides* Moench.*, Amorpha fruticosa* and *Parthenocissus quinquefolia* L.. Parameters of individual woody plants were measured: stem diameter at the height of 1,30 m ($d_{1,3}$) in cm and total height in meters. The occurrence was marked on the schematic map and the photodocumentation of plants was obtained. The research revealed that, based on abundance, *Robinia pseudoacacia* L. is dominant there due to former intentional planting of black locust individuals for anti erosion and soil stabilization purposes (fixing ravines, areas with critical slope and shallow soils). The goal of several former specific plantings was completed, sporadically the natural decline of older trees takes place but in many sites the considerable root and trunk sprouting capacity is manifested and it makes the forest park maintainance more difficult. The enormous invasive potential is manifested by the species *Ailanthus altissima* L. which dominates also in urban plantings as very aggressive and rapidly spreading species. In the reduction of invasive species abundance, only the

yearly repeated phytotechnical measures are really successful. Occasional elimination of woody plant individuals leads only to a time-limited positive effect and the result is a support of trunk and root sprouting capacity and consequently to the formation of hardly manageable compact stand of woody plants.

Keywords: invasive tree species, introduction, control

Introduction

The term „invasion“ is used to express the raids (sudden, collective, violent) of alien groups (tribes, military forces) into new areas and it is commonly connected with violation, destruction. In a more or less similar sense it is used also in biology and ecology. The term „invasive“ is derived from the Latin word “invado“enter somewhere, into (ELIÁŠ 2009). Invasion should be understood as a process running on several levels: global, regional and local (ELIÁŠ 1998). Biotic invasions usually run simultaneously on all three levels and they are manifested by formation of secondary spreading centres and by secondary areals of species in areas where they have not occurred before (ELIÁŠ 2009). Problems of invasions and problems of introduction of non-native woody plant species seem to be two sides of the same coin. Successful introduction is classified as naturalization of the species, its expansion and penetration of species into native natural communities. In terms of invasion ecology, this is evaluated as invasion and invasion behaviour of introduced woody plant species. (ELIÁŠ 2011). Different human activity can support the acclimatization of long-aged woody plants, their survival and autoreproduction in new conditions, what leads to naturalization. The naturalization enables the escapes of species into wild areas, their going wild and penetration into natural communities. The whole process is supported by planting of species in free landscape and distribution through commercial sale (ELIÁŠ 2011). The introduced species as alien species were and are intentionaly planted in areas behind the borders of their natural range with the aim to introduce them into culture or to extend their growing in new areas, especially as new beneficial species (BENČAŤ 1982, ELIÁŠ 1998). Most of introduced species is related to cultures or to the sites of first introductions (e.g. botanical gardens, arboreta, urban parks and gardens). In anthropogenic ecosystems and in the sites disturbed by human activities, the autoregulation is limited and biodiversity is depleted due to missing the less competitive species. There take place the distribution of expansible introduced species which behave in new areas in different way. In respect to the considerable vitality and large amount of phytomass production, some taxa are used as pioneer woody plants for devastated areas (in dumping sites recultivated with soil, in uncovered sites after superficial soil mining etc.).

Several authors dealt with introduction and invasion, especially BENČAŤ (1982) and TOMAŠKO (1999). Some authors dealt with invasive woody plant species

within the range of all Slovakia or locally in the environment of different cities, e.g. ELIÁŠ (1996), SUPUKA (1997), BARANEC & ELIÁŠ JUN. (1997), MODRANSKÝ et al. (2002), MODRANSKÝ, BENČAŤ (2003), KELBEL (2003), DANIŠ, BENČAŤ (2004), KOLOČAIOVÁ (2005), BENČAŤ & DANIŠ (2005), HOŤKA (2005), MODRANSKÝ , DANIŠ (2006). Invasions of non-native trees into forest stands were evaluated separately, e.g. by JURKO (1958, 1963), MAGIC (1974, 1997), ELIÁŠ (2010), and other. From the viewpoint of species presence, ELIÁŠ (1997, 1998, 2001) considers three most important invasive trees, namely *Ailanthus altissima* (Mill.), Swingle, *Robinia pseudoacacia* L. and *Negundo aceroides* Moench. In the list of serious invasive woody plants in Slovakia, the following species are presented: *Amorpha fruticosa* L., *Celtis occidentalis* L., *Gleditschia triacanthos*, *Lycium barbarum* L., *Juglans nigra* L., *Mahonia aquifolium* (Pursh) Nutt., *Fraxinus americana* L., *Parthenocissus quinquefolia* (L.) Planch., *Rhus typhina* L. and *Syringa vulgaris* L. (ELIÁŠ 2009).

The goal of this work in the area of Botanical Garden of PJŠU (thereinafter BG PJŠU) was to compare the original (2008) presence of woody plants with the actual one (2012) related to the selected woody species, in our view the invasive ones, along with determination of their frequency or their spatial representation. These data were plotted to the map source and photographic documentation was also taken. At the same time we present the survey of sanitation measures applied to the date.

Material and methods

Field research was done in the range of the Botanical Garden of P.J. Šafárik University in Košice. BG UPJŠ is located in the north – west part of Košice Basin, in locality of Bankov – Red Bank. Geographical coordinates are: 48˚ 45´ N and 21˚ 19´ E (MOCHNACKÝ 2001).

The main goal of research was the monitoring of the following invasive tree species: *Robinia pseudoacacia* L.*, Ailanthus altisima* (Mill.) Swingle*, Negundo aceroides* Moench.*, Amorpha fruticosa* and *Parthenocissus quinquefolia* L. Planch. For these species the following data were registered: diameter in height of 1,3 meters, number and height of individuals and also area of sprouts occurrence. Diameter of tree trunk was measured by forest calliper, height data were taken with the use of Blume-Leisse altimeter (type BL - 7). Some locations of BG UPJŠ were areas with massive occurrence of natural seedlings. Frequency of seedlings with their height to 1,0 meter was found out with the help of sample plots. Usually 5 plots with acreage of 1 m² were taken out and all seedlings of individual tree species were counted within a plot. The average number of seedlings within a spot was multiplied by total acreage of seedlings occurrence. The field position of individual species was also recorded graphically in the map. Sanitation measures were performed and their effects were evaluated.

Results and Discussion

1. *Robinia pseudoacacia* L. :

Tab.1: Diameter structure of *Robinia pseudoacacia* L.

Diameter intervals (cm)	Number of individuals (in 2008)	Number of individuals (in 2012)
0 – 10	49	64
11 – 20	81	52
21 – 30	86	54
31 – 40	28	21
41 – 50	3	2
51 – 60	0	0
61 – 70	0	0
71 – 80	1	1
81 – 90	0	0
91 – 100	1	0
total number	**249**	**194**

Occurrence in the area is presented in Fig. 1:

A. In the area of Historical dewpond, along its border, 28 individuals belonging to tree canopy were formerly registered. They occured in 38 m long zone, their heights ranged from 5 m to 14.5 m. The most robust individual of that time was 21.5 m tall and its tree diameter at 1.3 m height was nearly 100 cm. This tree was cut down at the height of 1 m above ground and consequently the secondary tree crown was formed from stump sprout shoots. The shoots covered the total area up to 1691 m². At the present time, the biggest individuals are cut down, dominant diameter class is < 10 cm (24 individuals) and 11-20 cm (22 individuals). They are stump shoots. Next diameter class (21-30 cm) was represented by only 4 individuals. The former area of sprout shoots was totally decimated by goat grazing. Goats keep the area in well arranged state, the invasion manifestations are under control..
B. In the area of hot-beds near the fence, the sprout shoots of *Robinia pseudoacacia* occurred in the area of 35 m² . At the present time, 26 sprout shoots are there, 24 of them are in diameter class of < 10 cm.
C. In the area of forest above Cherry meadow, 27 individuals were registered within the area of 398 m², one tree was a solitaire with tree diameter of 34 cm. The maximal trunk diameter was 40 cm, the minimal one was 18 cm. Heights ranged from 18 m to 21,5 m.
D. In the area of downhill ski course near the fence, 26 individuals were found. The tree trunk diameters were in the range 10 – 80 cm. Sprout shoots also occurred here, they covered the area of 163 m². The average height was 12 m, the maximum was 13,5 m .

E. In the area of former menagerie, 9 individuals were found, the biggest one with diameter of 27 cm, the smallest one with trunk diameter of 11 cm. The heights were in the range 7 – 7,5 m.
F. Along the way to the watchman's cabin, the sprout shoots covered the total area of 1267 m². They are the subject of repetitive mechanical interventions.
G. In the course out of the crossroads, other sprout shoots occurred on the area of 7 m². At the same time, 15 tree canopy individuals were found there. The diameter of the biggest one was 31 cm and 3 individuals had diameter of 3 cm.
H. In the area between former dog house and the crossroads (coomb zone), the highest number of individuals was recorded – till 144 individuals. The biggest individual had the diameter d 1,3 = 44 cm and the smallest one had diameter of 3 cm. The heights ranged between 12 m and 18 m. In this part, the most considerable reduction of number of trees took place, their diameters were up to 42 cm and their total number was 41.

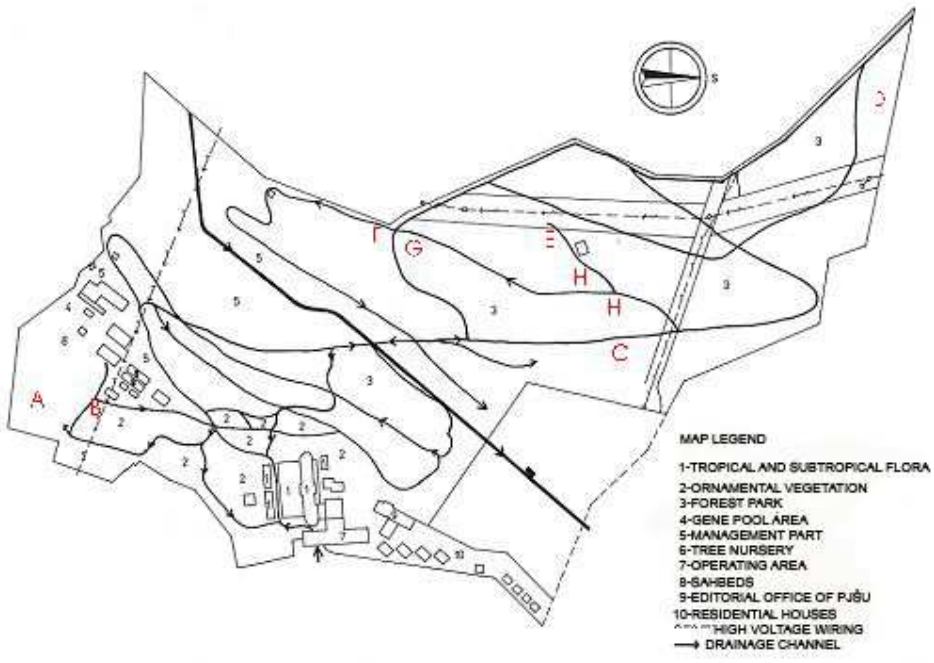

Fig. 1. Roadmap of BG UPJŠ in Košice (location of *Robinia pseudoacacia* L.)

Fig. 2: Stump shoots of *Robinia pseudoacacia* L. – Historical dewpond (A)

This woody plant species formerly occurred in the south-eastern part of North American continent. It was introduced to Europe by the gardener J. Robin in 1601 (PAGAN, RANDUŠKA 1988). In Slovakia, it grows especially in southern warm areas but also in sites of foothils. This species can tolerate low level of nutrients in soil, it is drought-proof and highly rated by beekeepers as significant melliferous woody plant. Black locust reproduces itself generatively – with seeds or vegetatively – by root and stump shoots. Pods ripen in September, they persist on trees where they crack and valves of pods fall separately. Seeds remain attached to valves which are spreading by wind, water or birds (pheasant, crossbill) (LHOTSKÁ ET AL. 1987). In respect to its aggresive spreading and toxic root secretions causing allelopathy, it can easily become difficult woody plant, what is also the case in BG PJŠU. LŐFFLER (1972) presents seed germinative capacity of 55 %. During analysis, the beetle species *Spermophagus cisti* FABR. was found in seeds with average infestation of 12,50 %, dry seeds reached the average proportion 21,50 % (KELBEL 2000). But diaspores are not main problem of invasive behaviour of this species, black locust spreads particularly by stump and root shoots which must be regularly chemically or mechanically removed (KELBEL 2000). Due to spreading by root shoots and due to rapid growth in juvenile stage, it overruns in growth other woody plant species.

JURKO (1958) described several separate associations wth dominant black locust, namely on aeolian sands, bottom land soils and humid soils rich with humus. Spontaneous distribution of black locust took place after World War II on ruins of largest cities (Berlin, Leipzig, Dresden, Prague, Wienna), especially in regions with continental climate and warm summer. The most dramatic changes in natural vegetation by influence of black locust take place just in xerothermal sites. Xerothermous grass communities are overgrown with black locust in the course of several years and species composition in herbal layer is also changed. Rare forest communities of warm and dry sites are also endangered, especially stands of downy oak and Turkey oak.

Initially, black locust was used only as decorative or alley woody plant, later it was planted with favour on forest edges as winter food source for pheasants. The first larger stands for wood production was founded in the end of 18th century. Black locust provides relatively quality hard and durable wood which is elastic and well workable. In respect to firmness and durability, it is similar to oak wood. Black locust wood is suitable for subjects in contact with water but it is used also for production of parquet blocks and stakes to vineyards etc. This tree flourishes also in dry and poor soils and it is often used to fixate unstable slopes.

2. *Ailanthus altisima* (Mill.) Swingle (Syn.: *Ailanthus glandulosa* Desf.) – occurrence in the area of BG PJŠU

Tab. 2: Diameter structure of *Ailanthus altisima* (Mill.) Swingle

Diameter intervals (cm)	Number of individuals (in 2008)	Number of individuals (in 2012)
0 – 10	17	190
11 – 20	25	11
21 – 30	5	9
31 – 40	5	3
41 – 50	4	2
total number	**56**	**215**

Occurence in the area is presented in Fig. 3:

A. In the area in front of garages at the fence, 26 tree canopy individuals were registered in 2008. Tree diameter was in the range 2 -19 cm, average height was 7,5 m. The presence of 13 sprout shoots with heights 88 – 93 cm was also registered. Both sprout shoots and tree canopy individuals were spreading in the area of 81 m². The mentioned individuals were fully eliminated and their root and stump shoots are mechanically removed yearly.
B. In the area of stock of substrates, 3 canopy tree individuals occurr. Their average height is 4,5 m, trunk diameters are 15, 20 a 22 cm. They begin to fructificate. At the same time, 7 individuals of self –seeding origin were registered, their diameter was less than 10 cm.

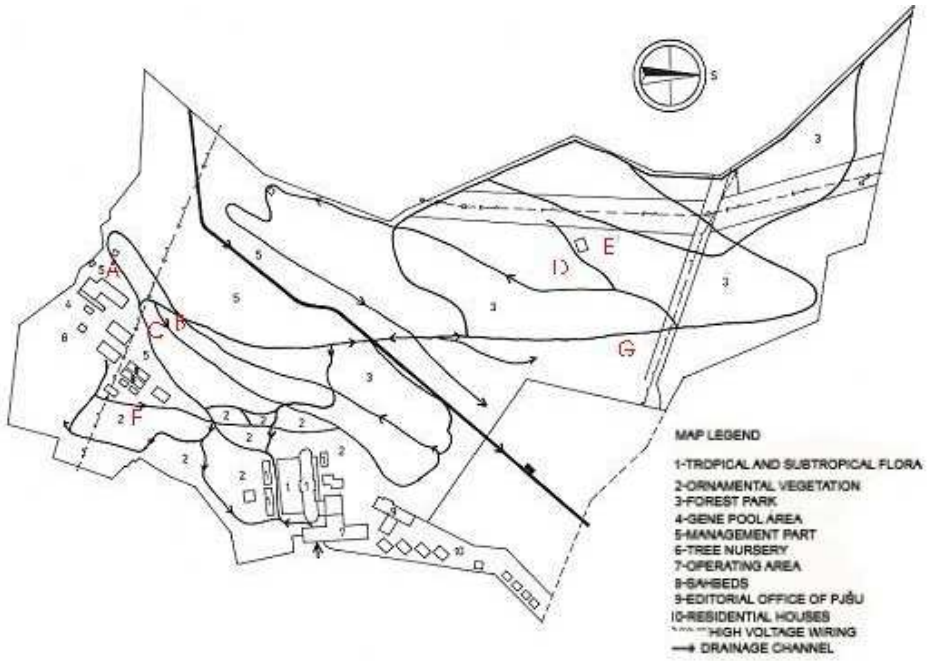

Fig. 3: Roadmap of BG UPJŠ in Košice (location of *Ailanthus altissima* L.)

C. Other individuals in the form of self-seeding and sprout shoots occur ath the corner of crossroads with accreage of 2911 m ² and along the road on the area of 58 m² . The source of diaspores was a tree of this taxon (diameter $d_{1,3}$ = 46 cm, height 14,5 m), which was a component part of outplantings. Original tree was removed, its sprout shoots are cut every year within limits.

D. In the area of the road below menagerie, 3 canopy tree individuals were found in forest stand. Their trunk diameters were 30, 23 a 20 cm and average height was 16,5 m.

E. In the area of former menagerie 21 individuals were found, their $d_{1,3}$ varied within the range 4 - 43 cm.

F. In the area of field below hotbeds 2 canopy tree individuals occur with $d_{1,3}$ = 36 and 42 cm, height is 14,5 m. They produce self seeding individuals with heights around 7 m in the area of arable field with accreage of 40 m². These individuals in immediate vicinity of false cypresses (*Chamaecyparis lawsoniana*) are removed every year by hand. Their accreage decreased to the value of cca 15 m² but number of sprout shoots and individuals of self seeding origin (diameter up to 10cm) in cultivated area increased.

G. In the forest above Cherry meadow one big canopy tree individual occur, its diameter $d_{1,3}$ = 23 cm and its height is 17 m. In its vicinity, sprout shoots with accreage of 286 m² were registered.

Fig. 4: Area A – original state registered in 2008 - *Ailanthus altissima* (Mill.) Swingle

Fig. 5: Area A – actual state registered in 2012 - *Ailanthus altissima* (Mill.) Swingle

Ailanthus altissima is considered to belong among wildly distributed, naturalized adventive woody plant species which express the highest intensity of natural spreading (BENČAŤ 1982). It has several properties which are the presupposition of massive spread, namely wide physiological amplitude, low requirements for soil quality, tolerance against drought, salts and air pollution, resistence against damage, high generative and vegetative reproduction ability (high seed production) and rapid juvenile growth (UHERČÍKOVÁ 2000). BÄRTLES (1988) mentions high percentage value of germination capacity but without specific quantification. At the same time he gives a notice that this woody plant spreads in warmer climatic regions (e.g. in former Yugoslavia and in Austria) in high numbers also out of gardens. LÖFFLER (1972) presents the germination capacity of seeds 70 %. Extreme sites, e.g. shambles, are also suitable for this woody plant. According to BÄRTLES (1988), *Ailanthus altissima* produces high numbers of seeds. It was confirmed also in our research, this woody plant in conditions of BG PJŠU has excelent abilities for both generative and vegetative reproduction. It spreads rapidly by anemochory and it occupies all free areas, even crevices below walls of buildings. According to KELBEL (2000), this woody plant withstands the climatic stress in urban environmnet very well and its shoots with rapid growth are able to overgrow planted individuals in the course of one year and later they can cause shading and space repression. In closed stand it forms relatively nice trunks, so in the past some growers suggested it as pioneer woody plant for aforrestation in karst areas (MAGIC 1974). Some forresters support or tolerate natural seedlings but it aggresively interfere with forest succession (MAGIC 1997). In Hungary, it is distributed in forests to such extent that it is regarded as aggresive woody plant species (MAGIC 1997).

From the viewpoint of park architecture, *Ailanthus altissima* is very attractive woody plant with interesting habitus, shape and size of leaves and high variability in fruit coloration. It withstands climatic stress very well in urban environment but its outplanting should be considered very thoroughly with respect to the mentioned risks (KELBEL 2000) .

3. *Negundo aceroides* L.

Tab. 3: Diameter structure of *Negundo aceroides* L.

Diameter intervals (cm)	Number of individuals (in 2008)	Number of individuals (in 2012)
0 – 10	43	17
11 – 20	11	23
21 – 30	1	4
31 – 40	0	0
41 – 50	0	0
51 – 60	1	0
61 – 70	1	0
total number	**57**	**44**

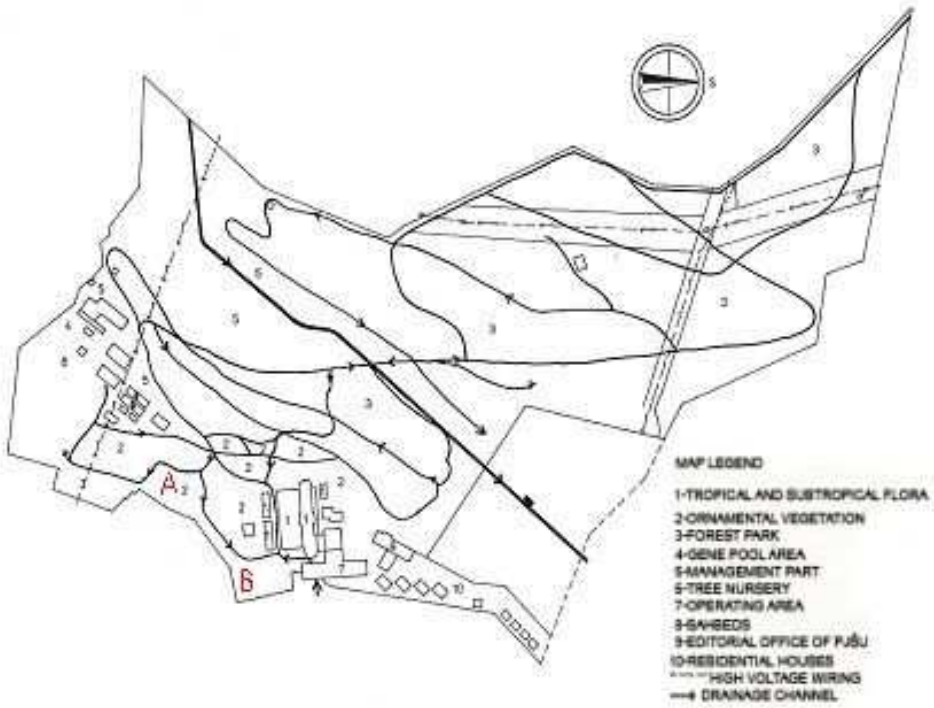

Fig. 6. Roadmap of BG UPJŠ in Košice (location of *Negundo aceroides* L.)

Occurrence in the area is presented in Fig. 6.

A. The area at SAS (along fence) – 55 canopy tree individuals were found, the biggest one was with tree diameter in height 1,3 m 21 cm, the smallest one with diameter of 2 cm. Interventions in this site were minimal, these trees have mainly covering function in the line of fence.
B. In the area of Mánesova street (at fence) – 2 canopy tree individuals with trunk diameters of 67 cm and 58 cm were found. They were removed on March 21st 2012 with the use of climbing technique for tree cutting. These individuals grew in the border with SAS, at the fence and their branches caused damage to SAS building. Moreover, with respect to the occurrence of rotting wood and cave in the trunk of one of them, there was also a risk of trunk break and possible fall to the building of SAS.

This woody plant species was formerly distributed in North American continent and it was introduced to Europe in 1688. It is undemanding for nutrient content in soil, resitant against atmogenic pollution and climatic stress, for all that it is often planted in parks or withim urban greenery. For these purposes the various coloured cultivars weere breeded. The dangerousness lies in its aggressive behaviour in free nature (PAGAN & RANDUŠKA 1988). We had registered no seed

Fig. 7: Canopy tree individuals - *Negundo aceroides* L. – original state (B)

Fig. 8: Removal of 2 canopy tree individuals of *Negundo aceroides* L. (B) with the use of climbing technique

pests during analyses in the past. The same results were reached also by ZEMKOVA (1970) or HRUBÍK (1975). It begin to fructificate very early, seed crops are regular and very rich. Winged achenes persist on trees for long time, so autumn winds and winter snowstorms can distribute them to the wide surroundings (MAGIC 1997). It enhances the spreading risk of this woody plant species for long distances (KELBEL 2000).

4. *Amorpha fruticosa* L. :

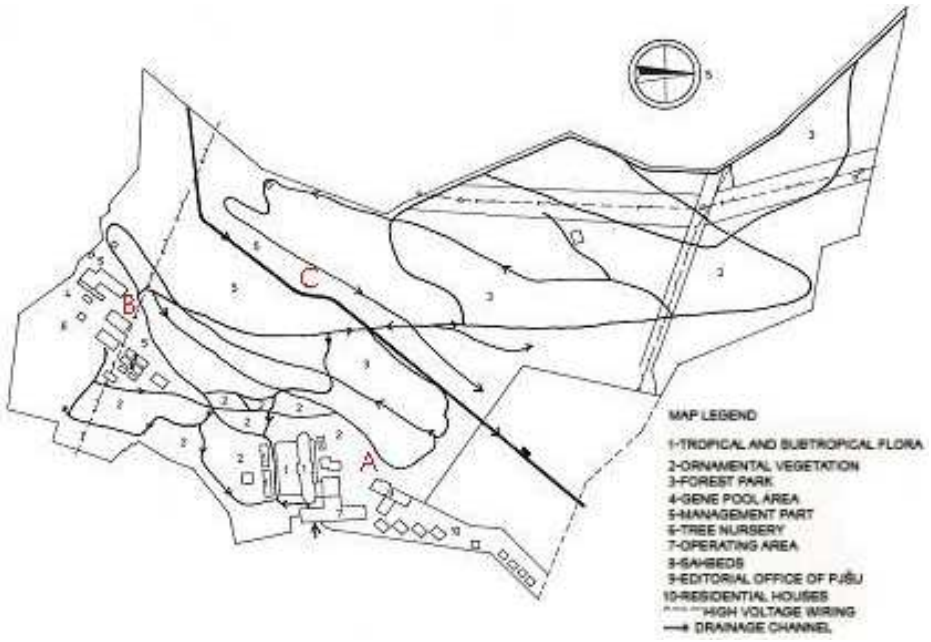

Fig. 9. Roadmap of BG UPJŠ in Košice (location of *Amorpha fruticosa* L.)

Occurrence in the area is presented in Fig. 9:

A. In the area above the former edition centre (now it is a private kindergarten) along the road, some shoots with accreage of 31,5 m² were formerly found in the past. At present, overall appearance and character of the area were changed due to vast plantation measures and this species was successfully eliminated there.
B. In the line of bordering fence between garages of PJŠU and management part of BG PJŠU, individuals of this species occur in the area od 56 m² . They have covering function and we will not take them into liquidation operations.
C. In the area of water reservoir along road, sprout shoots were formerly found in the area up to 106 m². This area is regularly mechanically treated with brush cutters. Despite of it, root sprouting capacity manifestations occur regularly.

Fig. 10. Area C – repeated sprouting of the taxon *Amorpha fruticosa* L.

It is growed in parks and hedgerows, it is also used for fixing ravines and coombs. In floodplain forests it usually grows wildly. (PAGAN, RANDUŠKA 1988). No damage from pests was recorded during seed analysis. Next to the spreading by diaspores, invasion is manifested by very strong root sprouting capacity which can be suppressed only mechanically or chemically. In the case of its potential outplanting in parks and gardens, the aspect of its invasive spread to environmnet should be taken into account (KELBEL 2000). Despite the regular defence measures (yearly repeated mechanical removal) the regular sprouting takes place.

5. *Parthenocissus quinquefolia* L. Planch

A. In the area near the bridge, the sprout shoots of Virginia creeper occurred in both sides of the bridge with accreages of S1 = 3497,5 m², S2 = 1204,3 m² (area A in Fig. 11).

According to KRÜSSMAN (1977), it is highly climbing brush which can cause plroblems not only by its wild growth but also by taking the necessary assimilates from woody plants coiled around with this liana. It was manifested also in BG PJŠU where this species not only covers soil surface but it was foud also in crowns of several trees. It is spreading mainly by long runners of shoots which

root themselves continuously. Present state in the registered location is decimated by regular and intentional animal grazing.

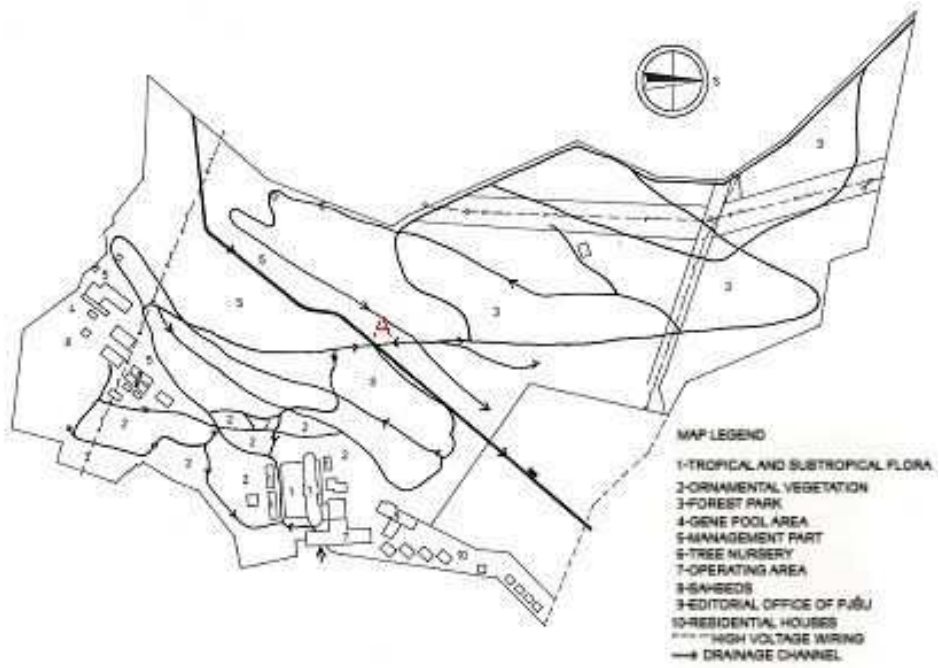

Fig. 11: Roadmap of BG UPJŠ in Košice (location of *Parthenocissus quinquefolia* L. Planch)

Sanitation measures

Our preliminary results show that the ideal solution is to use combined defence intervention, i.e. combination of mechanical measure at the end of the year and chemical measure next year in the first half of vegetation period with the use of system herbicides thoroughly sprayed to all green parts of the woody plant (not only assimilation apparatus but also green not lignified shoots). Thereby the active surface for herbicide activity, and also its effectiveness, is considerably enhanced.

In conditions of BG PJŠU the mechanical removal of seedlings and stump or root shoots is prevailing but interventions must be systematically repeated – namely next year in the first half of vegetation season, in time of soft unlignified green shoots when mowing with string trimmer can be used and seedlings and shoots can be cut together with grass. Later, after lignification of shoots, the intervention is more complicated and it is necessary to use special extensions for brush cutters in the form of star or saw circle. Such measure is more time consuming and both consumption of fuel and whole abrasion of tools grow.

In last years we use natural measure of liquidation of seedlings and sprout shoots of invasive woody plants with the help of animals (goats, sheeps) grazing the problematic areas. It is highly effective way of liquidation of undesired vegetation which is environmentaly friendly.

Conclusions

On the base of our findings to the date, conclusions can be summarized as follows: out of the selected invasive tree species, two of them dominated from the viewpoint of economic importance, namely *Robinia pseudoacacia* L. and *Ailanthus altissima* (Mill.) Swingle.

1. Black locust (*Robinia pseudoacacia* L.) has dominant position thanks to original intentional outplanting of individuals for anti erosion and soil stabilization purposes (fixation of gullies, areas with critical slope and with shallow soils). The role of several originally purposal outplantings was fulfilled, from site to site the natural dieback of old trees take place but in many sites the considerable stump and root sprouting capacity is manifested and it makes the management of forest park more difficult.
2. Enormous invasive potential is shown by *Ailanthus altissima* (Mill.) Swingle*.,* which dominates as very aggressive and rapidly spreading species even in urban outplantings.
3. Only those phytotechnical measures regularly repeated every year are really successful. Occasional removal of woody plants leads to only timely limited positive effects, it evokes higher stump and root sprouting ability and, as a result, compact stand which is difficult to manage.

Several conclusions are taken from ELIÁŠ (2011):

- It is needful to study invasive behaviour of introduced woody plant species at local level and their penetration to natural communities
- Performing monitoring in permanent plots, especially in forest stands adjacent to arboreta, botanical gardens and other cultivation areas
- It is desirable to make controls at the borders to be more strictly during intentional introduction of woody plants (external quarantine) and also in cases of outplantigs of exotic woody plants in settlements and along traffic roads
- In intentional introductions, it is needful to exclude species with invasive potential, namely the species with known invasive behaviour in both neighbouring and geographically more remote countries

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