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Review paper

Integrative system for monitoring and control of ragweed in urban and semi-urban areas of the City of Novi Sad (Serbia) – *NS-AmbrIneS*

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Summary. The consequences of ragweed range spread include changes in qualitative and quantitative composition of natural plant associations, as well as segetal associations in urban and semiurban areas. In addition, allergic manifestations and ailments caused by allergenic activity of ragweed pollen have a pronounced sociological and economic effect on normal activities and functioning of the society. The urban units, and especially cities in Central Europe, are faced with a particularly high-level challenge to ensure the level of everyday activities, especially in sectors of health and education. The experts from Faculty of Science and Faculty of Agriculture worked together with the city government of Novi Sad and public companies to set a unique system named *Integrative system of monitoring and control of ragweed in urban and semi-urban areas*, which is successfully implemented in the area of City of Novi Sad during a period of almost 25 years. The system has an abbreviation "*NS-AmbrIneS system*". Since its establishment it has been upgraded several times and it has shown exceptional efficiency so it was also adopted by other cities. This system relies on maximum coordination of components, trust among all participants as well as self-control and maintaining a high level of responsibility.

Keywords: alien plant, invasive, ragweed, suppression.

INTRODUCTION

Introduction and spread of allochthonous plants causes changes in the qualitative composition of flora, in natural as well as in semiurban and urban habitats. However, the changes in natural habitats, their transformation, fragmentation and disappearance, caused by introduction and spread of invasive species, are often noticed only much later, when these destructive changes are already in full swing and when the allochthonous species are already dominant in these habitats, initiating transformation of floristic composition and structure of phytocoenoses (Jovanović 1994). The negative impact of allochthonous species gets recorded at a much earlier date if they have additional characteristics that negatively influence the human society. One such plant is common ragweed, as its invasive character became recognizable as soon as it was discovered that it is one of the causes of allergic rhinitis and that a significant percentage of human population is exceptionally susceptible for pollen grains of this species (Makra et al. 2015). Once the "enemy" and disruptor of human life quality was recognized, this plant species become significantly better known. From "the species enriching our flora", as this North American arrival was first called, it immediately became allergenic, weed and invasive plant mentioned in everyday parlance, especially in the months when it blooms and when the allergic reactions in humans are most common. This in turn led to changes in everyday

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life and work, and directly and indirectly influenced the changes and significantly threatened the work process and health and educational systems (Boža et al. 2006).

The City of Novi Sad is geographically situated in the Pannonian Plain, along a great European river (Danube) and important international road and railway traffic lines, and it is surrounded from all sides by large complexes of agricultural areas. Therefore the spread of this intensive species in urban and semiurban habitats of the city area as well as in the natural habitats of its broader vicinity is permanent and intensive. The city structures and administration were among the first in both Serbia and region to recognize the problems caused by spread of ragweed, and in mid-1950s they already financed and enabled various activities on establishing a system for recognition, monitoring and control of spread of ragweed and other allergenic plants (Bojčić et al. 2018). After more than two decades of field work and active programs in the City, a recognizable system of monitoring, mapping and suppressing ragweed was formed under the name *NS-AmbrIneS*. This system was based both on scientific studies and first-hand experience in handling this invasive species.

DISCUSSION

Biological characteristics of ragweed and history of invasion

The genus *Ambrosia* includes 40 species. Their primary range is in North America, while four species appear as adventive species in Europe (Boža et al. 2002). One of these species, common ragweed (*Ambrosia artemisiifolia* L. 1753) is exceptionally invasive and widespread in Europe. In addition to its impact on biodiversity, it is primarily notable for its negative impact on human health and economy (Alberternst et al. 2016). This annual plant may reach 2.5 m in height and forms unisexual flowerheads, which in case of male flowers may include 10-150 flowers in each head. Ragweed is a monoecious plant with allometric distribution of sexes, meaning there is a much greater number of male heads (Božić 2018), maturing gradually from the base toward the tip and causing a much-prolonged period of pollen production (Smith et al. 2013). Unusual among composites (Asteraceae) for its use of wind as a pollinating agent, this species has a special type of pollen grains with air chambers, enabling transport to great distances (Payne 1963). Flowers open at daytime, more precisely from early morning to about noon, when temperature increases and relative air humidity decreases (Bianchi et al. 1959). Depending on size of an individual plant, it may produce millions of pollen grains, and during a single vegetation season one hectare of ragweed may release 66 kg of pollen (Makra et al. 2015), while the limit value for clinical symptoms is below 20 pollen grains per m^3 (Smith et al. 2013). In the conditions when air temperature and CO_2 concentration are increasing, which is common in urban environments, production of pollen grains, but also their allergenicity is additionally increased (Ziska et al. 2003). As ragweed is a short-day plant, the trigger for its flowering and creation of generative organs is summer solstice (Allard 1945), while temperature is also important as it regulates the length of generative phase. In addition to high plasticity, the high degree of invasiveness is also induced by very high production of seeds (3,000-65,000 for one plant) (Dickerson and Sweet 1971), as well as their very long germination period, which may reach 40 years (Basset and Crompton 1975; Hegi 1979). As in natural conditions ragweed seed falls very close (2-3 m) to the parent plant (Basset and Crompton 1975), the population spread is relatively slow, except in riparial areas (Fumanal et al. 2007). Accelerated spread of this species is exclusively anthropochorous, and contaminated cereal seed and bird food are the main sources of seed material (Bullock et al. 2012).

Ragweed seed was introduced to Western Europe accidentally in mid-19th century with North American clover seed, but climate conditions prevented formation of stable populations (Priszter 1960). Therefore certain authors assume that this species entered the natural habitats from botanical gardens (Dessaint et al. 2005). Although the first herbarium data for this species indicate presence of ragweed in three botanical gardens in France as soon as mid-18th century, the analysis of the oldest herbarium data has shown its presence at several different locations, and the oldest record is from 1863 (Chauvel et al. 2006). It is also important to note that first records of European regional Floristic studies, ragweed populations in the wild were from Dalmatia (present-day Croatia) from 1842 (Visiani 1847; Béres et al. 2005). In addition, the increase in trade between Europe and North America in late 19th and 20th centuries has led to constant import of new ragweed seeds and setting new populations independent of those already naturalized. The first established populations were recorded in eastern France in the valley of river Rhone, and due to the well-developed transport network this species spread further eastward. Therefore in addition to this region there are two additional areas with significant populations of ragweed: northern Italy and Pannonian Plain (Juhász 1998). Distinctiveness of these regions was supported by models of introduction and spread of ragweed in Europe, including the importance of trade and transport network, while the region of western Ukraine and southern Russia is additionally pronounced (Chapman et al. 2016). The present state is a result of further introductions, especially after the First World War, when the harbors in Mediterranean, Adriatic and Black Sea became the starting

points for further spread (Makra et al. 2015).

Although the first records of ragweed in the Pannonian Plain were from vicinity of Budapest in 1888 (Thaisz 1910) and lower flow of river Danube – port of Orșova circ. 1907 (Jávorka 1910), its intensive spread really began in the second half of 20th century, when reconstructed speed of invasion was 70 km per year (Song and Prots 1998). The first records for Serbia were from Vojvodina province after World War II, from vicinity of Sremski Karlovci, Petrovaradin and Novi Sad (Slavnić 1953), where Romanian ships were assumed to be possible carriers. In the following years, these records were proven and enriched with data from Fruška Gora (Obradović 1966), while ragweed gradually entered the ruderal flora of Novi Sad (Šajinović 1968). Šajinović and Koljadžinski (1978) stated that, 30 years after the first data, ragweed managed to spread almost throughout the territory of Vojvodina province, becoming an almost ubiquitous member of many ruderal associations and threatening agricultural crops. At the beginning of the 21st century, common ragweed was widespread in the Province, often creating compact stands in open, sand-based and ruderal habitats, while it was also a common weed in various crops (Boža et al. 2002; Anačkov et al. 2013; Boža 2013). The genetic analyses of ragweed populations in the southern part of the Pannonian Plain have indicated a high level of genetic variability and a low level of differentiation between populations, which may be explained by a series of introductions and a high rate of gene flow (Kočiš Tubić et al. 2014). In modern times, ragweed has spread from northern to the southern parts of Serbia, with the spread rate of 6-20 km per year, and has a significant percentage representation in weed flora of Serbia (Kočiš-Tubić et al. 2015; Božić 2018).

Harmful effects and impact on human health and human society

Combined analysis of optimal habitat conditions and recorded pollen concentration in the air, performed by Makra et al. (2015), shows the most threatened regions of Europe, in descending order: (1) southwest of European Russia, (2) Pannonian Plain, (3) valley of river Rhone, and (4) northern Italy. The analysis of pollen concentration recorded in 8 years (Šikoparija et al. 2017) has proven that the predicted regions are indeed characterized by the highest ragweed pollen concentration in Europe, but decreases were noticed in France as a consequence of successful control and suppressing and in northern Italy due to accidentally introduced oligophage insect species *Ophraella communa* (Bonini et al. 2015).

In the above analysis, the Pannonian Plain stands out due to the significant increase of pollen concentration, indicating an expansion of this species, insufficient suppressing measures as well as suitable climatic conditions for increased accumulation of pollen in the air. Although the pollen concentration in the Balkans is much lower, there are an increased number of consecutive days when people are exposed to low pollen concentrations (Šikoparija et al. 2017). It was determined that differences in air pressure between Central Europe and the Mediterranean lead to air masses moving southward while carrying ragweed pollen. Therefore the greatest pollen concentration in vicinity of Novi Sad was recorded in the morning hours, while later during the same day and in the following night lower concentrations of pollen from the Pannonian Plain were recorded at Niš, as well as up to 400 km southwards at Skopje (Šikoparija et al. 2009).

The estimated economic losses caused by common ragweed in Europe in the 2010s exceeded 6 billion Euros, while 80% of expenses were in field of agriculture (Bullock et al. 2012). The harmful impact and suppression of ragweed in agricultural fields was subject of numerous studies (Sölter et al. 2012; Essl et al. 2015; Makra et al. 2015; Božić 2018), while studies of impact on human health and life quality are still lacking (Smith et al. 2013). Ragweed pollen is one of the most common causes of seasonal allergies (CABI 2020). Therefore the countries with the greatest presence of ragweed also have the highest percentage of population affected by allergic reactions. The percentage of persons sensitized with pollen of this species reaches over 60% in Hungary, 20% in southern Bavaria, while there were no threatened inhabitants of Mediterranean countries and the far north (Smith et al. 2013). The trend of increase in number of sensitized persons was also noted, so in Hungary it doubled in the last four decades of the 20th century and quadrupled in the southern part of Hungary (Makra et al. 2005), while in Austria there was an increase from 8.5% to 17% in the period 1997-2007 (Hemmer et al. 2011). Although studies on number of sensitized persons are yet to be performed in Serbia, we believe that this percentage must be very similar to the results from southern Hungary, especially in the northern and central parts of Serbia. It is necessary to point out the exceptionally high pollen concentration recorded in Novi Sad and its surroundings, forming a hotspot source of pollen allergies (Šikoparija et al. 2009; Makra et al. 2015). This estimate is partially supported by the model of the future number of sensitized persons in Europe in 2041-2060, which predicts doubling of number of sensitized persons, with the greatest growth in the southern part of the Pannonian Plain and at Balkan Peninsula (Agnew et al. 2018).

Laboratory research as the foundation for setting the integrative system of ragweed monitoring and suppression

The laboratory research performed in order to establish the integrative system of ragweed monitoring and suppres-

sion included several smaller projects.

I – Research on distribution of ragweed in urban and semiurban areas (Boža et al. 2002; Gavrilović et al. 2012; Bojčić et al. 2016, 2018; Rat et al. 2017).

II – Research on biological characteristics of ragweed, including vegetative organs (Anačkov et al. 2012; Živanović et al. 2012), characteristics of seeds (Bojčić et al. 2019) and molecular characteristics, relatedness of ragweed populations and defining the time of their establishment in Serbia, and especially the most threatened part - Vojvodina (Kočiš-Tubić et al. 2014, 2015).

III – Research on the success of mechanical methods suppression of ragweed (Boža et al. 2006)

Mechanical suppression of ragweed – case study City of Novi Sad

In order to define the best dynamics of mechanical suppression treatment, studies and experiments were performed in real time (Boža et al. 2006). This was also the first realistic experiment (Fig. 1) used to define the optimal mowing schedule in local climatic conditions and defining the height of stem at which mowing should take place in order to achieve maximum efficiency of this method of mechanical removal of ragweed.

The experiments have shown that a single round of mowing (in season) reduced pollination by 17 times, while two rounds of mowing reduced it even 100 times. If two rounds of mowing are properly timed (before flowering), they provide excellent results in reduction of number of male inflorescences, flowers and stamens, while the third and fourth rounds of mowing also achieved sterility of male inflorescences (Table 1) (Boža et al. 2006). In order to achieve spontaneous decrease in pollen production, it was determined that mechanical treatments of plants must be performed in a specified way and in appropriate intervals (every time before flowering and in the phase of male inflorescence formation). In fact, the efficiency of the system is based on the necessary mechanical treatment of individuals immediately before or during formation of male inflorescences. This approach also indirectly reduces the total number of female fruits and reduction of number of fruits.

The results of this study, reduction of the area treated for ragweed control in the past 15 years, were used as a foundation for Strategy of monitoring and suppressing ragweed in Novi Sad. The goal of the Strategy is a program solution of decreasing the concentration of pollen grains in the air as they create allergenic manifestations in the local population. The system used in Novi Sad has been broadened and modernized during the intervening years, so today it is the

Fig. 1. Experimental plots for determining the real dynamics and appropriate height of mowing within the period 2002-2006 (Boža et al. 2006).

Table 1. Decrease in number of male inflorescences and stamens of *Ambrosia artemisiifolia* after the mechanical suppression (mowing) in 2005 (Boža et al. 2006).

		Length of racemes (cm)	Number of racemes	No. of male inflorescences	No. of male flowers	No. of stamens
Plants never mown	05.09.	17.5	246	13,822	317,906	1,589,530
Plants mown once	20.07. 05.09.	2.2	35	783	18,009	90,045
Plants mown twice	31.08. 20.09.	2.1	7	132	3,036	15,180

only program with decades of continuity, without interruptions, in this part of Europe. Since 2010, every location has been georeferenced with global system of satellite navigation (GNSS), providing precise location and approach to contractor. Since the beginning of use of GNSS model there were improvements in efficiency of continuous monitoring, establishment of appropriate analytic systems and direct prediction of dynamics of local and global populations of ragweed in this part of Europe. In addition, this type of approach enables easier work for supervision service through precise insight into the locations selected for treatment and the rate in which work orders are realized.

The results of the conducted research (Boža et al. 2006), which have been in active use for 15 years and the experience of 25 years of working on ragweed monitoring, have enabled the experts from the Laboratory for Invasive and Allergenic Plants (LIAP) at the Department of Biology and Ecology of Faculty of Science at University in Novi Sad and the experts from Laboratory for herbicides at Department of Plant and Environmental protection at the Faculty of Agriculture at University in Novi Sad to establish the Integrative system of monitoring and control of ragweed in urban and semiurban habitats in the territory of City of Novi Sad – ***NS-AmbrIneS*.**

Integrative system of monitoring and control of ragweed in urban and semiurban habitats – *NS-AmbrIneS* (example of Novi Sad)

Implementation of the integrative system of monitoring and control of ragweed in the urban unit of City of Novi Sad enables clear defining and scheduling of authority and responsibility within the activities of monitoring and mapping on one hand and control and suppressing on the other hand. A wealth of experience in mapping and control of ragweed within the territory of City of Novi Sad has contributed to establishment of an efficient integrative system of monitoring and control of ragweed.

The system is composed of three main units defined as "services", which are continuously networked on several levels, and its efficiency is based on well-defined schedule of authority and responsibility of all participants.

There are three services: (**1**) Service of mapping and monitoring; (**2**) Service of control (activities on suppressing ragweed populations), and (**3**) Expert supervision service.

Additionally, the system directly includes: Public Companies (PC), Public Utility Companies (PUC) and authorized Inspection services, all with the goal of suppressing ragweed on the maximum area of the city and suburbs. The City Central has the task of coordinating all activities. It includes representatives of customer, main services of the system, as well as short-term members invited by the Central.

Organization of mapping and monitoring service

Within the integrative system of ragweed suppression in the area of City of Novi Sad, the mapping and monitoring service includes combined activities of field and laboratory monitoring, mapping, prioritization of localities primarily based on expected flowering time, suggestion of time and form of suppression (work order), communication with all involved elements combined within the City Central, as well as direct communication with the community and legal persons who are owners of affected plots. Mapping and monitoring services includes a coordinator and field researchers.

As there are already 15 years of continual experience combined with additional initial knowledge gathered during the first years of organization and implementation of the System, there is enough experience to determine four seasonal (vegetative period of ragweed during the year) phases of activities: (**1**) preliminary field research (May-June), (**2**) first round of mowing (June-July), (**3**) second round of mowing (August-September) and (**4**) third and possibly fourth round of mowing (October).

The data collected in the field are synthesized, arranged and analyzed in the Laboratory. The results of many years of research have contributed to recognition and defining the

potential hotspots of ragweed spread within the City, as well as to noticeable decrease of ragweed population sizes and amount of pollen in the air. Considering each part of the city and suggested urbanism activities and changes, it is possible to determine the hotspots of ragweed spread even during the single season and thus determine the priority zones for proper, mostly mechanical treatment (especially in urban units of residence, work, rest and recreation) and increased and systematically applied monitoring. Additional fieldwork performed in phases enables recognition of local changes during short periods of time and therefore more precise data overview. Preliminary field research was proven to be crucial for successful prioritization of locations, enabling continuous monitoring of known and recognizable hotspots over many years, as well as early detection of potential new locations with greater abundance of ragweed plants. Defining and prioritization of most threatened urban and semiurban areas before each season of mapping and suppressing ragweed populations is the foundation for continuation of activities within the NS-Integrative system. Priority locations for treatment are chosen according to two main criteria: (a) number of individuals per m^2 and (b) surface area. All locations with surface areas above 10,000 m^2 and density of individuals above 20/m^2 are designated as potential hotspots. Their further prioritization is aligned with the level of urbanization, through proximity of housing units and distance from the spreading corridors (roads, railways and watercourses). The preliminary field research is particularly important for determining the areas selected for different forms of treatment (mechanical and chemical), especially in order to align the methods and removal efficiency with the urbanistic plans at city level.

Previous experience has shown that field research within the municipalities or local community offices (*mesna zajednica*) provides the best results for coordination with work units of contractors, where their authority is precisely matched with area under field monitoring. Before actual fieldwork it is necessary to define ownership of areas (public or private), as the System *NS -AmbrIneS* includes only the undeveloped public areas. Therefore the field researchers may record presence of ragweed in private areas or areas governed by different companies, enabling proper alerting of authority institutions and reporting to authority Inspection services, as well as to the Expert supervision and the City Central. The raw data collected in the field are sent to the coordinator of the monitoring service as daily reports with GNSS coordinates.

Procedure of creating a recommendation (work order)

All the collected field data are used to create recommendations for ragweed removal from each particular location. Within the present NS-Integrative system, the recommendation is sent to City Administration for Construction Land and Investments, which is the supervising organ, and they create a work order and send it to PUC "Gradsko zelenilo" as well as to the contractor. Each recommendation must include: precise location (referenced with urbanistic and geographic coding), description of locality, number of ragweed stands per m^2, present/estimated phenophase, precise surface area, recommendation of the form of treating the plot, and the recommended number of days so all the proposed activities would be finished.

Work order for mechanical removal includes mowing, collecting, transport and depositing the dry material, while the work order for chemical removal includes the specified adequate procedure and rules for chemical treatment. The recommendations should follow the suggested speed and available time of appropriate treatment and spatial distribution of selected locations, enabling efficient approach of contractor with minimal expenses of suggested activities.

Contractor for ragweed suppression

The contractor is either chosen after an offer or named by appropriate structure of city administration, in case when it is a company belonging to the system of local self-governance. The rights and obligations of contractors are defined by the contract.

Methods of suppressing ragweed

The contractor implements chemical and mechanical methods of ragweed suppression. Ragweed may be suppressed in following ways: (**1**) chemical – total herbicides; (**2**) mechanical – pulling out, weeding, plowing, harrowing, mowing; (**3**) biological – through monophagous insects and phytopathogenic fungi and competitor plant species.

In the NS-ambrines system they use the first two methods of suppression, as the method of biological control is still not used in Serbia.

Chemical suppression of ragweed

In the terrain not suitable for mechanized removal of ragweed stands it is possible to use chemical measures in forms of herbicides. Chemical suppression of ragweed is recommended for ruderal plots away from public objects, in orchards and vineyards, on slopes of canals, along railways and at other areas not used for agriculture (landfills, along road network, around industrial objects and yards). The most common and most efficient way of suppressing ragweed in these places is through total translocation glyphosate-based herbicide. Use of prepared mixtures based on this active sub-

stance (for example Glifosav, Glyphogan, Glifomark, Clinic, Blade...) in concentration of 3-5 l/ha, depending on height and development phase of ragweed plants, provides high efficacy. In spite of its effect (total herbicide), glyphosate is still one of the eco-toxicologically most favorable herbicides included in the lists of approved herbicides in Serbia, EU and around the world. Under the influence of microorganisms, the glyphosate molecule decomposes very quickly in the soil and leaves no residues. Although the ban on the use of these preparations has been announced in some EU countries, they are still in use. Suppressing ragweed with herbicides should be performed in the initial phases of development, when most individuals have germinated and already have a sufficient amount of leaf surface for absorption of the chemical preparation. If selective herbicides are used, it is necessary to perform the treatment at the development stage from cotyledons to the second pair of leaves. The treatment with glyphosate-based preparations (total herbicides) should be performed when plants are 10-30 cm tall, only using the minimal prescribed amount of herbicide. If there is a need for selective herbicides (herbicides that suppress only certain targeted weed species without affecting the surrounding vegetation) in certain places such as riverside embankments, where it is necessary to preserve the grass cover, it is important to note that they show good or satisfactory efficiency only if applied when weeds (in this case ragweed) are in the cotyledon phase or in the phase of four developed leaves (BBCH 14). There are several types of different selective herbicides (active substances with different mechanisms) and an even greater number of formulated brand mixtures, depending on the crops infested with this weed species. During application it is also necessary to consider the daytime air temperature which should not be below 15 °C or above 25 °C. Although it is possible to apply selective herbicides in agricultural plots, due to the above reasons and the complexity of application procedure the most common choice is glyphosate as total translocation herbicide.

In addition to advantages, chemical treatment of ragweed also has certain disadvantages (Janjić and Vrbničanin 2007), as the more recent studies have indicated development of resistance to certain herbicides (such as glyphosate) in countries where they have been used for several decades (Heap 2020).

Mechanical suppression of ragweed

The most economically sound procedure, which also has the least impact on natural processes and human, animal and plant health, includes mowing, digging up or pulling out the plants.

It is suggested that weeding should be done as soon as possible after most individual plants have germinated. Ragweed should be pulled out at the level of root neck and the plant is permanently destroyed in this process. This method of ragweed extermination is used at small surface areas, in urban environments around parking lots and side curbs with individual plants, where there is a limited possibility to perform activities. In the later developmental stages when abundance of ragweed is increasing, one of possible methods is excavation of entire plants. This method necessitates high levels of efforts by individual contractors, and this is the main disadvantage of the method. This method of ragweed suppressing is often used in artificially maintained plots, around alley trees, in flower beds etc.

Mowing is the only form of mechanical treatment that is economically sound and possible and successful in all environments. When it is performed by experts in the precisely defined time, the effect of ragweed suppression stands out as the only sound one. Mowing may be performed in two ways: by hand or by machine. Mowing by hand involves use of a trimmer. This type is mostly applied at smaller surface areas, in urban and rural conditions and at landfills. It is most efficient in uneven, undulating or completely tangled terrain at more angled slopes, as well as on terrain of dynamic configuration which has construction rubble or other waste material as substrate. The machine mowing is most efficient as it is possible to treat a large surface area in a short amount of time, and the best method is combined use of machine mowing and trimmers. In modern times, in addition to use of tractor 2 m and 4 m Taarup with a flexible handle, there are also other machines that bring the cost of ragweed removal even lower.

The most efficient method of mechanical removal of ragweed includes three precisely defined and carefully spaced rounds of mowing (Boža et al. 2006; Simard and Benoit 2011; Milaković et al. 2014). Ragweed must be mown in three rounds, but the proper treatment of the plot must also include a proper way of collecting, transport and storage of mown material. The workers must be properly dressed (gloves, caps, face masks, long sleeves and trouser legs) in order to prevent any health complications, especially the possible contact and pollen allergies. The removal of mown material must follow the work order, including that the level of material in truck trailer must not exceed the upper edge of the trailer sides, the material must be covered and properly tied up so no material would spill on the way to the landfill. In addition, it is necessary to clean the trimming device and mechanization, as studies have shown that uncleaned mowing equipment is one of the main vectors of spreading ragweed along the roads (Karrer et al. 2012).

Properly performed mowing includes the following objectives: (**1**) Equal treatment in all parts of the area; (**2**) If

plants are of different heights before mowing, after mowing they must be of approximately equal heights; (**3**) The slope of the terrain should not be negatively affecting the mowing process; (**4**) Once started, mowing of a ragweed-infested area should never be performed just partially, but the surface must be completely mechanically treated; (**5**) The mechanically treated area should retain a pronounced aesthetically pleasing look; (**6**) Selective mowing is performed only as top priority.

Material must be quickly removed from the mechanically treated surface in order to prevent spontaneous fire due to a large amount of dry plant material in the summer months. The mown plant material must be transported to a landfill, where it may be stored in a few prescribed ways. The most economically sound way, and the only one possible in landfills with low sanitary standards which are the most common in Serbia, is to bury the material in excavated pits.

The deposition method is crucial in the last phase of mechanical removal. If mown stems of flowering ragweed were just left untreated on the landfill, pollen dispersion would continue. A special place for such material must be designated at the landfill. The pits must be 5-10 m deep, 30-50 m long and 10-15 m wide, depending on the capacity of the landfill. Each pit must be assessable from all sides. After the material is lowered into the pit, construction rubble is placed on the top in order to ensure physical pressure on the material, followed by a thin layer of soil and quicklime (other material may be also added but it decreases the capacity of the pit as it would necessitate a thicker layer). Each successive layer is placed upon the previous one. Once the pit is full, its surface is leveled and marked, as the same spot may be used to following year. There is a similar system of material disposal at the organized landfills, only the locations are planned in advance. Instead of pit excavations the material is placed in underground boxes where decomposition of plant material is accelerated.

Organization of service of expert supervision

The service of expert supervision was organized according to the predetermined program of ragweed suppression, including following tasks:

I. Field supervision. (**1**) Receiving recommendations from the monitoring service (with georeferenced locations and predicted surface area for treatment); (**2**) Preparing and sending work orders to the contractor; (**3**) Visiting the area together with the representatives of monitoring service and contractors in the treated areas.

II. Obligations toward the City Central for coordination of activities and supervision in suppressing ragweed. (**1**) Preparing and sending weekly reports on performed contractual obligations of monitoring service and contractors at the regular meetings of the City Central; (**2**) Coordination with PC and PUC during the removal of ragweed under the surfaces in their jurisdiction; (**3**) Coordination with the local inspection services; (**4**) Checking the locations reported by citizens, according to the report by the monitoring service and contractors (Citizens submit applications to the institutions included in the *NS-AmbrInes* system or to local self-government); (**5**) Preparing and sending monthly reports with financial expenses, according to the contractual obligations of the monitoring service and the contractors; (**6**) Preparing the annual report on realization of contractual obligations of the monitoring service and the contractors.

The supervision service for control and coordination of PC, PUC and inspection services is determined by the Customer and includes two or more supervisors. This type of supervision is specific as it includes indirect control of PC, PUC and inspection services that are primarily responsible to the founder, and then also to the City Central and obligations accepted by the Regulation on ragweed suppression from 2006. The obligations of the supervising service include networking and coordinating ragweed suppression on land belonging to this type of companies, with authority provided by the City Central. In this type of plots, the caretakers often perform ragweed suppression inadequately and in wrong time, so it is necessary to implement internal control of such activities. In these situations, the supervising service is sent a report on ragweed suppression activities, with a precise location and size of treated area, and then sends it further to the City Central.

The supervision for control and coordination of monitoring service and contractors for ragweed suppression is determined by the Customer and includes two or more supervisors. This type of supervision is the most important link of the Integrative system as it directly connects the members of the City Central. This supervising team is obliged to directly control the contractual obligations of the monitoring service and the contractors. Obligations of the monitoring service and the contractors are precisely defined in the contract signed with the Customer.

The obligations of Monitoring service toward the Supervising services: (**1**) Sending recommendations for ragweed removal to the Supervising service (for more details on recommendations see the text on monitoring service); (**2**) Providing weekly, monthly and annual reports on realized contractual obligations; (**3**) The monthly report should include an invoice (bill) for the realized contractual obligations; (**4**) Suggesting the priority locations for ragweed removal; (**5**) Accompanying the supervisors in visiting the ragweed suppression areas; (**6**) Accompanying the supervisors in control of realized ragweed suppression.

The supervising service has an obligation to prepare and

send a work order to the contractors within 24 h from accepting the recommendation. The work order includes all parameters from the recommendations by the monitoring service.

Obligations of contractors at ragweed removal activities toward the supervising service: (**1**) Realize the work order in due time and according to the rules of service; (**2**) Keep a detailed list of all performed duties stated in the contract obligations, as paper trail of performed obligations which is signed as a legal evidence of realization of activities; (**3**) The realized contractual obligations must be reported as daily, weekly, monthly and annual reports; (**4**) The monthly report should include an invoice (bill) for the realized contractual obligations; (**5**) Accompanying the supervisors in visiting the ragweed suppression areas; (**6**) All established norms and rules of disposal of containers of chemical products must be implemented.

The supervising service has an obligation to officially provide evidence of realization of ragweed suppression by directly visiting the location, within seven days from realization of work order. The supervising service has an obligation to determine efficiency of ragweed suppression by mechanical means and determine the success of the chemical product used for chemical suppressing. The supervising service is part of the City Central and has an obligation to inform the City Central on realized activities of all participants of Integrative system through official reports.

City Central for coordination of activities and supervision in suppressing ragweed (Central)

City Central (Fig. 2) includes all the elements of Integrative system of ragweed suppressing and monitoring as permanent members, while the Central is headed by the authority from city structures (Customer). The main purpose of the Central is coordination of implementation of the *NS-AmbrIneS*, with possibility of inclusion of inspection services, public utility companies and public companies as temporary member of this body. The City Central adopts weekly, monthly, annual and stage reports by Expert supervisors, the monitoring service and the contractors, as well as the financial reports. Additionally, it is necessary to form a center for incoming reports by citizens, as well as the media campaign team.

Short description of obligations for each member of the Central:

(**1**) Financial supervision – performed by person with an authority to control the budget expenses for positions defined in the city budget for the running year, and a person communicating with the city structures in front of the City Central. They get the invoices and reports on performed contractual of obligations of the monitoring service and the contractors from the Expert supervision services.

(**2**) Representative of monitoring and mapping service – informs the members of the City Central on the results

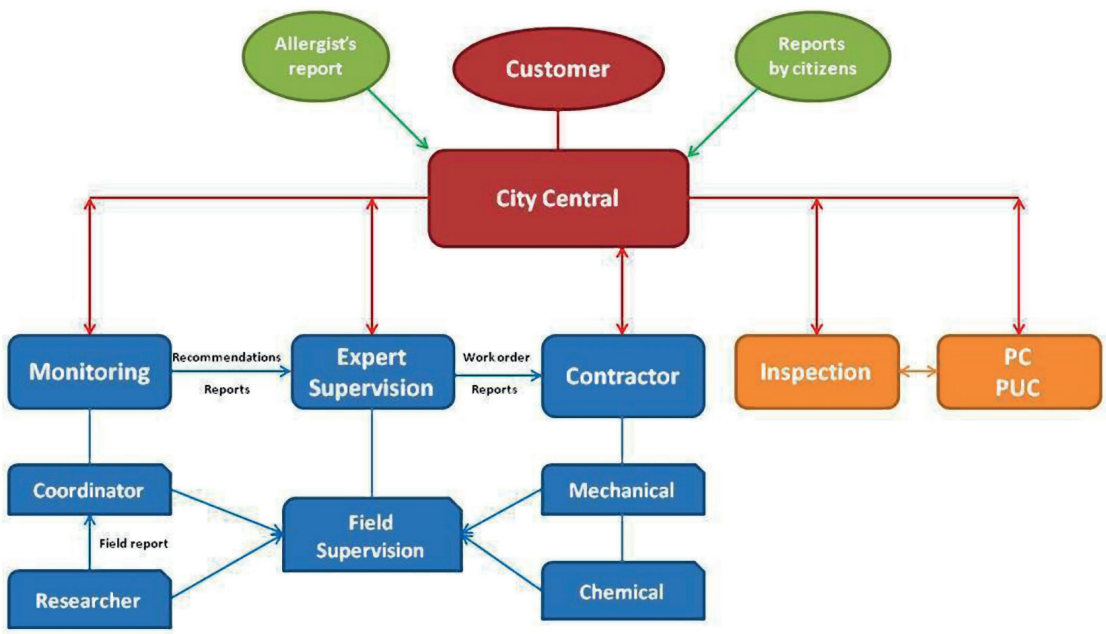

Fig. 2. Schematic representation of organization of Integrative system of monitoring and control of ragweed *NS-AmbrIneS*.

of preliminary research, prioritization of locations and the speed of realization of mapping and monitoring. At the weekly meetings of the City Central provides reports on realized mapping activities, treatment success and potential challenges in fulfilling the contract obligations, as well as a plan of activities for the upcoming work week.

(**3**) Representative of the contractor service – at the weekly meetings of the City Central provides a report on the rate and success of ragweed suppression, the plan of activities for the next work week and reports on potential challenges in meeting the contractual obligations.

(**4**) Expert supervision – performed by an authority person selected by the Central in order to control the contractual obligations of monitoring service and contractors. At the weekly meetings of City Central, provides reports on: a) the total surface area and number of recommendations provided by the monitoring service as well as the number of work orders issued to contractors; b) the total surface area on which treatment was performed by contractors; c) the fulfilled contractual obligations of the monitoring service and contractors (according to results of field control); d) ragweed suppression in private property and areas controlled by authority companies (according to results of field control); e) these reports are used to coordinate further activities with the authority inspection services; f) coordinates the reports by citizens, in agreement with the monitoring service and the authority Inspection services.

(**5**) Inspection services – according to the guidelines on activities of City and Republic-level inspections and authority on ragweed suppression, the inspection services have an obligation to control the activities of PC and PUC, within the obligation of maintenance and improvement of assigned plots.

(**6**) Allergist (medical doctor) – collects data and sends weekly reports on number of recorded patients with ailments caused by ragweed pollen.

The City Central combines the reports and recommendations by all the services and provides guidelines for the ragweed monitoring and suppressing campaign. After the contractual obligations of all members of Integrative system are successfully fulfilled, the City Central has an obligation to adopt the report on realization of ragweed suppression. In addition, City Central controls the activities of the team for media campaign and information spread.

Functioning of the Integrative system NSAmbrIneS was proven to be efficient on several occasions (Fig. 3), especially regarding the average annual surface areas treated by mechanical and chemical suppression methods. The urban area of City of Novi Sad is spreading rapidly, but there is still no need for increase in surface area that should be treated by mechanical or chemical suppression. In addition, the constant monitoring of the ragweed populations in the treated areas indicates a decrease in number of individuals in plots subjected to mechanical or chemical treatment.

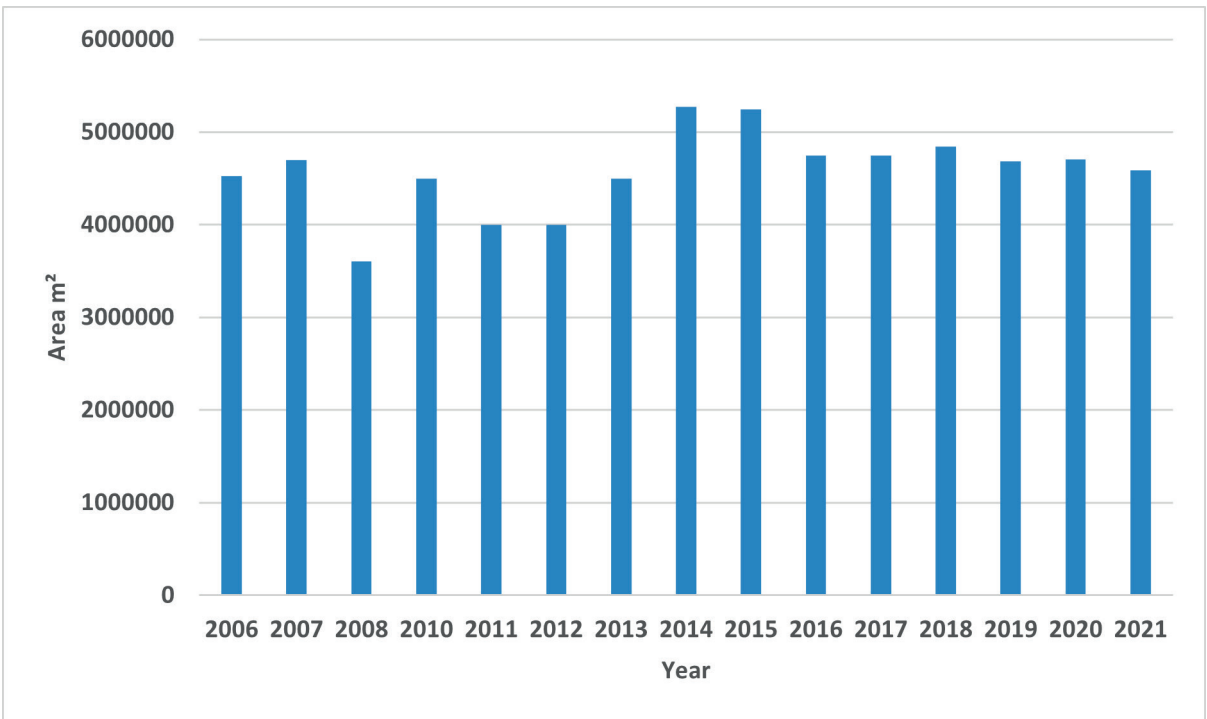

Fig. 3. List of areas treated within the period 2006-2021 in the area of City of Novi Sad, through use of *NS-AmbrIneS*.

CONCLUSION

The integrative system of monitoring and suppressing of ragweed in urban and semiurban areas of City of Novi Sad has changed immensely since its establishment, with numerous revisions. However, today it is a recognizable model implemented in several cities in Serbia (Pančevo, Bačka Palanka, and other). This model is also unique due to the fact that scientific institutions, local government and contractors have worked together as equal teammates throughout the process. The system consists of 12 interconnected components. The components are organized into three units. Part of practical application (mapping and monitoring, suppression contractors, expert supervision), part of inspection and control (PC or PUC) and part of coordination and general organization (City Central). As a model of the annual efficiency of the system, they are taken: (**1**) medical report on the prevalence of pollen allergic manifestations in the ragweed blooming season; (**2**) the size of the surfaces that were subjected to mechanical and chemical removal.

The system is based on the components but even more so on well-matched activities, team control and high insistence on responsibility of all stated components of the system.

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