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ENVIRONMENTAL ASPECTS OF *PHRAGMITES AUSTRALIS* USE AT FERTILIZATION OF CONTAMINATED SOILS

In consequence of the mining and processing of the magnesite ore, some areas of Slovakia have strongly damaged soil, when pH increased to 9 and more. The physical and chemical characteristics of the soil were changed, the erosion increased and phytocenosis decreased. A large number of the soils is impossible to use for agriculture. The fertilization requires huge resources. The future for the fertilization and prospective use of the soils is seen in the possible cultivation of *Phragmites australis*, which was selected in given area. It is an invasive plant with the possible technical and agricultural use. The use of *Phragmites australis* against strongly alkalized soils was suggested by previous investigation, as it grows also on the soils with pH 9.1 and produces very large biomass.

Thence during three years the most suitable method of the reproduction of this plant was investigated, i.e. generatively and vegetatively. On the basis of the statistical evaluation of the results it can be concluded that generative reproduction is technically more demanding and less successful, that the vegetative root segment reproduction is more suitable and can be recommended under these conditions.

Key words: contaminated soils, alkalization, magnesium, fertilizing of soils, *Phragmites australis*

Хронэк О., Вилчек Дж., Торма С., Лисняк А. А. ЭКОЛОГИЧЕСКИЕ АСПЕКТЫ ИСПОЛЬЗОВАНИЯ *PHRAGMITES AUSTRALIS* ДЛЯ ВОССТАНОВЛЕНИЯ ЗАГРЯЗНЕННЫХ ПОЧВ

Вследствие добычи и переработки руды магнезита, в некоторых районах Словакии была сильно загрязнена почва, что привело к увеличению реакции почвенной среды (pH) до 9 и выше. Физические и химические свойства почвы также были изменены, увеличилась эрозия почв и снизилось количество растительных сообществ. Из-за чего, большое количество почвы стало непригодным для использования в сельском хозяйстве, а рекультивация требует огромных ресурсов. Перспективой в восстановлении таких почв является выращивание *Phragmites australis*, который произрастает в данной местности. Это инвазионный вид растений, который возможно использовать в технических и сельскохозяйственных целях. *Phragmites australis* владеет устойчивостью к сильному подщелачиванию почвы, выдерживает почвенную среду с pH 9,1 и может давать очень большую биомассу.

На протяжении трёх лет изучен наиболее подходящий метод размножения этого растения, то есть генеративно и вегетативно. На основе статистической оценки результатов установлено, что генеративное размножение является технически более сложным и менее успешным, а вегетативное размножение корневыми отростками является более подходящим и может быть рекомендовано в этих условиях.

Ключевые слова: загрязнённые почвы, подщелачивание, магний, удобрение почв, *Phragmites australis*

Хронек О., Вілчек Дж., Торма С., Лісняк А. А. ЕКОЛОГІЧНІ АСПЕКТИ ВИКОРИСТАННЯ *PHRAGMITES AUSTRALIS* ДЛЯ ВІДНОВЛЕННЯ ЗАБРУДНЕНИХ ҐРУНТІВ

Внаслідок видобутку і переробки руди магнезиту, в деяких районах Словаччини було сильно забруднено ґрунт, що призвело до збільшення реакції ґрунтового середовища (pH) до 9 і вище. Фізичні та хімічні властивості ґрунту також були змінені, збільшилася ерозія ґрунтів і знизилася кількість рослинних угруповань. Через що, велика кількість ґрунту стала непридатною для використання в сільському господарстві, а рекультивація потребує величезних ресурсів. Перспективою у відновленні таких ґрунтів є вирощування *Phragmites australis*, який зростає в даній місцевості. Це інвазійний вид рослин, який можливо використовувати в технічних і сільськогосподарських цілях. *Phragmites australis* володіє стійкістю до сильного підлуження ґрунту, витримує ґрунтове середовище з pH 9,1 і може давати дуже велику біомасу.

Протягом трьох років вивчено найбільш прийнятний метод розмноження цієї рослини, тобто генеративно і вегетативно. На основі статистичної оцінки результатів встановлено, що генеративне розмноження є технічно більш складним і менш успішним, а вегетативне розмноження кореневими відростками є більш прийнятним і може бути рекомендовано в цих умовах.

Ключові слова: забруднені ґрунти, підлуження, магній, добриво ґрунтів, *Phragmites australis*

Introduction

Slovak republic is a country extremely rich in the natural crystal magnesite. Manufacture of the magnesite sinters by thermic disintegration and sintering operations belong to dust technologies. Two factories process magnesite raw material in the middle of Slovakia in the region of the towns Jelsava and Lubenik namely: SMZ Jelsava a. s., and Slovmag Lubenik a.s. Magnesium oxide, which alkalizes 12,000 ha of agricultural and 6,600 ha of forest soils, is emitted into the atmosphere during manufacturing process. The area of the interest is characterized by high oversaturation of the soils with magnesium where pH is 8-9 and higher. Neither practice nor science have known magnesitephilic plants yet, which would be able to draw off macrobiotic element from the soil by accumulation of magnesium. Magnesium immission causes a lot of unfavorable effects in the soil, vegetation and animals, which manifest themselves in the worse productive and economic results. The sites, where in past the fall of solid reduction was higher than 20 $g.m^{-2}$ showed disintegration of original phytocoenose in 30 days and only several resistant plants were left, which are of very low importance as to production, agriculture, forest growing and aesthetic point of view. The root system of these plants is very weak, reaching the depths of only 30-40 mm, they cannot protect soils sufficiently against the erosion. This subject is proceeded in the works of Hronec et al. [1], Steinnes et al. [2], Hovmand et al. [3], Kaleta [4], Hronec et Hajduk [5], Vilček, [6], Vilček et al. [7], and others.

By calcination of the magnesite in rotary and shaft furnaces solid and vapor waste products originate, which are emitted into the atmosphere and hence to the soil. These products cause alkalization of the soil as well chemical and mineralogical changes are originated: pH value is changed (above 8), macronutriment ratio is changed, biologic value and quality of humus is reduced, the soil erosion is increased, reception of phosphorus and microelements in the soil is reduced, the seeds of the nonresistant plants cannot germinate, therefore reduction of free grown plants occurs.

Long-term observation and investigation showed, that in this contaminated area was *Phragmites australis* (Cav.) Trin appeared in last years, which is originally humid plant, but in this area it grows literally in dry sites, where ground water is in the depth of several meters. Striking vitality of *Phragmites australis* (Cav.) Trin was found, as mega-population in more sites, where the pH value reached pH = 9.1 and in such sites, where it does not occur and according to the published statements its presentation was not recorded in the past [5]. It is hopeful, dominant, resistant, anti-erosive and technically available plant providing alternative solution of sanitation and fertilization of alkalized soils. Productivity and physiological relationship supporting this fact is discussed in works of the following authors: Dykyjova [8], Květ [7], Mason et Bryant [8], Ondok [9], Brisson et al. [10], Chambers et al. [11], Mal et al. [12], Derr et al. [13] and others.

Therefore we have established the aim to verify different methods of *Phragmites australis* (Cav.) Trin reproduction with possibility of its using for broadcast fertilization of excessively contaminated soils with the magnesite.

Material And Methods

Phragmites australis belongs to the family *Poaceae,* genus *Phragmites. Phragmites australis* occurs in two forms: S = terrestrial form. V = littoral form. Terrestrial ecoform occurs in the marginal parts of the pond, where there is minimal fluctuation of ground water level and respectable humus substratum. Littoral form is flooded by regular water with fluctuant water column from 20-90 mm. The substratum is sandy-loamy with low content of the

organic sediments.

The cultivation and reproduction of *Phragmites australis* in the greenhouse and field conditions was realized in the greenhouse of the Secondary Training Centre of Agriculture in Stitnik and field experiment was realized in the site of the soil devastated by magnesium immission in Jelsava in the immission area of exhalation sources. These methods of reproduction have been verified.

Vegetative reproduction

Green cuttings reproduction

Green vegetative cuttings of *Phragmites australis* were removed from the individual sites during five different terms from 9th to 25th of May. The segments were cut by the scissors, only matured stolons were chosen, from which part in the length of 30-40 mm from the top was cut and immediately put into the prepared bucket full of water. Green stalks were removed in five terms: the 1st term: 9th May, the 2nd term: l st May, 3rd term: 12th May, 4th term: 17th May, 5th term: 25th May.

Top green cutting reproduction

- in water solution
- in prepared composition in pot and seed box

The cuttings of *Phragmites australis* were processed on the day of their removal. The possibility of two methods of top green cutting reproduction was verified. The segments were cut from the top in length 300 mm, close (5 mm) under the node in slanting cut by budding knife. The segments cut in this way were dipped into the stimulator – STUMULAX – I and poked into the prepared box in 30 x 30 mm spacing. The box contained a composition of the soil (peat) mixed with sand in 1: 1. The bottle we full with ratio water from the pond and stimulator at the knife-point was added. The cuttings prepared in the same way as for the seed box were put into the bottle and covered with the plastic bag.

Middle green cutting with one node from the stalk reproduction

- in prepared composition in pot,
- in prepared composition in reproduction seed boxes.

This method of reproduction was from the middle green cutting of the *Phragmites australis.* Smaller segments were cut from the brought segments. The process was as follows: From the segment in the length of 300-400 mm was cut in lower part close under the node in slanting cut by budding knife and above the node in the height of 60-80 mm in straight cut. The component part of such cutting was a stalk and a part of the leaf. From one 300-400 mm cutting were removed 1-2 pieces of such segments, the top parts were not used as they were not matured enough. The stalk segments prepared by this method were dipped into the stimulator and poked into the prepared composition (sand and compost) in the pots with 180 mm in diameter and in the boxes 80 mm deep to the depth of 40 mm.

Root segment (rhizome) reproduction

Shallow grown roots of the *Phragmites australis* in the above mentioned sites under the surface of the soil were pulled from the soil by the above ground parts in the length of 0.5 to 1 m and were cut. These ones containing the top bud were cut with one node, the others were cut with two nodes. Root segments prepared by this method were planted into the prepared composition in the pots. The top cuttings were placed with vegetative top of the root 10 mm above the soil surface and the middle root segments with two nodes were placed in horizontal position in the prepared pots in the depth of 50-60 mm above the root.

Generative reproduction

Seed reproduction of the Phragmites australis

Summitas was isolated in two terms: the 1st term 20th October, the 2nd term 15th November next year. The seeds from the summitas were stripped by the comb and together with the glumes were sown on 20th January in the boxes with the composition (compost soil, sand), covered with 10 mm layer of the soil and put into the greenhouse with temperature 20°C. Grown plants 30 mm high with 2-3 leaves were planted in the boxes in 4 x 20 mm spacing since April and when they reached the height about 100 mm and had 3-4 leaves they were replanted in the pots with 120 nun in diameter.

Preparation of the location (or the planting)

For the planting of the pre cultivated plants the area 250 m southern from SMZ Jelsava, near the Muráň river was chosen. The

area with the acreage 10 x 20 m was demarcated and it was enclosed with the wooden fence. At the beginning of June the sad was removed from one half of the location. The samples of the soil were taken and the results are presented in the Tab 2. The pH value (pH/KCl) was 8.1. The content of the magnesium in the soil was 2988 $mg.kg^{-1}$.

Planting of the Phragmites australis

Phragmites australis was planted on 22nd June, at the day temperature of 31 °C from 9:00 am to 1:00 pm. The method was as follows: The 150 mm deep holes were digged and about 2 liters of water was poured there. *Phragmites australis* with the root ball was digged and planted into the holes in 600 x 600 mm spacing.

The care after planting on the site

Young plants after planting (because of the high temperatures in July and August) were regularly watered. Weeding preparation Roundup was applied in September. The new overgrows of *Phragmites australis* obtained by root segment reproduction were established in next year. The plants were evaluated during the vegetation (number of growths, internodes, leaves on the plants). The measurements were done in regular intervals. The measurements were continued one year more and acquired values from all three years of trial were evaluated and they are shown in the tables.

The investigation of *Phragmites australis* was realized during three years. During each year several measurements were done, which is shown in the tables. The height of the plant, number of growths and number of leaves was measured. For the analysis itself, the results of two comparable seasons were used (interannual ± 6 days):

- the 1st summer measurement (second half of July each year)
- the 2nd summer measurement (September each year)

The comparation and the measurement took place in 64 localities, whilst the plants in the localities 1-32 were sown from the seeds and the plants in the localities 33-64 were from the root segments.

The sites (localities), from which seeds and vegetative parts were removed for the verification of the most suitable method of *Phragmites australis* reproduction occur near the factories Slovmag Lubenik and SMZ Jelsava.

Statistical evaluation of the results

The following methods for statistical evaluation of the results were used: index analysis, correlation analysis and hypothesis testing.

The interannual changes of the method of reproduction (vegetative, generative) were investigated by the index analysis. The correlation analysis was used for finding out the dependability among the height of the plant, the number of the growths and the number of the leaves of the plant for all plants together and for individual methods of reproduction particularly as well. At the hypothesis testing we were concentrated on the testing of the equality of the average value above presented parameters of the plants (the height of the plant, the number of the growths and the number of leaves) obtained generatively and vegetatively.

Results And Discussion

The occurrence of *Phragmites australis* under the dry conditions against its appearance in the wetlands with the still water was the impulse for the verification of *Phragmites australis* reproduction in these localities. Several methods of *Phragmites australis* reproduction were tested, namely vegetative and generative. The samples were taken from the described localities. The cultivation of the plants was realized on the contamined soil in the distance of 250 m southern from the factory SMZ Jelsava. The soil samples showed pH 8.1 determinated electrometric and the content of permissible nutrients 67 mg $P.kg^{-1}$ of the soil according it Egner, 62 mg $K.kg^{-1}$ of the soil according to Schaschabel and 2986 $mg.kg^{-1}$ of the soil by method AAS in leach according to Schaschabel. The seeds for the seeding were taken in September from the free grown plants. The seeding was realized under the greenhouse conditions in next spring. The results achieved at vegetative and generative reproduction were noticed in the tables.

In next year the growth and the development of the plants in the testing locality were observed under the field conditions from

the seeds as well as the growth and the development of the plants cultivated from the root segments (rhizoma). The new overgrows in the test location were established from the root segments planted in the second year of trial. During the vegetation the number of plants, the growths, the number of internodes and the number of the leaves on the highest plant was measured. Phenological investigation of the place of the interest continued. The original plant kind representation was confirmed.

The results of the measurements during all three years of trial were statistically evaluated.

Table 1

Interannual changes of the observed signs

1st summer measurement (second half of July each year)			
		ratio 2nd/1st year	ratio 3rd/2nd year
from seed	height in mm	2.399	1.036
	leaves number	1.257	1.121
	growths number	1.927	1.148
vegetative	height in mm	2.195	1.051
	leaves number	1.105	1.107
	growths number	1.830	1.147
total	height in mm	2.288	1.043
	leaves number	1.179	1.114
	growths number	1.876	1.147
2nd *summer measurement (September each year)*			
		ratio 2nd/1st year	ratio 3rd/2nd year
from seed	height in mm	2.442	1.093
	leaves number	1.573	1.062
	growths number	1.930	1.083
vegetative	height in mm	2.191	1.113
	leaves number	1.363	1.072
	growths number	1.958	1.095
total	height in mm	2.309	1.103
	leaves number	1.463	1.067
	growths number	1.944	1.032

The highest index accumulation was noticed in 2nd year, i.e. one year after seeding. At the first or the second comparative measurement the plants grew in average about 128.8%, or about 130.9 % more than in 1st year. The more significant accumulation of the total height in mm was at the plants from the seed (139.9%, or 144.2 %), than at the plants from the root segments (119.5 %, or 119.1 %).The change of the plant height in 3rd year in comparison to the 2nd year was less significant - increasing of 4.3 %, or 10.3 %, whilst lower dynamic at the first summer measurement was noticed at the plants from the seed -3.6 % increasing in comparison to 5.1 % at the plants from the root segments, at the second summer measurement 11.3 % increasing of the plants from the root segments in comparison to 9.3% increasing of the plants from the seed.

The similar process – higher increasing in 2nd, lower in 3rd year was noticed at the observed parameter "leaves number". In 2nd year the number of leaves increased in 17.9 % at the first measurement or 46.3 % at the second one and in last year of trial the increase of leaves number was 11.4 %, or 6.7 %. The higher increase of the leaves number was noticed at the plants from the seed (25.7 % and 57.3 % at the measurements in 2nd year and 12.1 % and 6.2 % at the measurements in 3rd year) in comparison to the plants from the root segment (10.5 % and 36.3 % at the measurements in 2nd year and 10.7 % and 7.2 % at the measurements in 3rd year).

Likewise the third observed parameter - growths number - showed the similar change dynamic. In the second year increased the growths number at the observed plants in 87.6 % or 94.4 %, in third year of trial 14.7 % or 3.2 %. At the first summer measurements the

higher dynamic of the increasing number of growths at the plants from the seed (92.7 % in 2nd and 14.8 % in 3rd year) was noticed in comparison to the plants from the root segments (83 % and 14.7 % in 3rd year). At the second summer measurements was the dynamic of the increasing at the plants from the root segments (95.8 % in 2nd and 9.5% in 3rd year) and at the plants from the seed (93 % and 8.3 % respectively) similarly the same.

No significant dependence among the plant height in mm, leaves number and growths number was found out.

Hypothesis testing

The final part of the statistic evaluation of *Phragmites australis* cultivation was devoted to the hypothesis testing. The correctness of the assumption that the average value of the observed parameters the height of the plant in mm, the leaves number and the number of growths show for both compared methods of reproduction the same values. The testing was done individually for both summer measurements for each year. Enumeration of p-values was realized by using MS Excel software. The values are shown in Tab 2.

Table 2

Reached p-values at the individual measurements

	height in mm	**leaves number**	**growths number**
Measurement 1st year July	0.061	0.27	0.53
Measurement 1st year September	0.062	0.01^{+}	0.57
Measurement 2nd year July	0.071	0.17	0.53
Measurement 2nd year September	0,070	0.74	0.05^{+}
Measurement 3rd year July	0.030^{+}	0.07	0.46
Measurement 3rd year September	0.020^{+}	0.98	0.02^{+}

On the basis of such performed analysis it can be stated that the significant differences at the average height of the plants reproduced generatively and vegetatively were found out. The plants reproduced vegetatively reached at each observed measurement higher accumulation in comparison to generative plants. This accumulation was not during the two first years statistically significant. Till in last year of trial it can be affirmed with the probability higher than 95 %, that the average height of the plants reproduced from the root segments is significantly higher, than the plants reproduced from the seeds. The decreasing p-value in the Tab 2 persuades about the verity of such statement.

The method of reproduction has no influence to the leaves number according the performed analysis. The fining, that during vegetative period differences between the number of growths at the plants reproduced from the root segments in comparison to the plants reproduced from the seeds are increased, was interesting. This assumption can be accepted at the second summer observation during last two years with the probability 95 %. Presented hypothesis for the measurement processed could be accepted with the probability 99 %.

Statistical results showed only low to medium dependence among the observed parameters (the height of the plant, the leaves number, the number of the growths). At the hypothesis testing we were concentrated on the test of the concord of average values above described parameters of the plants obtained generatively and vegetatively. During the third year of the observation statistically significant differences were found out concerning the average height of the plants and the number of growths received by generative and vegetative reproduction on the behalf of vegetative reproduction.

The result of verified methods of vegetative and generative reproduction is, that the most suitable method of reproduction in given area and under given conditions is the root segments reproduction. The biomass production is influenced by the climate conditions. Cultivating of *Phragmites australis* from the seeds showed, that during individual observed years was the germinative activity different but generally the seeds germinated slowly.

Conclusions

In consequence of the mining and processing of the magnesite ore, some areas of Slovakia have strongly damaged soil, when pH increased to 9 and more. The physical and

chemical characteristics of the soil were changed, the erosion increased and phytocenosis decreased. A large number of the soils is impossible to use for agriculture. The fertilization requires huge resources. The future for the fertilization and prospective use of the soils is seen in the possible cultivation of *Phragmites australis* (Cav.) Trin, which was selected in given area. It is an invasive plant with the possible technical and agricultural use.

Thence during three years the most suitable method of the reproduction of this plant was investigated, i.e. generatively and vegetatively. On the basis of the statistical evaluation of the results arises, that the vegetative root segment reproduction is more suitable and can be recommended under these conditions.

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