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Influence of Different Factors on Productivity of Reed Growths

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***Abstract*. The study shows results of research on reed productivity and on factors influencing this productivity. The research was performed during winter period from 2010 until 2012 in 23 natural and artificial water bodies of Latvia. The author of this study analyzed indexes of reed growth productivity and found regularities that statistically significantly ($p<0,05$) explain changes of reed productivity in water bodies depending on individual reed growing conditions in each water body.**

It is established that the productivity of reed growth depends on the amount of nutrients in the water of water body and that this productivity rises if the total concentration of nitrogen and phosphorus in the water is increased.

The reed productivity is lower in clearer water. This parameter may be used in order to evaluate the amount of extractable biomass. The coherence is characterized by statistically significant ($p<0,05$) regression equation.

Keywords: **Common reed, reed yield, productivity of reed beds.**

I Introduction

Support for usage of renewable resources has become an important issue in the policy of European Union and in the rest of the world. [1]. Traditionally, wood is the most important type of biomass in Latvia [2], however lately it has become common to cultivate different energetic plants and to use them in energy production. One of the most suitable plants for energy extraction and saving is reed canarygrass (*Phalaris arundinacea L.*) [3,4,5] which is widely studied in the world and is suitable for energy extraction in the conditions of Latvia [6,7,8]. Besides, for energy extraction it is possible to use the biomass of hemp **(***Cannabis sativa* L) [9,10], flax *(Linum usitissimum L.)* [11,12], different grain and straw [13,14] and other plants. However, cultivation of energetic plants requires agricultural lands which conflicts with principles for sustainable development.

Another plant that could be used for energy extraction in Latvia is reed (*phragmites australis (Cav.) Trin. ex Steud.*) growing in lakes and pisciculture farms. In many literature sources from all over the world, reed is characterized as invasive and unwanted species that spreads rapidly, reduces biological diversity in water bodies [15,16,17] and creates emission of gases CH_4 and CO_2 in the atmosphere thus stimulating greenhouse effect [18,19]. Therefore, reed harvesting would be useful for solution of the aforesaid problems as well.

Biomass output or productivity is one of the most important factors characterizing suitability of plants for bioenergy production. [20]. Parameters of reed growths (length of stalks, dimensions of leafs, density, diameter, etc.) vary depending on climate zone [21]. Reeds offer 40–60 $t*ha^{-1}$ of green matter or 7,5–13,0 $t*ha^{-1}$ of dry matter [6]. Foreign literature sources show that the productivity of reed growth may reach even 30 $t*ha^{-1}$ of dry matter by cutting it in winter period. [22]. In reed growths that are used for sewage treatment in Estonia, dry matter of reed varies from 3 to 17,6 $t*ha^{-1}$ [23]. These wide variations of reed productivity in different international studies indicate that the productivity depends on reed location.

In order to ensure sustainable use of reed for bioenergy production in Latvia, it is necessary to study the distribution of reed growths, available volumes and principles for sustainable use. One of the main parameters that characterize the suitability of each reed growth for energy production is productivity. Hitherto, no studies on productivity of reed growths have been made in Latvia.

The aim of this study is to define the productivity of reed growths in the water bodies of Latvia and to explore factors influencing this productivity, to find regression equations that could assist in evaluation of reed growth productivity in Latvia's water bodies where no research on reed growth has been made.

II Materials and Methods

Studies on reed productivity were performed in 23 natural and artificial water bodies of Latvia. Studies were performed in areas that are potentially important for reed production in Latgale region - in Lubana lake, Kvapanu ponds, Idenas ponds, Raznas lake, Cirmas lake, L. Ludzas lake, Rusonas lake, Feimanu lake, Cirisa lake, Lukna lake and Sivera lake studies were made in spring of 2010, 2011 and 2012. In Papes lake studies were carried out in string of 2012, while in lakes of Birzkalna, Carmanis, Ilzas Geranimovas, Balvu, Ismeru, Aluksnes, Gaidulu, Adamovas, Zolvu, Zosnas and Nirzas studies were performed in spring of 2013. All studies were performed in March because this period is characterized by the thickest ice surface that allows mechanized reed harvesting, therefore the obtained data can be practically used for calculation of reed productivity.

For reed studies, in each water body four reed growths were selected which correspond visually by their characteristic parameters to the average level of the given water body. Two sampling plots were studied in every growth. In each of these plots, obtainable amount of biomass was defined. In every year of these studies (in lakes where the studies were carried out within three year period), the sampling plots were created in the same reed growths thus allowing to compare parameter changes over the years.

Method of direct measurement was used to determine the amount of dry matter (M_{dry}) that can be obtained in 1 m^2 of reed growth in lakes and pisciculture farms. Calculations include the part of reeds that is located above the ice in winter period. Reed mowing and sample weighting was performed in eight sampling plots (two sampling plots of four different growths) in each of the studied lakes. Surface of each sampling plot was 25 m^2. The plots were selected in places corresponding to the average thickness of the overgrowth. The thickness of the overgrowth was defined by surveying reed growth. The amount of obtained biomass was defined using indexes of natural moisture content. Reed mowing was performed using a scythe by mowing reeds above the ice surface (Fig. 1).

Fig. 1. Sampling plot for determination of reed biomass in Lubanas lake, winter 2010.

The mowed reeds were collected and weighted. Moisture content of the reed biomass was determined basing on standard method CEN / TS 14774-2. The amount of biomass obtained in the sampling plot was converted to t of dry matter * ha-1. For analysis, values of dry matter obtained from one plot unit were used.

In order to determine importance of influence of various factors on productivity of reed growths, the author used values of dry matter obtained within three years in the six largest lakes of Latgale region that are important for reed extraction: Lubanas lake, Kvapanu and Idenas ponds, Rusonas lake, Razna Lake and Sivera lake. For this determination, the method of three-factor dispersion analysis was used [24]. The water body, the year of extraction and the location in each individual water body were analyzed as the main influencing factors. The factor of water body is a complex index that characterizes each specific water body and includes growing conditions of individual reeds in the given water body. The year of extraction characterizes the influence of climatic conditions, while the location of extraction shows variations of reed productivity in one water body.

It was established that individual growing conditions in each water body have the most important influence on reed productivity. In order to evaluate the parameters affecting reed productivity, regression and correlation between average reed productivity and individual conditions in lakes, were analyzed. For this analysis, the author used studies on productivity in 23 water bodies of Latvia. Average values of the following indexes obtained in the last ten years were analyzed as characteristic parameters of each water body: transparency basing on Secchi disk, total concentration of nitrogen, total concentration of phosphorus in the water and electrical conductivity. These indexes were defined using information available in Lake Database of Latvia [25].

III Results and discussion

Results of the studies show that average amount of dry matter of reed obtainable in the six major water bodies in the region of Latgale (Lubanas lake, Kvapanu ponds, Idenas ponds, Rusonas, lake Razna lake, Sivera lake) varies from 4.2 to 7.7 t * ha^{-1}. The output of dry matter of reed is similar to the crops of reed canarygrass plantation which varies from 4 to 10 t * ha^{-1} [6.26]. Dry matter of reed in reed growths that are used for sewage treatment in Estonia varies from 3 to 17.6 t * ha^{-1} [23]. In our study, differences between the studied reeds growths were less pronounced (Fig. 2).

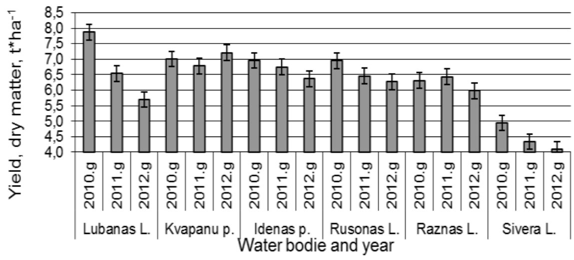

Fig . 2. Average obtainable amount of dry matter of reed in water bodies of Latgale region, 2010-2012.

Significant differences were established in reed productivity over the years in Lubanas lake. As shown in Figure 2, such differences were not established in other lakes. Therefore, it can be concluded, that climatic conditions are not the main factors creating these changes. The main influencing factors are individual growing conditions in Lubanas lake.

Previous studies show that for nutrition reed growths use N and P compounds located in coastal waters. [27]. N is the main element that stimulates reed growing, whereas the influence of P is much smaller, therefore the content of N in read biomass is more pronounced than the content of P [29.30]. Thus it can be assumed that the amount of nutrients in natural waters is one of the main factors affecting reed productivity.

Basing on monitoring data, reduction of water pollution and quality improvement in Lubanas lake during the years of studies can be seen. In summer 2009, the average total concentration of nitrogen was 1.765 mg * l^{-1}, the total concentration of phosphorus was 0.099 mg * l^{-1}, water transparency basing on Secchi disk was 0.6 m. In summer 2011, the concentration of nitrogen was 0.9 mg * l^{-1}, the total concentration of phosphorus was 0.065 mg * l^{-1} and water transparency basing on Secchi disk was 0.83 m [31]. These data indicate that reed productivity is directly dependent on the amount of nutrients available in growing process.

The three-factor dispersion analysis of the results of productivity studies over three years in six water bodies (Lubanas lake, Kvapanu ponds, Idenas ponds, Rusonas lake, Razna lake, Sivera lake) shows that the key factor that affects productivity of reed growths is the water body with its inherent reed growing conditions. The proportion of this influence is high, i.e. 66.34%, which indicates that the major differences in reed productivity are caused by different lakes. The influence of the factor of the year of mowing is much lower, i.e. 8.23%. The factor of the place of extraction within on lake has the lowest proportion of influence, i.e. 0.66%. The influence of all factors is significant (p <0.05) (Table 1).

TABLE 1

PROPORTION OF INFLUENCE OF THE WATER BODY, THE YEAR OF MOWING AND THE PLACE OF EXTRACTION ON THE AMOUNT OF OBTAINABLE DRY MATTER OF REED, Η, %

Factor	Ffact.	F0,05	η, %
Water body (A)	499.23	2.34	64,31*
Year of mowing (B)	154.89	3.13	8,41*
Place of extraction (C)	8.26	2.73	0,69*
Interaction (A×B)	27.91	1.97	8,77*
Interaction (A×C)	14.23	1.81	5,83*
Interaction (B×C)	16.79	2.23	2,77*
Interaction (A×B×C)	8.92	1.62	7,28*
Unstudied factors	-	-	1,92

* Influence of studied factors is significant, 95% of credibility ($F_{fact} > F_{0,05}$).

The results show great importance of the factor of water body on the amount of obtainable reed biomass which is related to the growing conditions of reed in each specific water body.

In order to find out the growing conditions of reed that affect productivity, the author analyzed regression and correlation between average indexes of reed productivity in 20 water bodies of Latvia and parameters characterizing amount of nutrients and the total pollution level in water bodies. Influence of the following parameters on indexes of reed productivity was analyzed: the total concentration of nitrogen and phosphorus in the water, transparency basing on Secchi disk and electrical conductivity. The author used average values of the total concentration of nitrogen and phosphorus in the water, transparency basing on Secchi disk and electrical conductivity in each water body in last ten years. These values were defined basing on monitoring data available in Lake Database of Latvia [25] (Table 2).

In order to define interconnection between reed productivity and factors influencing this productivity, correlation analysis of parameters was made.

In order to find regularity changing reed productivity if factorial features change, one-factor linear regression analysis was made.

The author found significant ($P<0,05$), average positive correlation ($r=0,51$, $n=20$) between obtainable dry matter and total concentration of phosphorus in the water of the studied lakes (Fig 3). This fact indicates that reed productivity is higher if the total concentration of phosphorus in water bodies rises.

The coherence is characterized by statistically significant ($P<0,05$) regression equation (1st equation), however its coefficient of determination is relatively low ($R^2=0,27$).

$$M_{dry} = 27{,}69P_{total} + 3{,}33 \qquad (1)$$

Where: M_{dry} – Yield, dry matter ($t*ha^{-1}$);

P_{total} – Average total concentration of phosphorus in the water of water bodies ($mg*l^{-1}$).

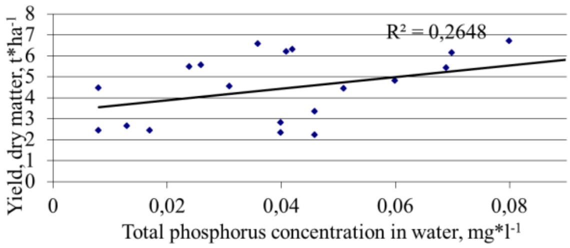

Fig. 3. Obtainable amount of dry matter in dependence on total concentration of phosphorus in water.

TABLE 2
INDEXES CHARACTERIZING REED PRODUCTIVITY AND GROWING CONDITIONS USED FOR CORRELATION ANALYSIS

Npk.	Ezers	Mdry,t*ha-1	Hsecchi, m	P total, mg*l-1	N total, mg*l-1	El, µs
1	Lubanas L.	6,69	0,4	0,08	1,94	335
2	Feimanu L.	4,8	1,3	0,06	1,21	246
3	Sīvera L.	4,46	3,1	0,008	0,9	217
4	Rusonas L.	6,56	0,95	0,036	1,18	269
5	Cirisa L.	4,41	0,9	0,051	1,44	293
6	Cirmas L.	5,55	1	0,026	1,47	300
7	Luknas L.	6,19	1,8	0,041	0,83	290
8	L.Ludzas L.	6,65	0,38	0,142	2,22	346
9	Birzkalna L.	6,29	0,48	0,042	1,21	242
10	Carmaņa L.	2,43	2,1	0,017	0,94	278
11	Ilzas Geranimovas L.	2,65	3,9	0,013	0,44	321
12	Balvu L.	6,12	0,55	0,07	1,63	227
13	Ismeru L.	3,33	1,21	0,046	0,79	300
14	Aluksnes L.	2,79	2,46	0,04	0,67	212
15	Gaidulu L.	2,22	2,95	0,046	0,35	303
16	Adamovas L.	5,42	1,03	0,069	0,82	282
17	Papes L.	5,46	1,7	0,024	1,14	287
18	Zolvu L.	4,54	1,2	0,031	1,53	261
19	Nirzas L.	2,32	2,73	0,04	0,49	267
20	Zosnas L.	2,42	3,5	0,008	0,62	288

Obtainable amount of biomass directly depends on the total concentration of nitrogen in the water of water bodies. The author found significant ($P<0,05$), average positive correlation ($r=0,76$, $n=20$) between obtainable dry matter and total concentration of nitrogen in the water of the studied lakes (Fig. 4). This fact indicates that reed productivity is higher if the concentration of nitrogen in water bodies rises. Such tendency has been noticed in other studies as well. [28,29,30].

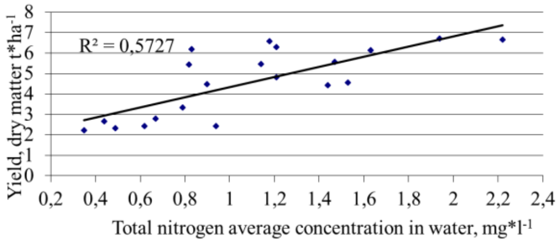

Fig.4. Obtainable amount of dry matter in dependence on total concentration of nitrogen in water.

The coherence is characterized by statistically significant ($P<0,05$) regression equation (2nd equation), its coefficient of determination is relatively high ($R2=0,57$).

$$M_{dry} = 2{,}48 N_{total} + 1{,}86 \qquad (2)$$

Where: M_{dry} – Yield, dry matter ($t*ha^{-1}$);
N_{total} – Average total concentration of nitrogen in the water of water body ($mg*l^{-1}$).

Both total concentration of nitrogen and total concentration of phosphorus in natural water promote productivity of reed growths. However, there is multicollinearity between both of these features therefore it is not possible to define summary influence of both of these features on reed productivity by using multifactorial regression analysis. One of factors characterizing the total intensity of eutrophication process in water bodies is water transparency basing on Secchi disk. If level of water pollution and intensity of eutrophication processes increases, water transparency is reduced. The author found significant ($P<0,05$), average negative correlation ($r=-0,79$, $n=20$) between obtainable dry matter and average indexes of transparency basing on Secchi disk in the studied lakes (Fig 5). This fact indicates that reed productivity is lower if water transparency basing on Secchi disk increases.

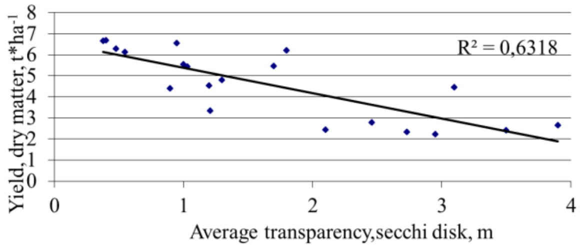

Fig 5. Obtainable amount of dry matter in dependence on water transparency basing on Secchi disk.

The coherence is characterized by statistically significant ($P<0,05$) regression equation (3rd equation), its coefficient of determination is relatively high ($R^2=0,63$).

$$M_{dry} = -1{,}2H_{secchi} + 6{,}59 \qquad (3)$$

Where, M_{dry} – Yield, dry matter ($t*ha^{-1}$);

H_{secchi} – Average transparency, Secchi disk (m).

No significant correlation was found between reed productivity and average values of electrical conductivity in water bodies.

Among all studied parameters, the most significant correlation was established between obtainable amount of dry matter and water transparency basing on Secchi disk. The given regression equation may be used to forecast average values of obtainable dry matter in places where biomass productivity has not been studied.

IV Conclusions

Reed productivity considerably ($p<0,05$) changes depending on water body, year of extraction and place of extraction within one water body.

The most significant differences were established in studies of reed parameters made in different lakes. The factor of water body had the largest proportion of influence on obtainable amount of biomass.

Reed productivity depends on the amount of nutrients in the water of water bodies. The productivity is higher if the total concentration of nitrogen and phosphorus in water is increased.

Reed productivity is lower if water transparency basing on Secchi disk in water bodies increases. This parameter may be used to evaluate the obtainable amount of biomass. The coherence is characterized by significant ($p<0,05$) regression equation.

V Acknowledgements

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VI References

[1] Latvijas Republikas prognožu dokuments par atjaunojamo energoresursu īpatsvara bruto enerģijas galapatēriņā līdz 2020. gadam sasniegšanu atbilstoši Direktīvas 2009/28/EK 4. panta 3. punktam.(2009), 1.-9. lpp. [tiešsaiste][28.01.2012] Pieejams: http://www.em.gov.lv/images/modules/items/EM_291209_forecast%281%29.pdf

[2] Biomasas izmantošanas ilgtspējības kritēriju pielietošana un pasākumu izstrāde (2009) Adamovičs A., Dubrovskis V., Plūme I. u.c. *Valsts SIA „Vides projekti”*, Rīga, 16-38. lpp.

[3] Tahir M., Casler M.D., Moore K.J., Brummer C. (2011) Biomass Yield and Quality of Reed Canarygrass under Five Harvest Management Systems for Bioenergy Production. *In: Bioenerg. Res. 4*, p.111–119.

[4] Schafer W. (2012) Fibre crops for energy production and energy saving. *In: Proceedings of the international scientific conference Renewable energy and energy efficiency*, Jelgava, p.7-12.

[5] Bassam N.El. (1998) Energy plant species. Their use and impact on environment and development. *In:James and James(Science publisher)* London, p.1-98.

[6] Enerģētisko augu audzēšana un izmantošana (2007) Adamovičs A.,Agapovs J., Aršanica A. u. c. Valsts SIA „Vides projekti”, Rīga, 43-133. lpp.

[7] Jansone B., Rancane S., Berzins P., Stesele V. (2012) Reed canary grass (Phalaris arundinacea L.) in natural biocenosis of Latvia, research experiments and production fields. *In: Proceedings of the international scientific conference Renewable energy and energy efficiency*, Jelgava, p.61-65.

[8] Poiša L., Adamovičs A., Strikauska S. (2012) Factors affecting the carbon content in reed canary-grass (*Phalaris arundinacea* L.) used for producing burning material in Latvia, *In: Grassland Science in Europe, Vol. 17,* p.390-392.

[9] Jankauskiene Z., Gruzdeviene E. (2012) Industrial hemp- a promising source for biomass production. *In: Proceedings of the international scientific conference Renewable energy and energy efficiency*, Jelgava, p.13-18.

[10] Пойша Л., Адамович А., Страмкале В. (2010) Конопля (Cannabis sativa L.) как растение для биомассы. *In: Proceedings of the international conference “Human and nature safety”*, Part 2, Kaunas, p. 132 – 135.

[11] Poiša L., Adamovičs A., Stramkale V., Komlajeva L. (2010)(b) Eļļas lini atjaunojamās enerģijas iegūšanai. No: *Latgales Tautsaimniecības pētījumi (Latgale National Economy research, Journal of Social Sciences). Nr. 1 (2)*, 291 – 299. lpp.

[12] Komlajeva Ļ., Adamovičs A. (2012) Evaluation of flax (*linum usitatissimum L.*)quality parameters for bioenergy production. *In: Proceedings of the 11th international scientific conference “Engineering for rural development”*, May 24.-25., Jelgava, Latvia p. 490-494.

[13] Jansone I, Gaile Z. (2012(a)) Ziemāju salmu izmantošana apkurei. *Zinātniski praktiskās konferences „Zinātne Latvijas lauksaimniecības nākotnei: pārtika, lopbarība, šķiedra un enerģija” raksti*, LLU Jelgava, 42-47. lpp.

[14] Belicka I., Miglāne V., Jansone Z. (2009) Vasarāju graudaugu sugu piemērotība siltumenerģijas ražošanai. *No: Vide.Tehnoloģija. Resursi.* VII starptautiskās zinātniski praktiskās konferences materiāli, Rēzeknes Augstskola, 24.-31.lpp.

[15] Able K., Ragan S. (2000) Effects of common reed (*Phragmites australis*) invasion on marsh surface macrofauna: response of fishes and decapod crustaceans.*In: Estuaries 23(5)*, p.633–646.

[16] Farnsworth E.J., Meyerson L.A. (1999) Species composition and inter-annual dynamics of a freshwater tidal plant community following removal of the invasive grass, *Phragmites australis. In: Biological Invasions 1*, p. 115–127.

[17] Keller B. (2000) Plant diversity in Lythrum, Phragmites and Typha marshes, Massachusetts, USA. *In: Wetl Ecol Manage 8*, p.391–401.

[18] Brix H., Sorrel B.K., Lorenzen B. (2001) Are Phragmites-dominated wetlands a net source or net sink of greenhouse gases? *In: Aquatic Botany 69*, p.313–324.

[19] Duan X.,Wang X., Ouyang Z. (2009) Influence of Common Reed (Phragmites australis) on CH4 Production and Transport in Wetlands: Results from Single-Plant Laboratory Eksperiments. *In: Water Air Soil Pollut 197*, p.185–191.

[20] Slepetys J., Kadziuliene Z., Sarunaite L., Tilvikiene V., Kryzeviciene A. (2012) biomass potential of plants grown for bioenergy production. *In: Proceedings of the international scientific conference Renewable energy and energy efficiency*, Jelgava, p.66-72.

[21] Bastlova D.,Bastl M., Čižkova H.,Kvet J. (2006) Plasticity of Lythrum salicaria and Phragmites australis growth characteristics across a European geographical gradient, *In: Hydrobiologia 570*, p.237–242.

[22] Reed up on Reed (2007) Ikkonen I., Roosaluste E., Pitkanen T.at.al. Southwest Finland regional Environment centre, Turku 2007., p. 5-115.

[23] Madison M., Soosaar K., Mauring T., Mander U. (2009) The biomass and nutrient and heavy metal content of cattails and reeds in

wastewater treatment wetlands for the production of construction material in Estonia. *In: Desalination 247*, p.123-128.

[24] Доспехов Б. А. (1985) *Методика полевого опыта.* Агропромиздат, Москва, 351 с.

[25] Latvijas ezeru datubāze (2013)- [tiešsaiste][17.01.2013] Pieejams: http://www.ezeri.lv/database/AdvancedSearch

[26] Sanderson, M.A., Adler, P.R. (2008) Perennial Forages as Second Generation Bioenergy Crops. *In: International Journal of Molecular Sciences,* 9 (5), p. 768-788, [tiešsaiste] (25.01.2010.) Pieejams: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2635706/

[27] Windham L., Lathrop L. (1999)Effects of *Phragmites australis* (Common Reed) Invasion on Aboveground Biomass and Soil Properties in Brackish Tidal Marsh of the Mullica River, New Jersey. *In: Estuaries Vol. 22, No. 4*, p. 927-935.

[28] Торохова О.Н., Глухов А.З., Арешков М.А., Агурова И.В. (2009) Изменчивость морфометрических параметров тросника обыкновенного и рогоза узколистного в искусственных водоемах промишленной зоны г. Горловки. *б: Промышленная ботаника. 2009, вып. 9*, ст. 82.

[29] Romero J.A., Brix H., Comin F.A. (1999) Interactive effects of N and P on growth, nutrient allocation and NH4 uptake kinetics by *Phragmites australis. In: Aquatic Botany 64*, p. 369–380.

[30] Meuleman A., Beekman J., Verhoeven T. (2002) Nutrient retention and nutrient-use efficiency in Phragmites australis stands after wasterwater application. In: *Wetlands, Vol. 22*, No.4 p.712-721.

[31] EWN-2 :Lake quality data, LVĢMC monitoringa dati, [tiešsaiste] (25.02.2013.) Pieejams: http://cdr.eionet. europa. eu/lv/eea/ewn2.