sciendo

DOI: 10.2478/ahr-2018-0001

Acta Horticulturae et Regiotecturae 1/2018 *Karolina Kraczkowska, Piotr Stachowski*

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 1–4

POSSIBILITIES OF QUANTITATIVE AND QUALITATIVE INVENTORY OF DRAINAGE DEVICES BASED ON SELECTED MAPS AND PHOTOGRAMMETRIC IMAGES

Karolina KRACZKOWSKA*, Piotr STACHOWSKI

Poznań University of Life Sciences, Poland

The aim of the work was to analyse which of the selected geodetic and cartographic materials (maps and high resolution aerial images) are useful for inventory of water drainage devices. Obviously, correct determination of their quantitative and qualitative statuses can be made through field inventory. Quantitative inventory can also be done on the basis of maps. For the purpose of this research, an analysis was carried out which consisted of checking which of the selected cartographic and photogrammetric materials best reflect the location of irrigation devices in the field. The analyses were based on both digital and analogue maps at the scale of 1 : 50 000 to 1 : 5 000. The selected photogrammetric materials included images at the scale of 1 : 10 000 and 1 : 1000.

Keywords: inventory, melioration devices, geodetic and cartographic materials, photogrammetry

According to the Water Law Act of July 20, 2017 (Journal of Laws of 2017, item 1566) water drainage systems consist in regulating water relations in order to improve agriculture soil's production capacity and to facilitate its cultivation. Water drainage devices include i.e.: ditches with functionally related structures, drainage systems (Fig.1), earthen fishponds or causeways in irrigated areas.

Most of the currently used drainage devices that were made between 1970 and 1980 are in their final phase of operation. It is 30 years for ditches and 40 years for underground drainage facilities. As a consequence of many years of negligence resulting from insufficient financing, which in turn has caused shortages in ongoing maintenance, some of them do not function properly. The issue is presented in more detail in works by Kaca (2011), Ostrowski (2011), Mioduszewski et al. (2013) and Liberacki et al. (2016).

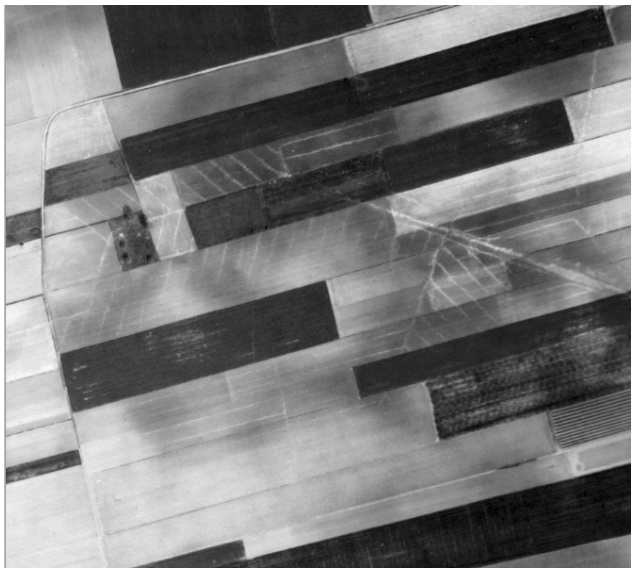

Fig. 1 Network of drains visible in the panchromatic aerial image
Source: Department of Soil Science and Land Reclamation, University of Life Sciences in Poznań

All drainage devices should be subject to periodic inventory carried out by Inspectorates and Regional Branches of the Provincial Land Drainage and Water Units Boards (in Polish: Wojewódzki Zarząd Melioracji i Urządzeń Wodnych, WZMiUW). It may proceed in different ways depending on the amount of money allocated for this purpose. The most accurate in terms of quantity and quality is field inventory. However, it is relatively expensive and time-consuming. Field inventory may also be limited due to difficulties in reaching certain places. Quantitative inventory can be carried out on the basis of maps – those that have drainage devices in their content. Unfortunately, the practice shows that maps are often outdated – they contain information that is not reflected in the field. These obstacles might be overcome with the use of photogrammetric materials. They are applied in many fields of science and economy, including taking aerial imaging for the development of flood hazard maps and flood risk maps (Kurczyński, 2012), as well as for creating Digital Terrain Models necessary for monitoring the condition of flood embankments (Long et al., 2010; Kurczyński and Bakuła, 2016). In forestry, aerial photographs allow for: specifying the species of growing trees, defining areas affected by natural disasters, monitoring pest attacks, estimating the amount of wood and facilitating work on arranging and planning forest reclamation. Based on aerial images, it is possible to create coverage maps, usage maps and maps on the decline in stands (Wężyk et

Contact address: Karolina Kraczkowska, Poznań University of Life Sciences, Faculty of Environmental Engineering and Spatial Management, Institute of Land Improvement, Environmental Development and Geodesy

al. 2017; R. Minařík and Langhammer, 2016). In Poland, the problems related to inventory of drainage devices on the basis of photogrammetric materials were dealt with by Świątkiewicz (1990) and Kowalczyk et al. (2016). However, from photogrammetric materials they mainly used the orthophotomap from the Geoportal and mainly focused on the usefulness of the Digital Terrain Model to identify the course of drainage ditches. The authors of the study carried out research extending them to other photogrammetric materials.

Material and methods

Performing various tests and analyses regarding drainage devices requires specific knowledge about their exact location. That is why it is so important to have the latest spatial data. Undoubtedly, the most important way to acquire them is field research, but in the era of the development of modern remote sensing techniques these have become a key source of information.

The area for which the analysis of geodesy and cartographic materials was conducted was the northern part of the Brodnica commune, located in the central Greater Poland in Poland. The study was based on geodetic-cartographic materials, obtained free of charge from various companies and institutions. They were verified against their best suitability for inventory works of drainage devices. The following materials were subject to analysing: analogue and digital maps, photogrammetric materials and orthophotomaps. The study used the subsequent analogue maps: a topographic map at the scale of 1 : 50 000, a land survey and height map at the scale of 1 : 10 000 and a site location plan of drainage devices at the scale of 1 : 5 000. The used digital maps were: a raster topographic map at the scale of 1 : 25 000 downloaded in digital form from the WMS server located on Geoportal, web portal to find and access geographic information (http://www.geoportal.gov.pl, date of access: 04.20.2017) using a free application Geox Editor 2.0 Demo, the Map of the Hydrographic Division of Poland 2010 at the scale of 1 : 50 000 and the List of Damming Structures at the scale of 1 : 50 000. The last two were available on the Geoportal of the National Water Management Board (http://geoportal.kzgw.gov.pl/imap/, date of access: 22.05.2017). In addition to the abovementioned maps, photogrammetric materials were used in the work. These included 106 panchromatic aerial images, taken on 29.04.1988, at the scale of 1 : 10 000, belonging to the Department of Soil Science and Land Reclamation, University of Life Sciences in Poznań. The study also included orthophotomaps from Geoportal and Google Maps. These materials were supplemented by technical documentation of the Commune Water Company in Brodnica, which consisted of a technical description and a list of technical data from 1986 obtained from resources held by the Inspectorate of Greater Poland Provincial Land Drainage and Water Units Board in Śrem. Additionally, the authors used aerial photographs at the scale of 1 : 1 000 and photos were taken with the use of a drone.

The purpose of the research was to answer the question: which of the selected cartographic and photogrammetric materials best reflect the location of irrigation devices in the field. The testing primarily consisted in visual analysing. Both maps and photos were corrected to improve their readability. The data on drainage devices included in individual geodetic-cartographic materials were compared in the computer program QGIS 2.18.0. The basis for performing comparisons between materials was the orthophoto at the scale of 1 : 10 000 (set in the coordinate system PUWG 1992 EPSG: 2180), as a type of graphic layers that most objectively reflect the real situation. Subsequently, by means of geo-referencing, the following materials were read into it: the topographic map at the scale of 1 : 25 000, the site location plan of drainage devices at the scale of 1 : 5 000 and the panchromatic aerial images at the scale of 1 : 10 000.

Results and discussion

The visual analysis of source materials in terms of their suitability for inventory of drainage devices proved that the topographic map at the scale of 1 : 50 000 was not suitable for this purpose. This was due to its scale, which caused a significant generalisation of situational details. The land survey and height map at the scale of 1 : 10 000 enabled general ground recognition and making a photo-sketch from analogue photos at the scale of 1 : 10 000. Unfortunately, these maps are inconvenient due to their large format. The most useful map was the site location plan of drainage devices at the scale of 1 : 5 000 (Fig.2), since it contained all information about field elements of the drainage system. Such maps also contain information on the boundaries of municipalities and communes, water companies, as well as individual villages and competitive areas, for which specific irrigation equipment exerts a beneficial influence. In addition, green areas, lakes, existing ditches, concrete pipelines and point facilities such as drainage outlets, culverts, gates and wells were marked along with their short characteristics (name and diameter). Their only drawback is their manual updating, therefore, the position of the elements is approximate. It should be borne in mind that elements removed from the records are deleted in an analogue way; as a consequence, the readability of these maps is significantly reduced as corrections are applied.

Similarly, the Map of the Hydrographic Division of Poland 2010 at the scale of 1 : 50 000 was not suitable for carrying out inventory of drainage devices due to its small scale. Its considerable disadvantage was that the database on which the basis of the map was displayed was not complete. The list of damming structures at the scale of 1 : 50 000 was also characterised by a small scale, whereby the location of damming objects was only approximate.

The Raster Topographic Map allowed for selection of the displayed scale, but there were very few details about drainage systems. The orthophoto from Geoportal was made of aerial photographs from the Central Geodetic and Cartographic Documentation Centre resources that were taken with high-resolution quality. The map allowed for noticing water reservoirs, channels, ditches, culverts, gullies, wells and earthen fishponds. Additionally, it was possible to display it on the selected scale. The second analysed orthophotomap, from Google Maps, also had the option of selecting the scale of display, however, it featured lower

Table 1 Drainage devices found in the analysed materials

	Water reservoirs	Channels	Ditches	Outlets	Culverts	Valves	Wells	Drains	Filters	Earthen fish ponds
Topographic map at the scale of 1 : 50 000	+	+	-	-	-	-	-	-	-	+
Land survey and height map at the scale of 1 : 10 000	+	+	+	-	+	-	-	-	-	+
Site location plan of drainage devices at the scale of 1 : 5 000m	+	+	+	+	+	+	+	+	+	+
Map of the Hydrographic Division of Poland of 2010 at the scale of 1 : 50 000	+	+	+/-	-	-	-	-	-	-	+
List of Damming Structures at the scale of 1 : 50 000	+	+	+/-	-	-	-	-	-	-	+
Raster topographic map at the scale of 1 : 25 000	+	+	+	-	-	-	-	-	-	-
Aerial imagery at the scale 1 : 10 000	+	+	+	-	-	-	-	+	+	+
Orthophoto from Geoportal	+	+	+	-	+	+	+	-	-	+
Orthophoto from Google Maps	+	+	+	-	-	-	-	-	-	+

+ – included,,- – excluded, +/- – partially included

Fig. 2 Fragment of the site location plan of drainage devices
Source: Inspectorate of Greater Poland Provincial Land Drainage and Water Units Board (WZMiUW) in Śrem

resolution than the orthophotomap from Geoportal. It is not known when the photographs, based on which it was created, were taken. Panchromatic aerial photographs at the scale of 1 : 10 000 allowed for making a quantitative inventory of line objects, and depending on the readability of photos, sometimes also point objects. Aerial photographs at the scale of 1 : 1000 showed drainage devices in the greatest detail. Yet, the disadvantage of both these types of images is that they are expensive to obtain. The photos can also be taken with the help of drones (Fig.3).

Fig. 3 The photograph of a drainage well taken using the eBee Plus drone
Source: TPI sp. z o. o.

GeoMelio Portals are Internet portals containing the same information as the land maps of land drainage devices; only the representation of objects is in the digital form. Their digital form makes them more convenient than analogue maps. The only downside is that there is no single base for the entire country, and only half of the Provincial Land Drainage and Water Units Boards provide such information on their websites.

The topographic map at the scale of 1 : 25 000 includes the network of open ditches. However, due to its generalisation, it represented on average one ditch every-second spacing.

Subsequently, there were compared the panchromatic aerial photographs at the scale of 1 : 10 000 with the situational map of drainage devices at the scale of 1 : 5 000. The photographs at the scale of 1 : 10 000 effortlessly allowed for determination of places with ditches, regardless of their shape – either in the form of a broken line or a curve. Linear elements were often visible due to the neighbouring growing vegetation. It was possible to deduce the existence of culverts under some roads from wide channels and roads running over them. After enlarging the photographs to the scale of 1 : 1 250, there were also seen culverts in the fields.

Conclusion

The analysis proved that panchromatic images in the visible band taken at the scale of 1 : 10 000 or 1 : 1 000 can be used to perform inventory of linear, ground-based elements of the drainage system, i.e. channels and ditches. When the scale is enlarged, it is also possible to see the location of culverts. Undoubtedly, the right season and proper weather conditions, during which photogrammetry takes place, have a big impact on the photographic quality of drainage devices. To a large extent, the readability of photogrammetric images depends on land cover vegetation, which simultaneously can either facilitate (as an indirect interpretive feature) or make it difficult (obstructing the view) to interpret the picture. In order to show an underground drainage network in photos, photographic documentation should be made short after the precipitation has stopped and using multispectral cameras.

Analogue (available at WZMiUW) or digital (made available on websites by some WZMiUW) situational maps of drainage devices are useful for making inventory of drainage devices, as they contain all drainage devices located in a given area. They should provide the latest available data on the drainage system, therefore, it is regrettable that often they are not updated on a regular basis

When choosing an orthophotomap for inventory purposes, attention should be paid to its high resolution and the maximum scale for display. Both of these parameters will ensure effective recognition of objects located in the field. Geoportal provides a high quality orthophotomap. For a more efficient computer processing of materials, it is worth to download a fragment of an orthophotomap with the analysed area and upload it as one of the raster layers. This will save time the program uses to update the WMS layer every time the view on the computer screen changes. In addition, it is worth checking if the orthophotomap downloaded via the WMS and from the Geoportal website is the same, because, as demonstrated in the study, it does not have to be and they may differ from each other. Ground Sampling Distance and the date of taking orthophotomaps prepared on Geoportal can be verified in indexes available at the CODGiK website (http://www.codgik.gov.pl/index.php/skorowidze.html).

Inventory of drainage devices can be done without financial outlays in an easy way by using free of expense and open for general use orthophotomaps along with free GIS software. Undoubtedly, the result of analysing (the quantity and quality of information obtained) is influenced by the experience and extensive qualifications of the person interpreting images.

References

CODGiK. 2017. http://www.codgik.gov.pl/index.php/skorowidze.html (access date: 16.06.2017)

GEOPORTAL. 2017. http://www.geoportal.gov.pl (access date: 20.04.2017).

KACA, E. 2011. Melioracje wodne jako czynnik ograniczający skutki ekstremalnych zjawisk hydrometeorologicznych. In Wiadomości Melioracyjne i Łąkarskie, 2011, no. 3, pp. 111–114.

KOWALCZYK, T. – POKŁADEK, R. – GOŁUCH, P. – ORZEPOWSKI, W. – KOWALSKA, J. 2016. Dane przestrzenne jako narzędzie identyfikacji i inwentaryzacji urządzeń wodnomelioracyjnych – studium przypadków. In Wiadomości Melioracyjne i Łąkarskie, 2016, no. 3, pp. 123–128.

KURCZYŃSKI, Z. 2012. Mapy zagrożenia powodziowego i ryzyka powodziowego a dyrektywa powodziowa. In Archiwum Fotogrametrii, Kartografii i Teledetekcji, 2012, no. 23, pp. 209–217.

KURCZYŃSKI, Z. – BAKUŁA, K. 2016. SAFEDAM – zaawansowane technologie wspomagające przeciwdziałanie zagrożeniom związanym z powodziami. In Archiwum Fotogrametrii, Kartografii i Teledetekcji, 2016, no. 28, pp. 39–52.

LIBERACKI, D. – BYKOWSKI, J. – KOZACZYK, P. – SKWIERAWSKI, M. 2016. Ocena konserwacji i modernizacji urządzeń melioracji podstawowych na obszarze północnej Wielkopolski. In Inżynieria Ekologiczna, 2016, no. 49, pp. 66–73.

LONG, G. – MAWDESLEY, M.J. – SMITH, M. – TAHA, A. 2010. Simulation of airborne LiDAR for the assessment of its role in infrastructure asset monitoring. Proceedings of the International Conference on Computing in Civil and Building Enginerering, Tizani W (ed). Nottingham, UK : Nottingham University Press, 2010.

MIODUSZEWSKI, W. – LIPIŃSKI, J. – KOWALEWSKI, Z. 2013. Melioracje – gospodarka wodna na potrzeby rolnictwa. In Wiadomości Melioracyjne i Łąkarskie, 2013, no. 2, pp. 52–59.

MINAŘÍK, R. – LANGHAMMER, J. 2016. Use of a multispectral UAV photogrammetry for detection and tracking of forest disturbance dynamics. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XLI-B8, XXIII ISPRS Congress, 2016.

OSTROWSKI, K. 2011. Rola urządzeń melioracji szczegółowych w rolnictwie i środowisku przyrodniczym. In Wiadomości Melioracyjne i Łąkarskie, 2011, no. 4, pp. 155–160.

ŚWIĄTKIEWICZ, A. 1990. Przydatność zdjęć lotniczych w inwentaryzacji sieci drenarskich. In Zeszyty Naukowe Akademii Rolniczej im. H. Kołłątaja w Krakowie, 249, Sesja Naukowa, 28, cz. II, pp. 157–183.

WATER Law Act of July 20. 2017. In Journal of Laws of 2017, item 1566.

WĘŻYK, P. – MUCHA, M. – SZOSTAK, M. 2017. Mapa użytkowania i pokrycia fragmentu Gorczańskiego Parku Narodowego opracowana w oparciu o fotointerpretację cyfrowych ortofotomapy lotniczych CIR z 2011 roku. In Roczniki Geomatyki, vol. 15, 2017, no. 1(76), pp. 119–131.

sciendo

DOI: 10.2478/ahr-2018-0002

Acta Horticulturae et Regiotecturae 1/2018 *Beáta Novotná et al.*

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 5–9

RIVER BASIN HYDROLOGICAL BALANCE EVALUATION IN TERM OF THE LAND USE CHANGE IMPACT

Beáta NOVOTNÁ[1]*, Ján ČIMO[1], Branislav CHVÍLA[2], Gabriela POZNÍKOVÁ[3]

[1]Slovak University of Agriculture in Nitra, Slovak Republic
[2]Slovak Hydrometeorological Institute in Bratislava, Slovak Republic
[3]CzechGlobe: Global Change Research Institute, Academy of Sciences, Brno, Czech Republic

Assessment of the land use impact on the processes of water balance in the river basin should be an indispensable part of integrated river basins management. This paper compares climatic conditions occurring during the long-term period (1951–1980), following the situation immediately after dry conditions (1993-1999) and extremely rainy dates (2009–2012) with emphasis to estimate the runoff components in the Žitava river basin: the Obyce sub-catchment, situated in its upper part (74.5 km^2) in the Slovak Republic. Modelling of the land use change effect on the total hydrology balance of the river basin characteristics was performed using the hydrological model WaSiM-ETH. The model was applied to evaluate the vegetation type influence and the water balance change in the presently mostly forested river basin (1), altering its replacement by the permanent grasses (2) and bushes (3), with emphasis to different total water balance characteristics change. The present state land use data were taken from the Corine Land Cover of the Slovak Republic. Model results show that actual evapotranspiration would decrease from -1.3% in case of bushes in 2009 up to -32.5% in case of grass in 2011. However, 13.3% rise was considered for bushes in 2010. Total annual discharge shows its increment in all observed changes from 5.9% for bushes in 2010 up to 65.3% for grass in 2012. Only in case of bushes in 2011 there was observed slight decrease of about -3.1%. Regarding the very expected land use change, especially in connection with the ongoing global climate change, the estimation of the hydrology balance components is of utmost significance.

Keywords: climate characteristics, total water balance, river basin, hydrological model, land use change

Sustainable water management requires the quantification of spatial and temporal changes of water balance variables (Wagner, Kunstmann and Bárdossy, 2006). In Slovakia, hydrological models have recently been used to assess the impacts of land use and climate change on drainage and snow melt processes and simulation of sediments transport. Possible changes of the runoff characteristics, caused be modifications of land use features, represent one of the main sources of uncertainty in the area of water resources management and in flood protection (Jurík et al., 2008).

Identifying changes in runoff and quantifying the impacts of climate change and human activities are of great significance for water resources planning and management in a river basin (Zhang et al., 2017). The hydrological processes are very complex and highly non-linear. Models based on the linear system theory generally fail to represent the non-linear processes (Raveendra, Rai and Mathur, 2008). In this study, there were used alternations applying the hydrological model in order to identify the trends of the hydrological components responses to climate changes in connection with land use, which is a well-established tool for investigating the spatial and temporal variability of hydrological processes in a complex river basin.

The river basin response to vegetative changes is predictable (Bulantová, 2009). However, there are conflicts between the science and the public perception of land and forest use and hence the impact on the overall hydrological cycle of water in nature (Jewitt, 2005, in Bulantová (2009). As an example, there are two conflicting studies. The first one highlights that the forests, including soil and roots, behave like a "sponge" that draws water during precipitation and release it during drought. According to this study, forests should contribute to improving the water supplies by replenishing groundwater resources, maintaining the basic runoff and mitigating floods. In opposite, the second study states that roots do not release water during dry periods, but absorb it from the soil (Hamilton and King, 1983; Jewitt, 2005 in Bulantová, 2009).

The individual effect of forest vegetation in a particular river basin can be a very specific one, because the runoff is determined by a complex of factors, from those some may react adversely and thus complicate the behaviour of the entire rainfall-drainage system. For integrated river basin management, it is therefore advisable to examine each river basin or region separately and possibly verify several model approaches (Bulantová, 2009). The issue of the water balance in changed climate condition was also developed by Tátošová (2006), Bárek, Halaj and Takáč (2008) and Halaj et al. (2010).

Contact address: Ing. Beáta Novotná, PhD., ING.PAED.IGIP, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Water Resources and Environmental Engineering, Hospodárska 7, 949 76, Nitra, Slovak Republic, e-mail: Beata.Novotna@uniag.sk

Material and methods

Research area

The Žitava river basin (903 km^2) was chosen as a model area, with 99.3 km of the total stream length. The Žitava is a partial sub-basin of the Nitra river basin. There is about 60.5% of the agricultural land in the sub-basin; forests represent about 32.5%, built-up area covers 6.8%, and water areas and other areas 0.2% and 0.1%, respectively. During the years 2009 and 2012, flood events occurred; therefore the causes of such phenomena need to be analysed and appropriate measures to prevent them taken. From the whole Žitava river basin, the Obyce water gauge profile was chosen for evaluation of the river basin hydrological balance (74.5 km^2), because it is mostly covered by a deciduous forest. For land use, there was applied the Corine Land Cover of the Slovak Republic, where land cover is a map of the surface of Europa from the LANDSAT satellites (see Figure 1a). Green areas represent forested areas and pink circle shows the Obyce profile water gauge station. Review of the profile water gauge stations in the Žitava river basin is showed in Figure 1b). The land use is very diverse in the catchment area from forest (the most common deciduous forests are: oak, hornbeam and beech trees, as well as coniferous forests: spruce or pine trees), through grazed meadows on the slopes of mountains to agriculture in the lower parts of the basin (Zorád, 2010).

Distribution of monthly average air temperature values and monthly average precipitation totals during the periods of years 1951–1980, 1993–1999 and 2009–2012 is displayed in Figures 2a) and 2b). Based on 30 years of data, period of the years 1951–1980 characterises "reference term."

The period of the years 1993-1999 represents the dry term. The seven years period (1988-1994) was the warmest and driest in Slovakia since 1871 (Smith et al., 1996). The period of the years 1989–1993 was the driest season in the middle and lower Danube region and the warmest consecutive three-year and five-year period was between 1998 and 2002, with the decades clearly dominating the 1990s (Blinka, 2009).

The period of the years 2009–2012 characterises the wet term. Zeleňáková et al. (2017) analysed the temporal and spatial precipitation distribution trends over Slovakia, utilizing 487 gauging stations; in 1981–2013 it showed that annually, there was a significant, although only slightly increasing precipitation trend. The absolutely highest precipitation total on an annual scale was in 2010. However, from the monthly point of view, there is evidence of a very different rain distribution over the studied area.

Even though the second and third periods are inadequate to distinguish between changes due to long-term trends, they indicate inter-annual and inter-period variability.

Hydrological model

The hydrological **Wa**ter Flow and Balance **Si**mulation **M**odel (WaSiM-ETH) was used (Schulla, 1997) to inspect the hydrological balance alteration under the possible modified land use characteristics due to the global atmosphere change in near future. Richard's equation is composed for unsaturated zone modelling. Main parameters of this model

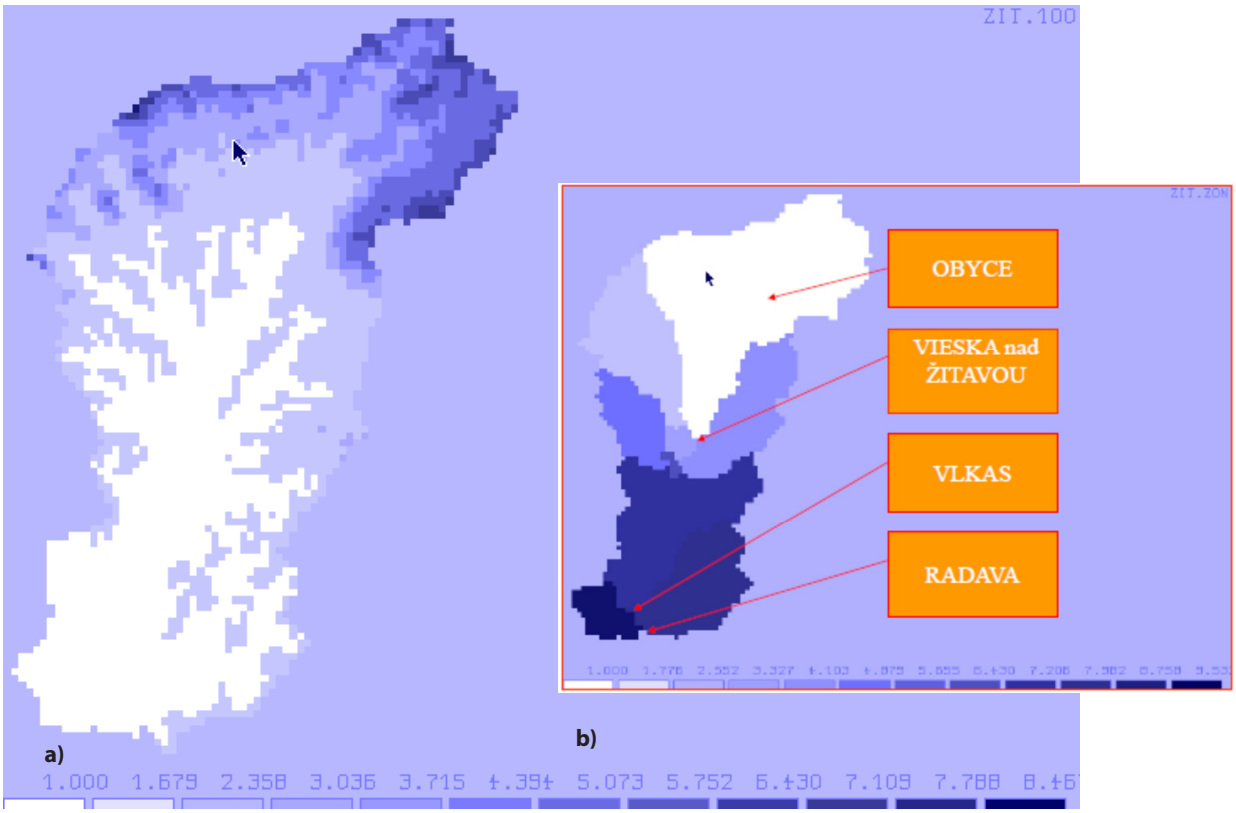

Fig. 1 **a)** Digital elevation model of Žitava river basin with a spatial resolution on regular grids of a cell size of 100 × 100 m.; **b)** Map situation of Žitava individual sub-basins, arrows show the specific water gauge stations: Obyce, Vieska nad Žitavou, Vlkas and Radava in Žitava river basin

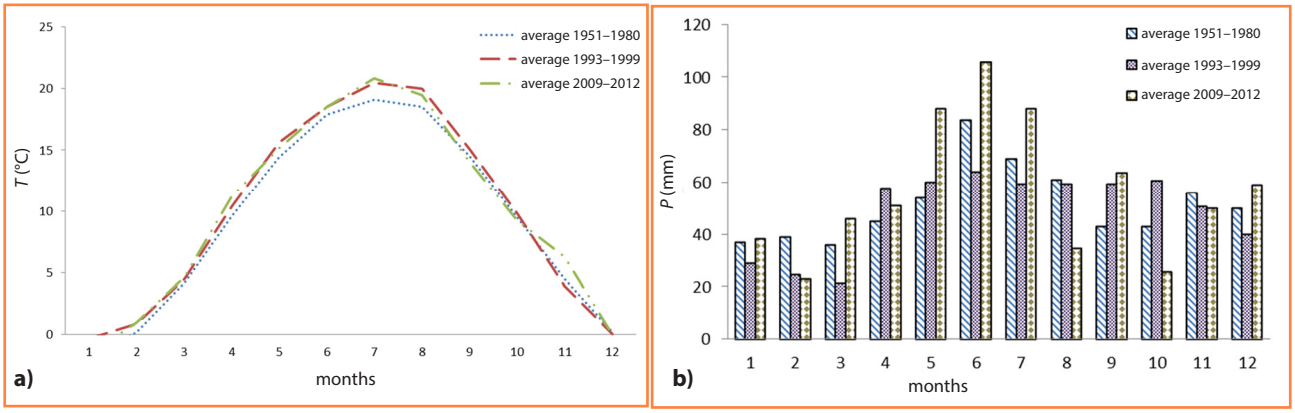

Fig. 2 **a)** Monthly course of the mean air temperature T (°C) values during the observed periods: 1951–1980, 1993–1999 and 2009–2012; **b)** Monthly values of the mean precipitation totals P (mm) during the observed periods: 1951–1980, 1993–1999 and 2009–2012

are: full surface runoff distribution, time step 1 day, spatial resolution on regular grids with a cell size of 100 × 100 m. Input climate data in daily time step were: air temperature (°C) (10 stations), precipitation totals (mm) (16 stations), global radiation (Wh.m^{-2}) (2 stations), relative sunshine duration (hours) (1 station), vapour pressure (mbar) (4 stations), wind speed (m.s^{-1}) (8 stations). Model routines are: precipitation correction, input meteorological data interpolation according to different methods, snow accumulation and its melting using inverted distance weighting methods, plant interceptions modelling using a leaf area index depending on the interception reserve, infiltration model used by Green-Ampt. Within the model, outflow is defined as the total amount of water that flows out of the river basin per time unit. According to Cudlin et al. (1999) it is divided into surface, subsurface (hypodermic) and underground direct and base discharge. Direct runoff is also specified within a model, what is a summary designation for the surface and leakage subsurface effluent that still has not reached the groundwater level yet during the precipitation duration or immediately after the precipitation event (Pavková, 2010). Hydrological model calibration was performed during the period: 1993–1999 (coefficient of determination: r^2 = 0.71) and validation: 2009–2012 (r^2 = 0.79). During the calibration,

Table 1 Evaluation of the hydrological balance in term of the land use change impact related to the Žitava sub-catchment, the Obyce water gauge profile, using the results of the WaSiM-ETH model

Year	Land use	Mean annual air temperature (°C)	Anual precipitation totals (mm)	Actual evapotranspiration totals (mm)	Influence of the vegetation cover to change of the actual evapotranspiration (%)	Total annual discharge from Obyce sub-basin (mm)	Influence of the vegetation cover to change the total annual discharge (%)
2009	present state	10.7	885	429		142	
	grass			346	-19.4	225	58.4
	bushes			423	-1.3	177	24.7
2010	present state	9.5	1,352	524		454	
	grass			355	-32.3	684	50.8
	bushes			594	13.3	481	5.9
2011	present state	10.5	763	590		242	
	grass			398	-32.5	386	59.4
	bushes			548	-7.0	235	-3.1
2012	present state	11.1	895	522		232	
	grass			411	-21.3	383	65.3
	bushes			496	-5.1	254	9.7

Individual land use changes are under the same climate conditions: 1. for the present time land use, e.g. mostly forested river basin, 2. replaced by permanent grasses, 3. replaced by bushes

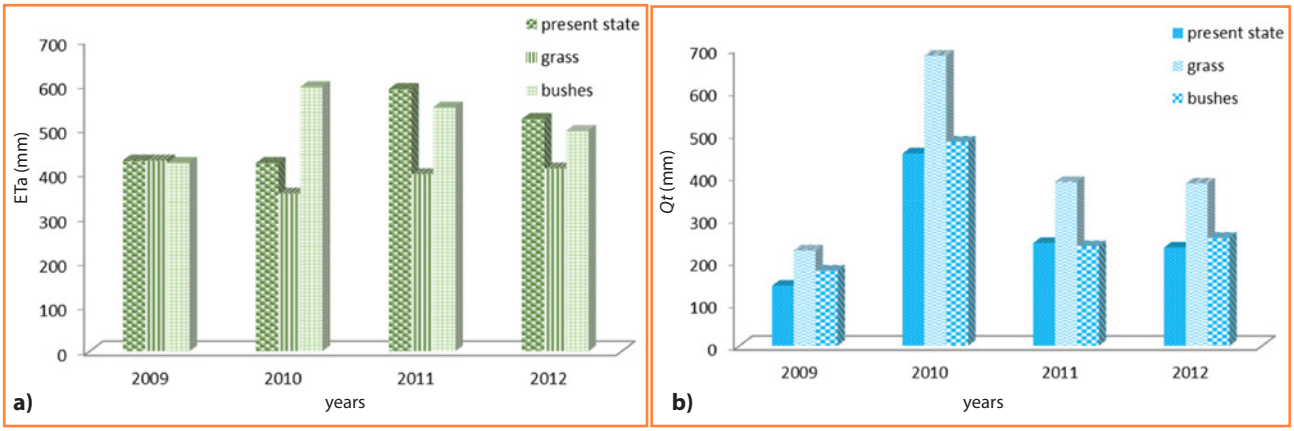

Fig. 3 a) Annual totals of actual evapotranspiration ETa in mm expressed for: present state of the land use, grass, bushes in the period of the years 2009–2012; **b)** Total annual discharge sums *Qt* in mm expressed for: present state of the land use, grass, bushes in the period of the years 2009–2012 in the Obyce catchment

total discharges computed by the model were compared with the real total discharges data measured in the Obyce profile.

Results and discussion

Annual mean air temperature during the evaluated period 2009–2012 was 10.4 °C, average value of the annual precipitation totals was 974 mm and average annual actual evapotranspiration totals was 473 mm. These whole climate characteristics data were used as input data to calibrate and verify model results according to Novotná (2004). Evaluation of water balance in the Obyce profile, according to the individual land use change, but under the same climate conditions was performed for the present time land use, e.g. mostly forested river basin (1), replaced by permanent grasses (2) and replaced by bushes (3) using model WaSiM-ETH. The model results are displayed in Table 1.

According to the model results, under the consideration of the same climate characteristics, changing only land use exploitation from the present state: deciduous forest 1) to grass and bushes 2) in all cases there was reported the actual evapotranspiration decrease from the smallest -1.3% for bushes in 2009 up to the -32.5% for grass in 2011. Only one increase is considered equal to 13.3% for bushes in 2010.

Similarly, the influence of the vegetation cover to the change of the total annual discharge was established in all cases from 5.9% for bushes in 2010 up to 65.3% for grass in 2012. The only reduction -3.1% was considered for bushes in 2011.

The comparison of the annual totals of actual evapotranspiration (mm) 3a) and total discharges related to the water gauge profile Obyce (mm), during the individual years is displayed in Figure 3a) and 3b).

Conclusions

Influenced by land use changes, significant hydrological cycle modifications are expected to occur in the observed sub-basin according to the results. These changes are identified and attributed to climate change, especially the decreased precipitation and the increased air temperature, in accordance with the study of Zhang et al. (2017). This study provides insights into changes in hydrological balance distribution and water resources availability that may occur as the result of global change in small-scale mostly forested sub-basin.

The results underline the importance of the forest communities in the water cycle and in the nature. Forests are related to the water balance through the processes of evaporation, evapotranspiration, infiltration, transpiration, and interception – the important functions of forest ecosystems.

The land-use/land-cover change is a widespread, accelerating, and significant process. Modelling these changes is critical for formulating effective environmental policies and management strategies (Agarwal et al., 2002). While assessing the effects of climate change at global or regional scales, local factors responsible for climate change are generalized, which results in the averaging of effects. However, climate change assessment is required at a micro-scale to determine the severity of the climate change. This shows the contribution of land use/land cover change and several other local anthropogenic activities on the climate change (Pingale et al., 2015).

The results of our study agree with Holko (2010) who states that possible technical measures to increase landscape retention have to be compared with the data about probable rainfall amount and intensity in the given area. In conditions of less permeable areas, where the main runoff formation mechanism is a surface runoff caused by exceeding of the soil infiltration capacity, it has to be taken into consideration that the measures performed to increase the soil infiltration capacity do not cause disruption of the soil surface. Hydrological response to the river basin, possibly leading to floods, depends on many factors. However, hydrological models provide the detailed information about the runoff formation and about the most frequent causes of floods in our territory as well as the most threatened areas. Present technologies make it possible, with some likelihood and precision, to alert the flooding risk and compute the flood wave characteristics and possible extent of the flooded area.

The results of this study can be useful for the identification of optimal climate change adaptation and

mitigation strategies based on the severity of climate change at different spatial scales as it was proposed by Pingale et al. (2015). Possible parameters change estimation of the extreme runoff phases due to global climate change, in the design of adaptation and mitigation measures for water management as well as to evaluation the land use characteristics in terms of the risk of floods were also intended by Húska and Tátošová (2005).

Acknowledgement

The results obtained in the research project KEGA no.004SPU-4/2016 was used/presented in this paper.

References

AGARWAL, CH. – GREEN, G. – GROVE, J.M. – EVANS, T.P. – SCHWEIK, CH.M. 2002. A review and assessment of land-use change models: dynamics of space, time, and human choice. Gen. Tech. Rep. NE-297. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 2002. 61 p.

BÁREK, V. – HALAJ, P. – TAKÁČ, J. 2008. Assessment of the moisture demand for the special crops and vegetables in changed climate conditions of Slovakia. In Acta horticulturae et regiotecturae, vol. 11, 2008, no. 1, p. 9–13. ISSN 1335-2563.

BLINKA, P. 2009. Climatic assessment of drought in Czech and Moravia during the years 1875–2002. Disertation Thesis : Praha : UK, 2009, 139 p.

BULANTOVÁ, M. 2009. Assessing the impact of forests on drainage processes in river basins. In 21th Conference of Young Hydrologists, Bratislava : Sloval Hydrometeorological Institute, 2009, 14 p. ISBN 978-80-88907-70-1. [on-line]. Available on: <http://www.zzvh.sk/data/files/70.pdf> [cit. 2018-03-01].

CUDLÍN, P. et al. 1999. Příčiny snížení vodohospodářské funkce lesa v krajině. Závěrečná zpráva úkolu VaV 610/2/98, DÚ 01/07. České Budějovice : Ústav ekologie krajiny AV ČR, 1999, 84 p.

HALAJ, P. – BOŽOŇ, V. – HORNÍKOVÁ, H. – BÁREK, V. – ČIMO, J. – TÁTOŠOVÁ, L. – ĎURIŠ, J. 2010. Hydraulic stream habitat study based on acoustic doppler velocity measurements. In Journal of International Scientific Publications: Ecology & Safety, vol. 4, 2010, no. 1, pp. 192–200. ISSN 1313-2563.

HAMILTON, L.S. – KING, P.N. 1983. Tropical Forested Watersheds: Hydrological and Soil Response to Major Uses for Conservation, Westview Press : Boulder, 1983.

HOLKO, L. 2010. Voda v krajine a povodne. In Urbanita, vol. 22, 2010, no. 4, pp. 20–24.

HÚSKA, D. – TÁTOŠOVÁ, L. Sustainable land use in hilly areas. In Protection of soil and water resources in forestry areas. Warsaw : Forest Research Institute, 2005, pp. 143–146. ISBN 83-87647-38-1.

JEWITT, G. 2005. Water and Forests. In Encyclopedia of Hydrological Sciences (Ed. Anderson, M. G. – McDonnell, J.J.), chapter 186, John Wiley & Sons, Ltd., 2005, pp. 2895–2909.

JURÍK, Ľ. – HÚSKA, D. – TÁTOŠOVÁ, L. – BAZSÓ, R. 2008. Water for landscape or landscape for water. In Zeszyty problemowe postepów nauk rolniczych, 2008, no. 532, pp. 121–131. ISSN 0084-5477.

NOVOTNÁ, B. 2004. Influence of the climate change on the need of water demand for irrigation in Žitava river basin. Disertation Thesis : Nitra : SAU, 2004.

PAVKOVÁ, K. 2010. Modelling of the surface runoff in ArcGIS Server. Palacky University in Olomouc, Olomouc, [on-line]. Available on: <http://www.geoinformatics.upol.cz/dprace/magisterske/pavkova10/model.html> [cit. 2018- 2-28].

PINGALE, S. – ADAMOWSKI, J. – JAT, M. – KHARE, D. 2015. Implications of spatial scale on climate change assess- ments. In Journal of Water and Land Development, 2015, no. 26, p. 37–56.

RAVEENDRA, K. – RAI, B. – MATHUR, S. 2008. Event-based sediment yield modeling using artificial neural network. In Water Resour. Manag., 2008, no. 22, pp. 423–441.

SCHULLA, J. 1997. Hydrologische Modellierungvon Flussgebieten zur Abschätzung der Folgen von Klima änderungen. Diss ETH 12018, Zürich : Verlag Geographisches Institut ETH, 1997, 187 p.

SMITH, J.B. – HUQ, S. – LENHART, S. – MATA, L.J. – NEMESOVA, I. – TOURE, S. 1996. Vulnerability and Adaptation to Climate Change: Interim Results from the U.S. Country Studies Program. Dordrecht, The Netherlands : Kluwer, 1996, 366 p.

TÁTOŠOVÁ, L. 2006. Possibilities of precipitation water interception in the landscape. In Inžynieria srodowiska, 2006, no. 434, pp. 185–193. ISSN 1233-569X.

WAGNER, S. – KUNSTMANN, H. – BÁRDOSSY, A. 2006. Model based distributed water balance monitoring of the White Volta catchment in West Africa through coupled meteorological-hydrological simulations. Advances in Geosciences, European Geosciences Union, 2006, no. 9, pp. 39–44. <hal-00296954>.

ZELEŇÁKOVÁ, M. – VIDO, J. – PORTELA, M.M. – PURCZ, P. – BLIŠTÁN, P. – HLAVATÁ, H. – HLUŠTÍK, P. 2017. Precipitation Trends over Slovakia in the Period 1981–2013. In Water, vol. 9, 2017, no. 12, p1–20, 20 p.

ZHANG, Y. – ZHONG, P.A. – CHEN, J. – BING, J. – XU, D. – WANG, M. 2017. Impacts of Climate Change and Human Activities on the Three Gorges Reservoir Inflow. In Water, vol. 9, 2017, no. 12, 57 p. doi:10.3390/w9120957

ZORÁD, L. 2010. Simulation of flood zones at Žitava river and stream Hostiansky. In Proceedings of the scientific work of PhD students and young scientists "Young Scientists 2010", Nitra : UKF, 2010.

sciendo

DOI: 10.2478/ahr-2018-0003

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 10–12

SEDIMENT MOVEMENT MODE IN RIVERS OF UZBEKISTAN – ENVIRONMENTAL ASPECTS

Aybek M. ARIFJANOV[1], Tursunoy A. APAKHUJAEVA[1], Dušan HÚSKA[2]*

[1]Tashkent Institute of Irrigation and Mechanization of Agriculture Engineers, Uzbekistan
[2]Slovak University of Agriculture in Nitra, Slovak Republic

Central Asian rivers are rich in sediments that affect the construction of hydrotechnical constructions. In this article the influence of sediments on water quality and amelioration conditions of agricultural fields was analyzed and information was given on possibilities of controlling the sediment flow.

Keywords: water, channel, river, sediment, chemical parameters

The largest rivers of Central Asia such as the Amu Darya and the Syr Darya have reported the increase in sediments, which creates certain problems when they are used for irrigation purposes. Irrigation canals supplied from such kind of rivers not only deliver water to fields, but also contribute to fertilization of soils (Fig 1). It is known that ecological conditions of soils and value of yields depends on quality of irrigation water. It is necessary to take into account this factor since the river water that irrigates the areas brings a huge number of suspended sediments. The solution of this problem is particularly important for the channels of the Amu Darya system (where in some periods the turbidity of the stream reaches 20 kg.m^{-3} and the fractional composition of the sediments varies in large (0.001 : 1.5 mm) limits), passing in easily eroded soils and bearing greater amount of suspended particles of sediment containing valuable mineral fertilizers in its composition.

In the works of researchers (Klyukanova, S., Abu Alyants S., X., Latipov, I., S., H., Arifjanov, A. and others) it was noted that the sediments which come from the Amu Darya River into irrigated fields cause the increase in soil fertility and bring positive conditions for vegetation growth.

Fig. 1 Map of Aral Sea basin
Source: Mirishkor and Big Fergana Channel

Material and methods

For a more detailed analysis of this problem, field experiments and analyses of other researchers' work were carried out.

The studies were carried out on the Mirishkor and the Big Fergana Channel (BFC). The Mirishkor channel takes water from the Amu Darya River. The length of the channel is 120 km, the flow rate of the channel is 130 m^3.s^{-1}; The width of the channel along the bottom is 24 m; depth of the channel -5.1 m; the shape of the channel is trapezoidal. The channel BFC takes water from the Syr-Darya River.

The results of field experiments performed in the Mirishkor and the Big Fergana Channels (BFK) showed that 60% of total suspended sediments consist of particles with diameter of less than 0.05 mm. Main parts of sediments, which can be used as humus and other mineral fertilizers, were collected in sediment reservoirs (Tables 1, 2).

Dissolved salts and mineral fertilizers composition of suspended sediments depend on sediment size.

Contact address: Dr.h.c. prof. Ing. Dušan Húska, PhD., Slovak University of Agricultural in Nitra, Faculty of European Studies and Regional Development, Department of Regional Bioenergy (FESRD), Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, phone: +421 37 641 56 51, e-mail: dusanhuska@gmail.com

Table 1 Fractional composition of suspended sediments (the Mirishkor channel)

GP	Size of fractions (mm) in %				
	>0.25	0.25–0.10	0.10–0.05	0.05–0.01	0.01–0.005
GP – 620	0.0	0.7	36.8	53.8	28.8
GP – 720	0.1	0.8	26.5	56.5	31.7
GP – 1060	0.6	0.7	50.2	52.4	34.0

GP – distance from channel entry

Table 2 Fraction of suspended sediments in BFC

GP	Size of fractions (mm) in %				
	>0.25	0.25–0.10	0.10–0.05	0.05–0.01	0.01–0.005
GP – 930	0.0	0.6	31.4	58.3	8.6
GP – 1500	0.2	1.2	35.4	56.4	6.6
GP – 1710	3.2	22.5	22.5	27.4	6.5

GP – distance from channel entry

Table 3 Chemical composition of suspended sediments in the Mirishkor channel

Chemical composition	Diameter of suspended particles in mm		
	0.1…0.05	0.05…0.01	0.01
SiO	61.6	55.5	46.7
Al_2O_3	10.8	9.2	11.5
Fe_2O_3	3.6	3.9	6.1
CaO	9.3	10.6	12.7
MgO	2.1	2.7	3.9
K_2O	3.1	1.7	1.8
Na_2O	2.5	2.3	1.8
P_2O_5	0.12	0.15	0.21
CO_3	6.6	11.3	14.0

As shown in the result of the field experiment analysis, with decreasing size of sediments, the volume of chemical components such as SiO_2, Al_2O_3, Fe_2O_3 also decreases, but the amount of humus, potassium and calcium salts increases (Table 3).

Results and discussion

The results of the analysis show that a large volume of suspended sediments can be transported into irrigation channels.

But in the planning and construction of hydraulic, irrigation and drainage constructions specialized in regulation of water and sediments, the size of sediments is not always considered. These constructions often, with retaining river sediments, significantly destroy the natural hydrobiological regime of channels. Sediments in tanks, reaching volumes in hundreds of cubic meters, become an environmental problem in each area when removed. Therefore, in the projection of hydraulic engineering constructions, specialized on the regulation of runoff regime in sediments, it is equally important to consider the fractional composition of river sediments.

The irrigational importance of suspended sediments is evaluated not only by mineral fertilizers. The passage of fine fractions to irrigation sets improves the hydraulic characteristics of channels, while reducing water loss due to filtration.

Based on terrain experiments performed in the channels, the dynamics of the distribution of suspended sediment particles along the depth and length of the channel flows were determined. Rational regulation of river sediment regimes can be achieved by considering the fractional composition of suspended sediments. Transportation of sediments by water flows depends on the regime of flow. Figure 2 shows changes in the composition of sediment fractions along the Mirishkor channel.

According to the results of field experiments, the share of particles with the diameter less than 0.01 mm is more

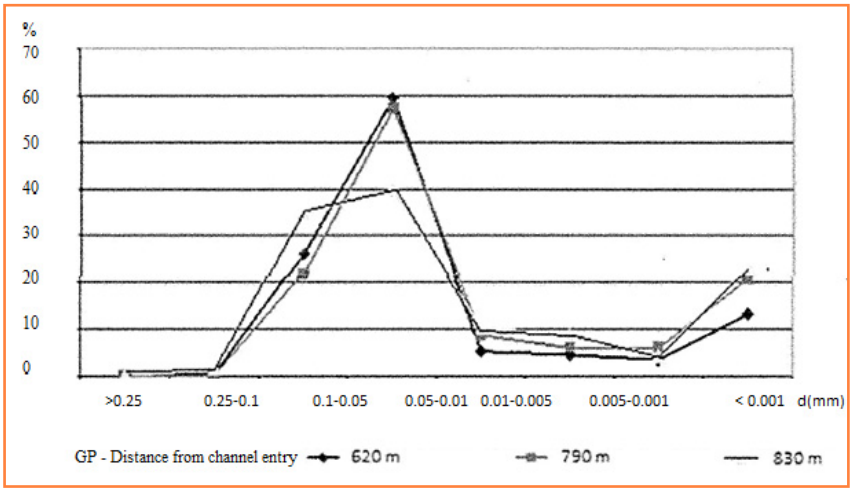

Fig. 2 Changes of fractional compositions of suspended sediments in the Mirishkor channel

than 55% in the Mirishkor channel. The average turbidity of water in the canal during the vegetation period is 0.7 $g.l^{-1}$. The proportion of sediments containing mineral fertilizers is 0.3–0.4 $g.l^{-1}$.

Channel flow capacity (on 640 m), during the vegetation period (May–September) is 100–110 $m^3.s^{-1}$. Based on the above, the amount of water-borne nutrients can reach up to 14 tons for the irrigated area without costs. The main problem is distribution of minerals along the field. It depends on the water intake system from the canal to the irrigated fields.

Conclusion

As the analysis results (Fig. 2) show, particles of large diameter are deposited in the channels. This creates difficulties in operation of the channel. To solve this problem, it is recommended to build a settler at the beginning of the channel. The settling pool reduces the flow rate of water and large sediments are deposited on the bottom of the hold. Such tanks are modified so that after the end of the irrigation season, these sediments can be easily removed and used. The length of such sedimentation tanks is determined based on the Stokes Act which determines the settling rate depending on the size, shape and density of the grains, as well as the viscosity and density of the liquid phase of the suspension (Fig 3):

$$w = \frac{2(\rho_p - \rho_f)gr^2}{9\mu}$$

In formula w is the deposition rate, ρ is the density (p – solid component, *f* – fluid), g is the gravitational acceleration, and μ is the dynamic viscosity of the fluid. We calculate the settling time of the selected particle from the water level to its impact on the bottom, and the flow velocity (*v*) vector determines the site of particle impact. This length is typically increased by 50%.

Using the above scheme (Fig 3), the formula for determining the length of the sedimentary pool can be written down as follows:

$$L = \frac{\vartheta H}{\omega}$$

where:

L – length of the sedimentary pool
ϑ – flow velocity
H – depth of flow in the settler

Fractional regulation regime of the sediment contributes to the solution of the following problems:

- Sedimentation of big sized sediments in reservoirs preserves the irrigation channels from debris and silting. Simultaneously, the passage of fine fractions of suspended sediments into irrigated fields improves the quality of irrigation water, which contains mineral fertilizers of humus, etc., which affect soil fertility;
- This activity can decrease the volume and cycle of sewage works in reservoirs, which saves resource and energy consumption, and improves the ecological situation of the given territory. It is pertinent to note here that the sedimentation of fine sediments brings to leads to the crystallization deposits, which makes it difficult to clean them with dredgers.

Thus, rational regulation of regime of the river sediments can significantly affect the ecosystem of water use in land reclamation.

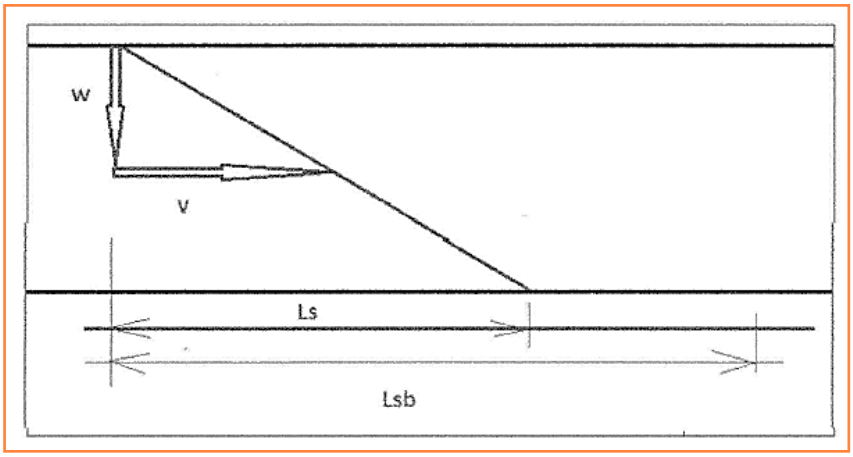

Fig. 3 Scheme of deposition of particles
Source: Custom sketch
Ls – length of particle sedimentation, L – length of the sedimentary pool

References

ABU ALYANTS, S. X. 1981. Stable and transitional regimes in artificial channels. L .: Gidrometeoizdat, 1981, 232 p.

HÚSKA, D. – JURÍK, L. – TÁTOŠOVÁ, L. – JAKABOVIČOVÁ, J. 2017. Cultural landscape, Foods and remote sensing. In Journal of Ecological Engineering. 18.3 2017, p. 31.

KLYUKANOVA, I.A. 1971. Suspended sediments of the Amudarya and their irrigation importance. Moscow : Nauka, 1971, 120 p.

LATIPOV, I. SH. – ARIFJANOV, A. Tasks (Questions) of movement of mixed flow in open channels. Tashkent, 1994. 110 p.

sciendo

DOI: 10.2478/ahr-2018-0004

Acta Horticulturae et Regiotecturae 1/2018 *Weronika Masłowska, Daniel Liberacki*

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 13–16

THE YIELD OF SELECTED VARIETIES OF AMERICAN BLUEBERRY (*VACCINIUM CORYMBOSUM* L.) IN THE FIRST YEARS OF FRUITING IN THE WESTERN PART OF POLAND

Weronika MASŁOWSKA*, Daniel LIBERACKI

Poznań University of Life Sciences, Faculty of Environmental Engineering and Spatial Management, Institute of Land Improvement, Environmental Development and Geodesy, Poland

This paper presents the influence of meteorological conditions prevailing in the western part of Poland on the yield of selected blueberry varieties. The research was conducted on a small plantation located in the Przyczyna Górna village, in the Wschowa district of the Lubuskie province. There are five varieties of blueberry: Patriot, Duke, Chandler, Elliott and Bleuecrop. The studied years 2014, 2015, 2016, as the first fruiting years, were presented in relation to the multi-year 2006–2016. The 2014 was the warmest year during this period with an average air temperature of 10.3 °C, whilst the lowest temperature was 7.6 °C recorded in 2010. The highest precipitation was in 2016, with the precipitation level of 760 mm. However, the year with the lowest precipitation of 418 mm turned out to be 2011. The goal of the study in 2014–2016 was to evaluate the respective yields of five varieties of blueberry on a small plantation, taking into account various meteorological conditions.

Keywords: blueberry, precipitation, temperature, yield

For many years, Poland has been recognised as a leading European and world producer of blueberries. Continuous growing interest in and demand for its fruits have led to increased areas of growth. With the correct conditions for growth, it can fruit for 40 years, and even more (Kaiser et al., 2014). Plantations in Poland have brought high profits due to the favourable climatic conditions for the growth and yielding of blueberries. However, the high blueberry is a demanding plant and for optimal results it should be provided with optimal conditions for growth and fruiting. The blueberry requires specific soil parameters, such as a pH value of approximately 4.0 and adequate moisture (Pliszka, 2002). Humus content should be about 3.5% (Eck, 1988). During the vegetation period, the groundwater level should be maintained at the levels of 0.35 m to 0.6 m, depending on the type of soil (Smolarz, 2008).

One of the factors affecting the productivity of the crops is climate. Unfortunately, a number of unfavourable weather events have been reported in recent years. There has been an increase in the occurrence of atmospheric drought, especially during the growing season, as well as the occurrence of intense precipitation (Bokwa and Skowera, 2009).

This study was conducted on the influence of meteorological conditions prevailing in the western part of Poland on the yield of the selected blueberry varieties. The main task of the conducted research was to compare the yields of five selected blueberry varieties in the area of a small, home-grown plantations.

Material and methods

The subject of the research is located in the area of the Przyczyna Górna village. The village is located in the area of the Wschowa district within the municipality of Wschowa in the Lubuskie province. In the autumn of 2011, 150 bushes of blueberry were planted in the plantation. Because of a lack of adequate protection of the young seedlings from frost, a large part of plants was already frozen in the first year. This was consistent with the results obtained by Krzewińska (2009). The plants have grown in 11 rows of 7 bushes with a spacing of 3.0 × 1.5 m. The research was conducted on five varieties of blueberry: Patriot, Duke, Chandler, Elliott and Bleuecrop. The pH level before acidification was 6.0. One year before the plantation, the soil was acidified by sulfurization (Wigor S) at the dose of 12.0 kg.100 m^{-2}, resulting in the change of pH level to pH 4.0. In the later years, soil care was based on the use of sawdust mulching under each bush. Sawdust was scattered around the plants in the radius of 0.5–0.8 m, for the thickness of 0.03–0.05 m.

Fertilization of potassium and phosphorus was carried out before the plantation started. Later, phosphate and potassium fertilizers were mixed and sown mainly after harvesting fruit (Schönthaler et al., 2015). In the paperwork, we observed plant reaction of the used fertilizers and decided to use Substral's ready fertilizer mixes. The fertilizing dose was 10 g.100 m^{-2}.

The plants were pruned once a year, after fruiting (Pliszka 2002). According to Kovaleski's research (2015) no pruning

Contact address: mgr inż. Weronika Masłowska, Uniwersytet Przyrodniczy w Poznaniu, Instytut Melioracji Kształtowania Środowiska i Geodezji, Piatkovska 94, 60=649 Poznan, Poland, phone: 004861-846-64-30, e-mail: weronika.maslowska@up.poznan.pl

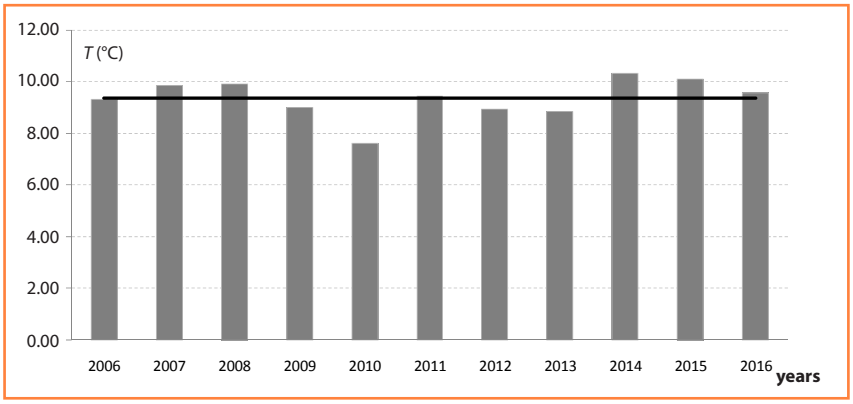

Fig. 1 Average annual air temperature on the average background of multiple years 2006–2016

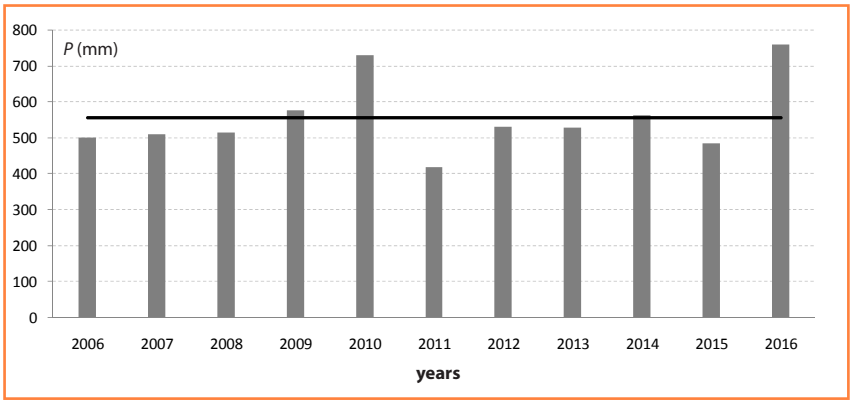

Fig. 2 Annual precipitation in the years 2006–2016

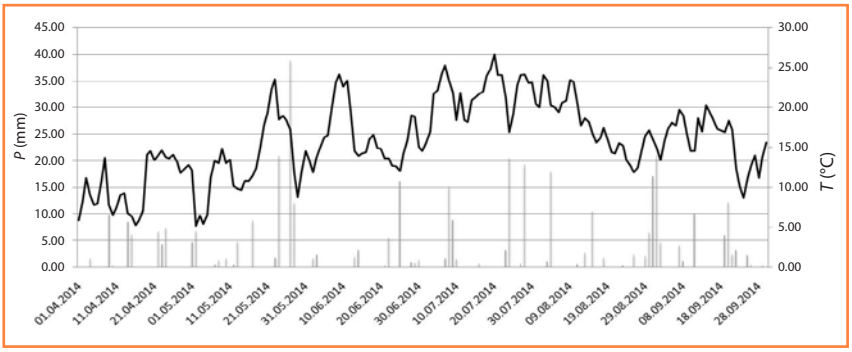

Fig. 3 Daily precipitation in mm and air temperatures in °C for 2014, during the growing season of blueberries

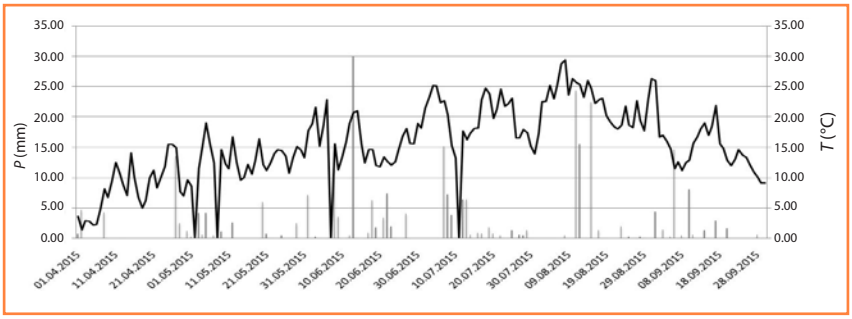

Fig. 4 Daily precipitation in mm and air temperature in °C for 2015, during the growing season of the blueberry

in the first year does not affect the plant. However, in subsequent years, no pruning decreased vegetative vigour. The bushes on the plantation have not been pruned since planting.

Prior to evaluating the yields of the selected varieties of blueberries, meteorological data was obtained from the measurement station located in Leszno. This station is located 20 km from the plantation. The average air temperature for the year and the vegetation period was calculated, as well as the precipitation in the period of study.

The work focused in particular on the years 2014, 2015 and 2016, as the first blueberry crops in the plantation were recorded during this period. The daily temperature distribution and precipitation in the vegetation period was analysed in the selected years.

The measurements and observations were:

- total weight of harvested fruits in each of the years of testing;
- total weight of harvested fruits from the bushes of each variety, in the years 2014–2016.

Based on the data of yields from the farm in the years 2014–2016, the impact of meteorological conditions was evaluated. The results are summarised in tables and graphs. The obtained data were referenced to the meteorological conditions prevailing in the years of research, during the whole year and the vegetation period.

Results

The obtained meteorological values, presented in the graphs (Figure 1, 2), concerned daily temperatures and precipitation in the period 2006–2016.

Based on the meteorological data, it was found that the year 2014 recorded the highest average air temperature of 10.3 °C whilst the lowest air temperature of 7.6 °C was recorded in 2010. The average annual temperature of the multi-year period was 9.4 °C. The highest annual precipitation was in 2016, with the precipitation of 760 mm. However, the year with the lowest total precipitation of 418 mm turned out to be 2011. The average total annual precipitation in the multi-year period of 2006–2016 amounted to 555 mm.

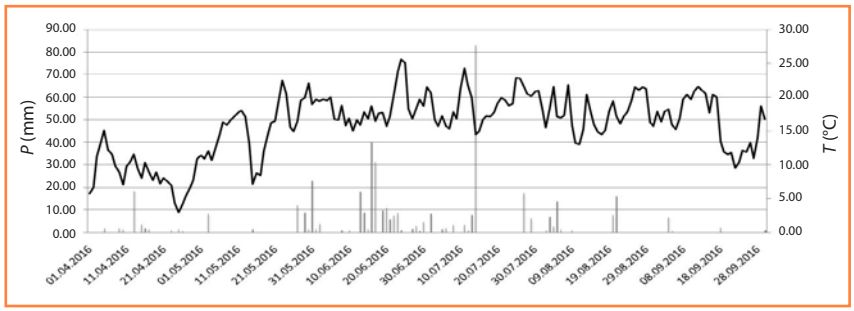

Fig. 5 Daily precipitation in mm and air temperature in °C for 2016, during the growing season of the blueberry

After precise metrological analysis, 2014–2016 can be described as characteristic for the multi-year period. The air temperatures in the analysed period were similar to the average temperature of the multi-year period and did not differ significantly from each other. Analysing the annual precipitation levels, it can be said that 2014 was the year of a similar value to the multi-year average. The year 2015 can be defined as dry, with the total rainfall of only 484 mm, which is by 71 mm lower than the average. The last year of 2016 was estimated to be wet with precipitation of 760 mm, higher than the average of 205 mm.

The diagrams (Figures 3, 4, 5) showed daily temperatures and precipitation during the growing season, from April to September, for the years 2014, 2015, 2016.

During the analysis of precipitation distribution in the growing season, attention was paid to periods without precipitation. There were considered periods without precipitation, minimum seven days. There were five such periods in 2014, the longest was 12 days, lasting from the 11th to 22nd July. In 2015, the number of precipitation free periods was seven, and the longest of them lasted for 18 days, and occurred from the 9th to 26th April. Despite the long drought, the total precipitation for the month did not differ from the average monthly precipitation of 46 mm. In the last year of 2016, eight precipitation free periods were recorded. The longest ones were from 22nd August to 3rd September, and from 5th to 17th September. The precipitation free periods, shorter than seven days, were observed at the beginning of the growing season, in April and May. However, in the months of June and July, the highest daily precipitation throughout the year was marked.

During the research, it was noticed that the average temperatures in 2014, 2015 and 2016 were similar. The blueberry yield was dependent on precipitation and changed in individual years of research. The total weight harvested in the analysed years was 256.0 kg. In 2014, the best yields were recorded, with the total of 114.0 kg. In the following year 2015, the yield was 83.0 kg and in the last year of 2016 it was only 59.0 kg. By comparison, Figure 6 shows how the fruit weight changed during the analysed years.

These results are confirmed by studies according to Koszański, Rumasz-Rudnicka and Friedrich (2008), where he wrote about the

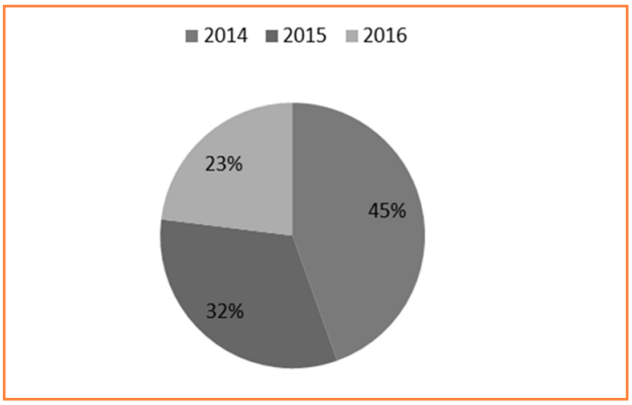

Fig. 6 Percentage of yield of tested crops in 2014–2016

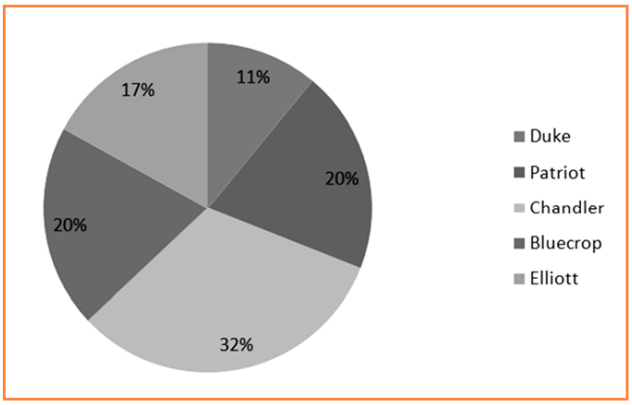

Fig. 7 Percentage of yield of selected varieties of blueberries in the examined years 2014–2016

Table 1 Average weight of fruit from one bush, each variety in the analysed years 2014–2016

Variety	Average weight of the fruits per bush in kg			
	2014	2015	2016	average
Duke	1.0	0.8	0.4	0.8
Patriot	1.0	0.7	0.5	0.7
Chandler	2.5	1.7	1.3	1.8
Bluecrop	1.5	0.9	0.9	1.1
Elliott	1.6	1.6	0.8	1.3

optimum soil moisture for cultivation in order to increase the yield.

The variety that yielded the best was Chandler, whose fruit accounted for as much as 32% of all crops, and the worst yield was produced by Duke. Patriot, Bluecrop and Elliott were comparable. The graph (Figure 7) shows the percentage of fruit weight of each variety.

Also, the yield from individual bushes of each variety was evaluated, in relation to the examined years 2014–2016 (Table 1). In the analysed period of 2014–2016, the variety with the highest crop from one bush was Chandler, with the average weight of 1.8 kg of fruits. The Patriot variety gave the lowest yield from a single bush, only 0.7 kg.

Conclusions

The study evaluated the impact of weather conditions in western Poland on crops of five selected varieties of blueberries in 2014–2016. As a result of the research, the following conclusions were obtained:

- The best yields (114.0 kg) were recorded in 2014, with regular distribution of precipitation during the growing season. In 2015, during the growing season, the precipitation was by 92 mm lower than in 2014, and the yield decreased by 27%. In 2016, the yield was by 48% lower than the yield in 2014. This is the consequence of the occurrence of precipitation-free periods in the growing season.
- The high yield of blueberries was caused by the quantity and distribution of precipitation in the growing season.
- The study of the total weight of harvested fruits in 2014–2016 showed that the worst yield was given by Duke and the best by Chandler.
- Analysis of the mass of harvested fruits per bush of blueberry showed that the worst crop was Patriot and the best one was Chandler.

References

BOKWA, A. – SKOWERA, B. 2009. Występowanie ekstremalnych warunków pluwialnych w Krakowie i okolicy w latach 1971–2005. In Acta Agrophysica, vol. 13, 2009, no. 2, pp. 299–310.

ECK, P. 1988. Blueberry science. New Brunswick : Rutgers Univ. Press, 1988, 284 p.

KAISER, C. – ERNST, M. 2014. Highbush blueberries. Cooperative extension service University of Kentucky College of agriculture, food and environment, 2014.

KOSZAŃSKI, Z. – RUMASZ-RUDNICKA, E. – FRIEDRICH, S. 2008. Wpływ nawadniania i nawożenia NPK na budowę anatomiczną i morfologiczną oraz plonowanie borówki wysokiej. In Acta Agrophysica, vol. 11, 2008, no. 3, pp. 677–684.

KOVALESKI, A.P. – WILLIAMSON, J.G. – CASAMALI, B. – DARNELL, R.L. 2015. Effects of Timing and Intensity of Summer Pruning on Vegetative Traits of Two Southern Highbush Blueberry Cultivars. In Hortscience, vol. 50, 2015, no. 1, pp. 68–73.

KRZEWIŃSKA, D. – SMOLARZ, K. – TRYNGIEL-GAĆ, A. 2009. Porównanie kilku odmian borówki wysokiej i półwysokiej. In Zeszyty naukowe Instytutu Sadownictwa i Kwiaciarstwa, Tom 17 (20909), 2009, pp. 5–16.

PERRIER, C. – MINGEAU, M. – AMEGLIO, T. – FERREIRA, M.I. – JONES, H.G. 2000. Effects of water stress on transpiration, radial growth and yield in highbush blueberry. In Acta Hort., vol. 537, 2000, no. 2, pp. 923–928.

PLISZKA, K. 2002. Borówka wysoka. Państwowe Wydawnictwo Rolnicze i Leśne.

SCHÖNTHALER, J. – BIENIASZ, M. – ŚCIBISZ, K. – MICHALSKI, P. – BULER, Z. – ŁABANOWSKA, B. – PIOTROWSKI, W. 2015. Nowe możliwości w produkcji owoców miękkich. In Centrum Doradztwa Rolniczego w Brwinowie Oddział w Radomiu, 2015.

SMOLARZ, K. 2008. Borówka wysoka.

WOŚ, A. 1995. Zarys klimatu Polski. Poznań : Bogucki wydawnictwo naukowe, 1995.

sciendo

DOI: 10.2478/ahr-2018-0005

Acta Horticulturae et Regiotecturae 1/2018 *Anna Báreková, Elena Kondrlová*

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 17–19

THE IMPACT ASSESSMENT OF DIFFERENT FEE SYSTEMS ON THE MUNICIPAL WASTE MANAGEMENT EFFECTIVENESS

Anna BÁREKOVÁ*, Elena KONDRLOVÁ

Slovak University of Agriculture in Nitra, Slovak Republic

The most widespread monetary motivation in the municipal waste management is a pay-as-you-throw (PAYT) or unit-based pricing scheme when fees are directly based on the volume of waste produced by a household. This approach forces the households to carry the full social costs of their waste disposal decisions, inducing more efficient choices. Volume-based schemes usually require households to purchase waste bags or stickers (tokens) that they can attach to their waste containers. The aim of our research was to assess the waste management system in the municipality of Dolný Ohaj, where different payment systems for municipal solid waste (MSW) charges were introduced during the monitored period (2012–2016). While a lump sum had been used in the municipality up to the end of 2014, a volume-based scheme in a form of the token system was introduced and applied in the municipality from the beginning of 2015 onwards. The main focus was to analyse the waste management of the municipality during the studied period 2012–2016 with the emphasis on municipal solid waste fees, the generation of MSW and residual fraction, municipal waste management revenues and expenditures as well as evaluation of economic results. The production of MSW in kilograms per person had decreasing tendency during the monitored period. The highest MSW production was observed in 2012 (262.68 kg.capita^{-1}.year^{-1}) and the lowest in 2016 (175.85 kg.capita^{-1}.year^{-1}). During the monitored period, also the amount of landfilled residual waste was decreasing. In 2016, the lowest quantity of landfilled MSW (237,150 kg) was recorded. The municipality reached noticeably better economic results in waste management during the period under the volume-based waste collection scheme.

Keywords: municipal solid waste, waste management, municipal solid waste fees, Dolný Ohaj municipality

Proper legal implementation and practical enforcement of EU waste legislation are the key priorities of the EU environmental policy. In particular, major discrepancies exist in the implementation of the Waste Framework Directive (2008), defining the basic principles of environmentally sound waste management. The Report on the Thematic Strategy on the Prevention and Recycling of Waste, published by the European Commission in 2011, stipulates that the proper implementation and enforcement of the EU acquis remains a priority and related monitoring at Member States (MS) level will be performed. One of the main recommendations for the Slovak Republic (SR) was to extend and enforce the PAYT scheme (also known as unit pricing (Dijkgraaf and Gradus, 2004) and differential and variable rate or variable fee charge systems (Van Beukering et al., 2009)) and to provide incentives and support for households to participate in separate collection (European Commission, 2013). Slovak legislation has not supported PAYT schemes yet and Slovak municipalities only rarely co-opt economic incentives to develop separate collection.

According to the current legislation, the collection of residual MSW generated on the territory of a municipality should be financed solely by local fees for MSW, collected annually from the individual waste producers. The means of waste collection depends mainly on whether a lump sum for its transport is levied by the municipality authority or the fee amount is directly proportional to the volume, respectively the mass of produced residual MSW. We focused on comparison of two different payment methods of fees for MSW collection in the Dolný Ohaj municipality (Nitra Region, Slovakia) during the studied period from 2012 up to 2016. While a lump sum scheme had been used in the municipality up to the end of 2014, a volume-based scheme in a form of the token system was introduced and applied in the municipality from the beginning of 2015 onwards. The main aim of the paper was to find out which of these fee methods was more efficient for the purposes of municipal waste management.

Material and methods

The municipality of Dolný Ohaj is situated in the Nové Zámky district and has got a population of 1,554 citizens and with its cadastral area of 17.03 km^2 it can be classified as a medium-sized municipality in this specific district. Up to the end of 2014, the citizens had paid the local community fee for MSW collection in the form of a lump sum per household member (Table 1). In January 2015, the method of MSW fee payment changed to volume-based scheme in the form of a token system. Under this scheme,

Contact address: Ing. Anna Báreková, PhD., Slovak University of Agricultural in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Landscape Planning and Ground Design, Hospodárska 7, 949 76 Nitra, Slovakia, phone: +421 037 641 52 22, e-mail: anna.barekova@uniag.sk

Table 1 Lump sum rate for residual MSW at Dolný Ohaj municipality during 2012 - 2014

Year	Lump sum rate in €.person^{-1}.day^{-1}	Lump sum rate in €.person^{-1}.year^{-1}
2012	0.03836	14
2013	0.03836	14
2014	0.07672	28

Table 2 Lump sum rate for single waste disposal according to the collection container volume at Dolný Ohaj municipality in 2015 and 2016

Type of container	Token price in 2015	Token price in 2016
0.110 m^3 container	1.70 €	1.85 €
0.120 m^3 container	1.85 €	2.00 €
1.100 m^3 container	17.00 €	18.50 €

the household pays its fee for residual MSW by purchasing tokens at the local authority, price being dependant on the volume of the waste container (Table 2). Only containers marked with a purchased token are emptied when the residual MSW is collected. If the household does not participate to volume-based scheme during the first half of the year, the municipality has the right to levy a lump sum of 20 € per year per each person in a household. The monitored municipality participates in separated waste collection of glass, plastics, paper, metals, electric household waste, edible oils and fats from households, used portable batteries and accumulators, automobile batteries and accumulators, and biodegradable waste. Specific sacks and collecting containers are designated for separated waste. If necessary, every citizen can deliver separated MSW components also to the collection yard free of charge.

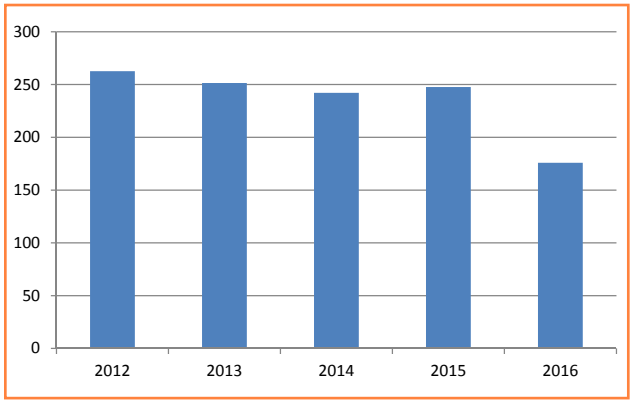

Fig. 1 MSW production in Dolný Ohaj during the period of years 2012–2016 (kg per capita per year)

Results and discussion

According to the data analysis from the Annual reports on MSW in the Dolný Ohaj municipality and the number of citizens for the period of the years 2012–2016, the following results were obtained. The lowest quantity of MSW was produced under the established volume-based scheme in 2016. In the same year, the most significant decrease in the amount of produced MSW by 112,870 kg was recorded in comparison to the previous year. Also, the waste production per capita had a declining trend over the whole studied period. The highest waste production rate (262.68 kg.capita^{-1}.year^{-1}) was observed in 2012, while the lowest one (175.85 kg.capita^{-1}.year^{-1}) was recorded in 2016 (Figure 1). Regarding the residual MSW which was deposited at landfills, the same trend in gradual decrease of produced waste quantity with time was observed. While there were 383,120 kg of residual MSW disposed at landfills in 2012, the amount dropped to 237,150 kg in 2016. After the shift from the lump sum waste collection scheme to the volume-based scheme, no increase in occurrence of illegal landfills in municipality proximity was recorded.

The municipality achieved a better economic result in waste management after introduction of the volume-based scheme (Table 3). In 2015, the municipality gained a profit of 1,096 €, which nearly tripled in 2016 (2,792 €). Under the lump sum scheme, the municipality was profitable only in 2012. In 2013 and 2014, the municipality incurred losses that had to be paid out of its budget (Table 3).

Table 3 Income and expenditure in the waste management division at Dolný Ohaj municipality for the period of years 2012–2016

Year	2012	2013	2014	2015	2016
Income in €	23,955	22,405	22,730	19,537	20,595
Expenditure in €	23,250	24,500	22,800	18,441	17,803
Expenditure per capita in €	14.54	15.57	14.51	11.87	11.51
Net income in €	705	-2,095	-70	1,096	2,792

In some of the front-running EU Member States such as Germany and the Netherlands, PAYT has very often been called for in the past as an instrument to address citizens' concerns and demands for fair treatment in response to ever increasing charge burdens. Higher transparency as to the individual cost allocation for waste management services provided may also be a crucial driver for a wider dispersion of the PAYT approach in Europe in the future (Reichenbach, 2008). Numerous communities nationwide have found it beneficial to adopt various forms of the PAYT scheme to reduce solid waste output, promote greater equity, and increase recycling by residents (Skumatz and Freeman, 2006; Lee and Paik, 2011; Park and Lah, 2015) as well as their environmental awareness (Adamcová et al., 2016).

Conclusion

Based on the comparison of the periods when different fee methods for waste collection were applied, it can be concluded that the introduction of the volume-based scheme in a form of the token system was the right decision made by the authority of the Dolný Ohaj municipality. The waste management is more effective and the municipality gained better results in the area of waste disposal.

Acknowledgment

This paper was supported by project KEGA 026SPU-4/2017.

References

ADAMCOVÁ, D. – VAVERKOVÁ, M.D. – STEJSKAL, B. – BŘOUŠKOVÁ, E. 2016. Household Solid Waste Composition Focusing on Hazardous Waste. In Pol. J. Environ. Stud., vol. 25, 2016, no. 2, pp. 487–493.

ANNUAL reports on MSW at Dolný Ohaj municipality in 2012–2016.

DIJKGRAAF, E. – GRADUS, R.H.J.M. 2004. Cost savings in unit-based pricing of household waste: The case of the Netherlands. In Resour. Energy Econ., vol. 26, 2004, pp. 353–371.

DIRECTIVE 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

EUROPEAN Commission. 2013. Final Report : Support to Member States in improving waste management based on assessment of Member States' performance.

LEE, S. – PAIK, H.S. 2011. Korean household waste management and recycling behavior. In Build. Environ., vol. 46, 2011, pp. 1159–1166.

PARK, S. – LAH, T.J. 2015. Analyzing the success of the volume-based waste fee system in South Korea. In Waste Management, vol. 43, 2015, pp. 533–538.

REICHENBACH, J. 2008. Status and prospects of pay-as-you-throw in Europe – A review of pilot research and implementation studies. In Waste Management, vol. 28, 2008, no. 12, pp. 2809–2814.

REPORT from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Thematic Strategy on the Prevention and Recycling of Waste (SEC (2011) 70 final, 19.1.2011).

SKUMATZ, L.A. – FREEMAN, D.J. 2006. Pay As You Throw (PAYT) in the US: 2006 Update and Analyses. Prepared for U.S. EPA by Skumatz Economic Research Associates, Superior, CO.

VAN BEUKERING, P.J.H. – BARTELINGS, H. – LINDERHOF, V.G.M. – OOSTERHUIS, F.H. 2009. Effectiveness of unit-based pricing of waste in the Netherlands: Applying a general equilibrium model. In Waste Management, vol. 29, 2009, pp. 2892–2901.

sciendo

DOI: 10.2478/ahr-2018-0006

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 20–24

GLOBAL SOLAR RADIATION ANALYSIS OF THE MODIFIED SAVIN-ANGSTRÖM METHOD BY USING PYRANOMETERS CMP 6 AND CMP 11

Ján ČIMO*, Beáta NOVOTNÁ

Slovak University of Agriculture in Nitra, Slovak Republic

Solar energy is one of the most available energy sources and the most ecological one. Currently, the firm Kipp & Zonen belongs to prominent producer of sensors for measuring global radiation. These sensors are the most used ones in our country and also in network of meteorological measurements of WMO. Therefore, the two types of measuring sensors for global radiation (pyranometer PMP 11, CMP 6) in comparison with the calculation method Savin-Angström are analysed. By processing the experimental measurements of global radiation in locality Nitra, there can be observed differences between standard CMP 11 and CMP 6. The measured values by CMP 6 pyranometer in comparison with secondary standard CMP 11 are lower by about 21% to what corresponds to the accuracy level (First Class) of sensor CMP 6. Differences may have been caused by higher aberrance of non-linearity, aberrance at sunrise and sunset i.e. directional errors and also by the fact that sensor CMP 6 is not equipped with integrated temperature compensation. The similar situation was also in the comparison of global radiation, which was calculated according to the modified Savin-Angström method and CMP 11. Notional differences were 7% compared with the measured values of CMP 11 standard.

Keywords: global radiation, pyranometer, Savin-Angström method

One of the most important agricultural requirements is information about condition and progress of atmospheric environment, which influences evolution of vegetation, diseases and pests and other prognosis (Meza, 1999). One of the most important and the most monitored component is global radiation, which is the main subject of our study at the meteorological station Nitra. Global radiation is sun radiation which incidents on the Earth´s surface. As it is introduced in Kanuk (2007), solar radiation is the most important energy source, following the most processes in land to work. Radiation input power to biological systems determines a lot of processes in the system soil-plan-atmosphere (Czégény, 2016). Besides biological processes (photosynthesis, respiration, water and substances transport in plants, and others), evapotranspiration and through it also the total water balance are underlain through the energy balance (Čimo et al., 2014).

Material and methods

Systematic monitoring of atmosphere conditions started at the Slovak University of Agriculture in 1961. The original localization of its meteorological station did not fulfil the conditions for meteorological observation activity; therefore, the new automated meteorological station was initiated into operating in the Botanical Garden of the Slovak University of Agriculture in Nitra, in 2007. Later, in 2009, a specialized centre for measuring UVA, UVB and global radiation was added. Measurement and registration of global radiation is systematically done with using two separate datalogers situated at each station. Pyranometers from the leading producer Kipp & Zonen are used. The automated meteorological station AWS 200 is equipped with the pyranometer CMP 6 and the specialized centre for global radiation is equipped with the pyranometer CMP 11 (Fig. 1).

CMP 6 has a similar detector to CMP 3, but it has improved performance due to the increased thermal mass and the double glass dome construction. It is recommended for cost-effective, good quality measurements in meteorological and hydrological networks and agriculture. CMP 11 uses a different detector design with temperature compensation. It is a step up in performance from CMP 6, and particularly suitable for upgrading meteorological networks. The faster response time meets the requirements for solar energy research and development applications. CMP 11 is also ideal for use in sun tracker based solar monitoring stations.

For measurement evaluating accuracy of different pyranometers types in comparison with the used methodology of modified method for radiation calculation following the Savin-Angström, we were based on the Kipp & Zonen data, so the pyranometer CMP 11 was determined as standard for the measurement accuracy. This pyranometer reaches aberration of less than 0.2% on 1,000 $W.m^{-2}$ (Tab. 1). Several chosen months were analysed (March, April, May, June and July) in 2015 and 2016, and values of global radiation were monitored and recorded in 1 minute step. Consequently the recorded values for global radiation were compared with calculated values (from sunshine)

Contact address: Ing. Ján Čimo, PhD., ING.PHD., Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Biometeorology and Hydrology, Hospodárska 7, 949 76, Nitra, Slovak Republic, e-mail: Jan.Cimo@uniag.sk

Fig. 1 Demonstration of pyranometers CMP 11 and CMP 6 at the meteorological station

according the mentioned Savin-Angström modified method for calculation of global radiation. Sunshine duration was observed with the heliograph Campbell-Stokes.

$$G_i = G_{0i}\left[1 - l\left(1 - \frac{s}{s_o}\right)\right], \quad \text{k.Wh.m}^{-2}$$

where:

G_i – global radiation in month, k.Wh.m^{-2}
G_{0i} – global radiation of clear sky in month, k.Wh.m^{-2}
k – coefficient of reflection and diffusion
s – sunshine, h
s_o – astronomical sunshine, h

Table 1 Kipp & Zonen sensor specification

Specification	CMP 3	CMP 6	CMP 11	CMP 21	CMP 22
ISO CLASSIFICATION	second Class	first Class	secondary standard	secondary standard	secondary standard
Response time (95%)	<18 s	<18 s	<5 s	<5 s	<5 s
Zero offsets Thermal radiation Temperature change	<15W.m^{-2} <5 W.m^{-2}	<W.m^{-2} <4 W.m^{-2}	<7 W.m^{-2} <2 W.m^{-2}	<W.m^{-2} <2 W.m^{-2}	<W.m^{-2} <1 W.m^{-2}
Non-stability (change/year)	<1%	<1%	<0.5%	<0.5%	<0.5%
Non-linearity (0 to 1,000 W.m^{-2})	<1%	<1%	<0.2%	<0.2%	<0.2%
Directional error (up to 80° with 1,000 W.m^{-2} beam)	<20 W.m^{-2}	<20 W.m^{-2}	<10 W.m^{-2}	<10 W.m^{-2}	<5 W.m^{-2}
Temperature dependence of sensitivity	<5% (-10 °C to +40 °C)	<4% (-10 °C to +40 °C)	<1% (-10 °C to +40 °C)	<1% (-20 °C to +50 °C)	<0.5% (-20 °C to +50 °C)
Tilt error (at 1,000 W.m^{-2})	<1%	<1%	<0.2%	<0.,2%	<0.2 %
Other specifications					
Sensitivity	5 to 20 µV/W/m^2	5 to 20 µV/W/m^2	7 to 14 µV/W/m^2	7 to 14 µV/W/m^2	7 to 14 µV/W/m^2
Impedance	20 to 200 Ω	20 to 200 Ω	10 to 100 Ω	10 to 100 Ω	10 to 100 Ω
Level accuracy	1°	0.1°	0.1°	0.1°	0.1°
Operating temperature	-40°C to +80°C	-40°C to +80°C	-40°C to +80°C	-40°C to +80°C	-40°C to +80°C
Spectral range (50% points)	300 to 2,800 nm	285 to 2,800 nm	285 to 2,800 nm	285 to 2,800 nm	200 to 3,600 nm
Typical signal output for atmospheric applications	0 to 20 mV	0 to 20 mV	0 to 15 mV	0 to 15 mV	0 to 15 mV
Maximum irradiance	2,000 W.m^{-2}	2,000 W.m^{-2}	4,000 W.m^{-2}	4,000 W.m^{-2}	4,000 W.m^{-2}
Expected daily uncertainty	<10%	<10%	<10%	<10%	<10%
Recommended applications	economical solution for routine measurements in weather stations, field testing	good quality measurements for hydrology networks, greenhouse climate control	meteorological networks, PV panel and thermal collector testing, material testing	meteorological networks, reference measurements in extreme climates, polar or arid	scientific research requiring the highest level of measurement accuracy and reliability

Fig. 2 Demonstration of Campbell-Stokes for measurement of sunshine

Results and discussion

Experimental measurements processing global radiation in Nitra produced several results. Values of global radiation according to the modified Savin-Angström methodology and by direct measurement using the CMP 6 and CMP 11 are listed in Figures 3–12.

From calculated and measured values there may be seen differences between the CMP 11 standards and the data measured by the pyranometer CMP 6 and the calculated values of global radiation. We observed that the values measured with the CMP 6 in comparison with the secondary standard CMP 11 (Table 2 and 3) are lower by about 21 % to what corresponds with the level of accuracy established by producer (first class) of the sensor CMP 6.

Differences of the measured values between each sensors may be caused by greater non-linearity mistake of sensor (1% – (0 to 1,000 W.m^{-2})), or a mistake caused by sunrise and sunset i.e. directional error (up to 80° with 1,000 W.m^{-2} beam), but also because the sensor CMP 6 is not equipped with the integrated temperature compensation and, therefore, it has higher temperature dependency.

Comparison of global radiation calculated according to the modified Savin-Angström method and the CMP 11 sensor is similar. The presented difference was 7% in

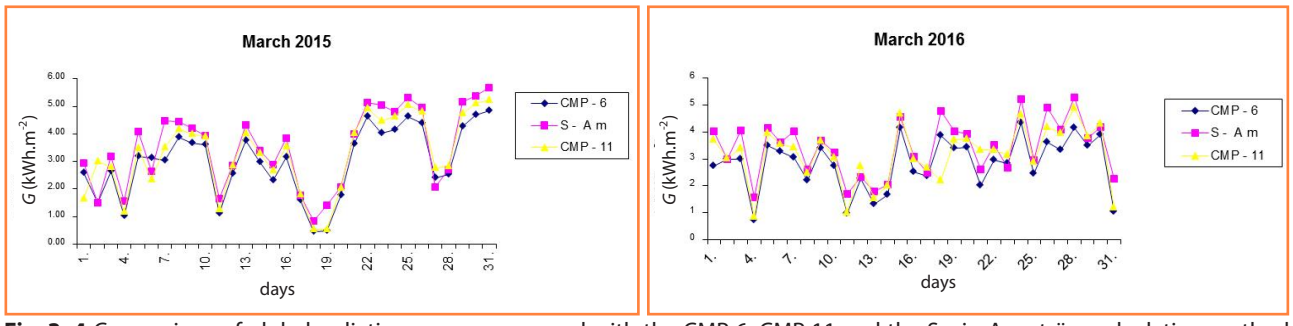

Fig. 3–4 Comparison of global radiation course measured with the CMP 6, CMP 11 and the Savin-Angström calculation method (March; 2015, 2016)

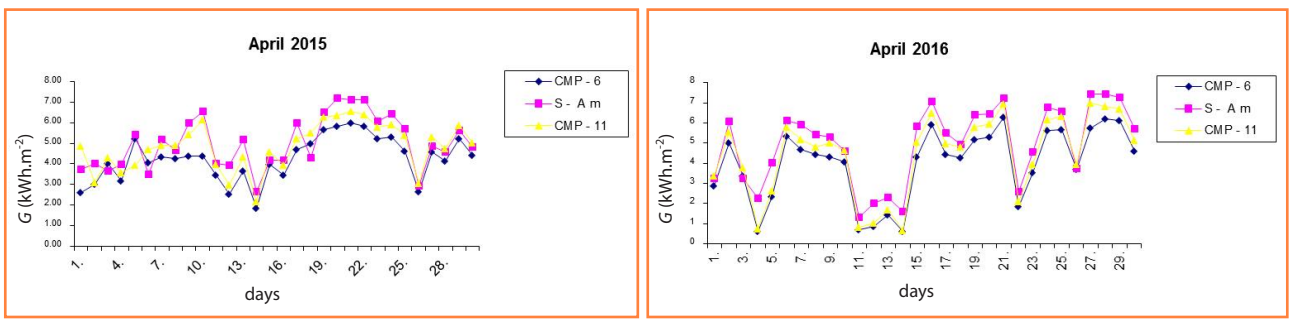

Fig. 5–6 Comparison of global radiation course measured with the CMP 6, CMP 11 and the Savin-Angström calculation method (April; 2015, 2016)

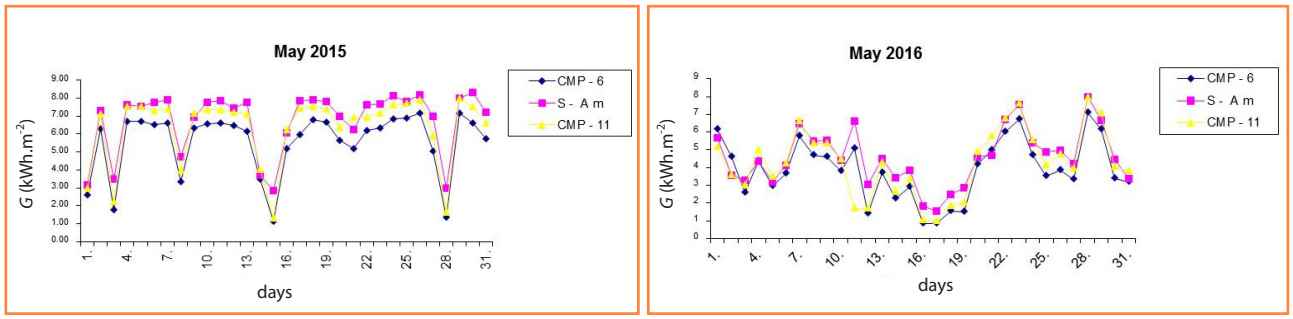

Fig. 7–8 Comparison of global radiation course measured with CMP 6, CMP 11 and Savin-Angström calculation method (May; 2015, 2016)

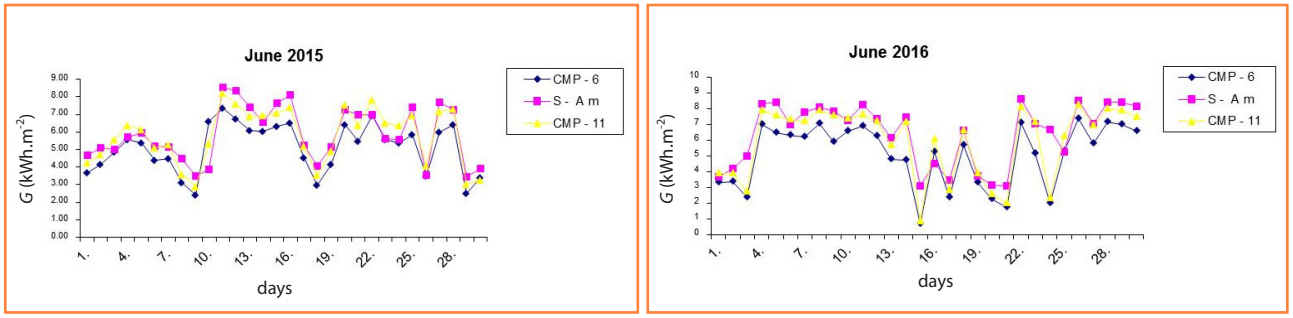

Fig. 9–10 Comparison of global radiation course measured with CMP 6, CMP 11 and Savin-Angström calculation method (June; 2015, 2016)

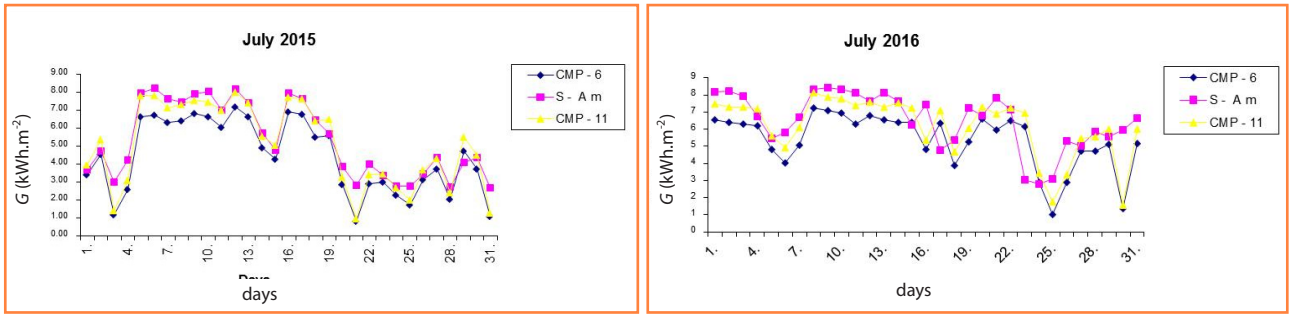

Fig. 11–12 Comparison of global radiation course measured with the CMP 6, CMP 11 and the Savin-Angström calculation method (July; 2015, 2016)

Table 2 Percentage difference of global radiation values measured by the CMP 6 sensor and the Savin-Angström method compared with the CMP 11 sensor values (2015)

Sensor	Year 2015						
	III.	IV.	V.	VI.	VII.	X.	sum
CMP 11 vs. CMP 6 (%)	16.4	19.6	21.5	17.1	19.5	20.7	19.1
CMP 11 vs. S-A (%)	7.1	5.6	6.4	2.1	4.2	12.3	6.3

Table 3 Percentage difference of global radiation values measured by the CMP 6 sensor and the Savin-Angström method compared with the CMP 11 sensor values (2016)

Sensor	Year 2016						
	III.	IV.	V.	VI.	VII.	X.	sum
CMP 11 vs. CMP 6 (%)	20.1	24.5	18.2	23.6	25.1	15.8	22.2
CMP 11 vs. S-A (%)	7.1	11.2	4.8	5.3	8.7	8.6	7.6

adversum to the measured values of CMP 11 standard (Table 2 and 3). These differences may be caused by input data on sunshine. Entering value on sunshine (in hours) using the Savin-Angström methodology does not take into account the intensity of global radiation in different time period during the day.

Conclusion

To sum up, it is possible to say that in comparison with the pyranometer CMP 11, which is used within the World Meteorological Organization, the mentioned calculation method of Savin-Angström seems to be more accurate for the determination of global radiation for our geographical latitude than the measurements made using the pyranometer CMP 6.

References

ČIMO, J. et al. 2014. Biometeorológia. Nitra : SPU, 2014, 145 p. ISBN 978-80-552-1219-7.

ČIMO, J. et al. 2012. Praktická biometeorológia 1. Nitra : SPU, 2012, 201 p. ISBN 978-80-552-0771-1.

CZÉGÉNY, G. et al. 2016. UV-B effects on leaves – Oxidative stress and acclimation in controlled environments. In Plant Science, vol. 248, 2016, July, pp. 57–63.

KANUK, J. 2007. Analýza solárneho žiarenia pre urbánne územia. In Zborník zo VIII. vedeckej konferencie doktorandov a mladých vedeckých pracovníkov, Nitra : UKF, 2007. ISBN 978-80-8094-106-2.

MEZA, F. – VARAS, E. 1999. Estimation of mean monthly solar global radiation as a function of temperature. In Agricultural and Forest Meteorolog, Elsevier, 1999, pp. 231–241. Dostupné na: <https://pdfs.semanticscholar.org/9572/744d791c1f4966c4ffdea920eaecd2e6e7b4.pdf>

ŠPÁNIK, F. et. al. 2009. Agroklimatické hodnotenie krajiny a základy agroklimatickej rajonizácie. Nitra : SPU, 2009, 88 p. ISBN 978-80-552-0236-5.

ŠPÁNIK, F. – TOMLAIN, J. 1983. Časové rozloženie slnečnej energie a možnosti jej využívania v poľnohospodárskych oblastiach ČSSR. Nitra – Bratislava : OVHZM ČSAZ, 1983.

SUNITA, K. et al. Impact of increasing Ultraviolet-B (UV-B) radiation on photosynthetic processes. In Journal of Photochemistry and Photobiology B: Biology, vol. 137, 2014, August, pp. 55–66.

sciendo

DOI: 10.2478/ahr-2018-0007

Acta Horticulturae et Regiotecturae 1/2018 *Marcel Golian et al.*

Acta Horticulturae et Regiotecturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2018, pp. 25–29

THE EFFECT OF SODIUM SELENATE APPLICATION ON GROWTH OF THE FRUITING BODIES IN THE FIRST FLUSH OF MUSHROOM *PLEUROTUS OSTREATUS* (JACQ.) P. KUMM

Marcel GOLIAN[1]*, Alžbeta HEGEDŰSOVÁ[1], Marianna TROCHCOVÁ[2], Eva SZABOVÁ[1], Ondrej HEGEDŰS[3]

[1]Slovak University of Agriculture in Nitra, Slovak Republic
[2]Central Control and Testing Institute in Agriculture in Bratislava, Slovak Republic
[3]Regional Public Health Authority Nitra, Slovak Republic

Pleurotus spp. is in the top three of the most widely grown mushrooms in the world production. It is known that mushrooms are able to accumulate most of the substances found in the culture medium very well. Selenium is a significant antioxidant and plays a very important role in the prevention of various types of diseases. This paper points to the possibility of enriching the culture medium of *Pleurotus ostreatus* (Jacq.) P. Kumm. with inorganic selenium. The aim is to obtain a biologically active food applicable to wide population nutrition. Using such foods as nutraceuticals can make a significant contribution to the positive influence of human health.

Keywords: *Pleurotus ostreatus*, nutraceutical, selenium, fortification

Selenium (Se) is an essential element with antioxidant effects. It is an important component of several major metabolic reactions, including synthesis of thyroid hormones, antioxidant defense systems and immune functions (Kohrle and Gartner, 2009; Gandhi et al., 2013). The essentiality of selenium was demonstrated in 1957 (Hegedűs et al., 2006; Hegedűs et al., 2007). In 1976, the necessity of selenium for humans was proven, despite the fact that its negative effects were highlighted previously (Hegedűs et al., 2008; Jakabová et al., 2008; Jakabová et al., 2009). Selenium is effective at low concentrations in heavy metal poisoning such as mercury and arsenic (Ralston and Raymond, 2010). The World Health Organization's report recommends taking 55–65 μg selenium per day. This dose is necessary to ensure the optimal functioning of the adult human organism. The upper limit of the daily dose for adults is 400 μg (FAO/WHO, 2002). Mushrooms as a part of food can have antioxidant effects related to the selenium and phenolic compounds content (Werner and Beelman, 2002; Beelman and Royse, 2006; Wong and Chye, 2009). Cultivation of saprophytic fungi on substrates rich in selenium may be an effective means of producing food with built-in selenium. Selenium plays an important role in the functioning of the catalytic center of several selenoproteins (Rayman, 2000). It is the only trace element identified in the genetic code as selenocysteine (Sec), which was recognized as the 21th amino acid (Rayman, 2002).

Oyster mushroom occurs mainly in European forests, where it is completely autochthonous. Production period is from the end of summer, through autumn till winter. These edible fungi can sometimes be found through to cold months of January and February. Oyster mushroom is a pleasant, slightly spicy mushroom (O'Reilly, 2011). Oyster mushroom was first scientifically described in 1775 by the Dutch naturalist Nikolaus Joseph Freiherr von Jacquin (1727–1817), under the name Agaricus ostreatus. It is a fungus with variable size, shape and colour. There are a lot of strains in the world; therefore, the identification of this species is relatively difficult. In practice, there are most common cross-species and bred strains of native species, which differ from wild strains mainly in the growth rate of fruiting bodies, yields, and other specific properties. For successful mass production, it is essential for a farmer himself/herself to realize that oyster mushroom grows in situ on wood, above ground, in damp and light conditions, predominantly in deciduous forests (Kurtzman, 2014).

Material and methods

Biological material

Oyster mushroom strain KRYOS B was provided from the Department of Horticulture, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences in Prague. Nowadays, this model strain is commonly used in mass production.

Selection of selenium concentration levels

Concentrations of selenium were derived from the results of the research tasks, which were solved at the Department of Vegetables Production of the Horticulture and Landscape

Contact address: Ing. Marcel Golian, PhD., Slovak University of Agriculture, Faculty of Horticulture and Landscape Engineering, Department of Vegetable Production, Tr. Andreja Hlinku 2, 949 76 Nitra, Slovak Republic, tel.: +421 37 641 43 22, e-mail: marcel.golian1@gmail.com

Engineering Faculty of the Slovak University of Agriculture in Nitra. The required dose of sodium selenate for the preparation of the fortification solutions with 0.5 mg.dm^{-3} Se, 1.0 mg.dm^{-3} Se and 2.0 mg.dm^{-3} Se was calculated. Growth of oyster mushroom at selected selenium concentrations was verified in partial experiments on agar nutrient medium before the main experiment was established. The ability of radial growth of mycelium was evaluated optically.

Establishment of experiments to produce oyster mushroom fruiting bodies

Mushroom production was based on controlled cultivation conditions in the premises of The AgroBioTech Research Centre, in the Laboratory of Explant Cultures headed by Ing. Filová, PhD., in two cultivation periods. In accordance with existing knowledge, the production of mushrooms proceeded in the following phases:

- inoculum preparation,
- preparation of the substrate pasteurization, 48 hours at 25 °C, then 24 hours at 60 °C),
- inoculation by inoculum and incubation (mycelium substrate growth) at 25 °C about 2 weeks,
- initiation of the fruiting bodies at 11 °C for one day,
- fructification (12 hours, 16 °C in dark and 12 hours, 16 °C under light).

During all phases there was ensured optimal cleanliness of production premises, tools and equipment, personal hygiene, optimal relative air humidity and CO_2 content. The experiment consisted of 4 variants, each variant had 10 repetitions. The whole experiment was carried out in two cultivation periods in the following terms:

1. First cultivation period – from 4 April 2016 to 26 May 2016.
2. Second cultivation period – from 9 June 2016 to 27 July 2016

Created variants of experiments:

Preparation of all substrates consisted of wetting of dry straw pellets in water in a weight ratio of 1 : 2.6.

C – control – 0.0 mg.dm^{-3} Se.
X – with addition of 0.5 mg.dm^{-3} Se in the form of sodium selenate aqueous solution.
Y – with addition of 1.0 mg.dm^{-3} Se in the form of sodium selenate aqueous solution.
Z – with addition of 2.0 mg.dm^{-3} Se in the form of sodium selenate aqueous solution.

The ratios of the components in the growing substrates are given in Table 1.

Growing of fruiting bodies: The first cycle conditions: duration 12 hours, temperature 16 °C, relative air humidity 90%, dark, intense ventilation. The second cycle conditions: duration 12 hours, temperature 16 °C, relative air humidity 90%, light, intense ventilation.

Determination of selenium content

The homogenate of the lyophilized samples of fruiting bodies was mineralized in a "CEM Mars X" (microwave digestion oven). The total selenium content was determined by electrothermal atomisation (ET-AAS) with Zeeman correction on SpectrAA240FS (Varian, Mulgrave Virginia, Australia). Assay conditions: Selenium cathode lamp – current on the lamp 10 mA, wavelength 196 nm, slot width 1.0 nm. The atomizing medium was a graphite cuvette heated to 2,600 °C. The volume of the sample was 10 µl. The palladium modifier $Pb(NO_3)_2$ with a concentration of 0.1 mol.dm^{-3} was used and 1% ascorbic acid. The results were evaluated by the calibration curve method. CertiPur stock calibration solutions (Merck, Germany) had been prepared in advance with well-known concentrations of the heavy metals to be monitored. The final values of the measured parameters were subsequently obtained by software translating the calibration curve with the absorbance of the monitored analyte in the sample.

Statistical processing methods

Statgraphics Centurion XVII – multifactor analysis of variance (MANOVA, LSD test).

Results and discussion

Based on the experiments solved in collaboration with Ing. Jablonský from the Czech University of Life Sciences in Prague, we used a substrate consisting of a pelletized wheat straw, which is used as a litter for horses in practice. This substrate has a satisfactory quality and is easy to manipulate. The straw is pressed into the pellets without the addition of any binding agents. Selection of the substrate corresponds with authors such as Choi (2004), Lin (2004), Poppe (2004), Mandeel (2005), Yildiz et al. (2006) and others, who claim that wheat, barley straw and other lignocellulosic materials are ideal substrates for intensive production of oyster mushrooms.

Table 1 Ratio of components in the substrate for one growing container

Variant	Dry pellets : water : inoculum	Weight of substrate in kg	Weight of dry pellets in kg	Water volume in dm^{-3}	Weight of inoculum in kg
C	1 : 2.6 : 0.189	2	0.52	1.37	0.1
X	1 : 2.6 : 0.189	2	0.52	1.37	0.1
Y	1 : 2.6 : 0.189	2	0.52	1.37	0.1
Z	1 : 2.6 : 0.189	2	0.52	1.37	0.1

Source: author
Explanatory notes: C – 0.0 mg.dm^{-3} Se; X – 0.5 mg.dm^{-3} Se; Y – 1.0 mg.dm^{-3} Se; Z – 2.0 mg.dm^{-3} Se

Quantitative evaluation of fruiting bodies production

In the experiment there was evaluated the first flush of oyster mushroom on experimental substrates. These results were statistically processed, but did not reflect the total production potential of these substrates. The first harvests of the first flush of the first cultivation period were carried out 7 days after the start of the breeding phase, on four substrates of the variant Z (2.0 mg.dm^{-3} Se) and one substrate variant Y (1.0 mg.dm^{-3} Se). The last harvests of the first flush were carried out 14 days after the start of the breeding phase on the control variant C.

This phenomenon indirectly correlates with the findings of authors Upadhyay and Hofrichter (1993), Magae (1999), Sugimoto et al. (2001), Domondon et al. (2004), Berne et al. (2007), who worked on accelerating the formation of fruiting bodies germs and the subsequent fructification of substrates. The principle of accelerating fertility is based on the induction of a variety of stress types, which induce the mushroom to rapidly create a new population. It results from this, that by adding sodium selenate into the substrate, the fertility of the substrates may be accelerated, which agrees with the above-mentioned authors. After the first flush of the first cultivation period, substrates were removed from the cultivation boxes and moved to the botanical garden of the Department of Vegetables Production HLEF Horticulture and Landscape Engineering Faculty due to the time consuming of the experiment. The discarded substrates were regularly irrigated with a large dose of water, and the potential of the second and the third flush was monitored. It has been found that substrates are able to breed in other flushes. Parallel to the transfer of the first cultivation period substrates from the cultivation boxes, a second cultivation period was established.

In Table 2, we report the results fertility of substrates in terms of yields in the first flush per cultivation period and average for both cultivation periods.

In the first cultivation period of the experiment, it was statistically confirmed that in the control variant without selenium application the lowest average yield per substrate marked 217.46 g. The highest average yield of the first production period reached substrates in the variant Y with 1.0 mg.dm^{-3} Se, i.e. 261.44 g. In the second cultivation period, the highest yield was in the control variant C, i.e. 367.09 g of fresh fruiting bodies per substrate. The lowest yield was determined in the variant X with 0.5 mg.dm^{-3} Se (281.66 g). No statistically significant differences on average were found between the variants in both cultivation periods, the lowest yields were determined in the variant X with 0.5 mg.dm^{-3} Se (268.72 g) and the highest in the control variant C (292.28 g). If we consider the average yields without selenium application as 100% then the average yields in the variant X are lower by 16.33%, in the variant Y are lower by 3.24% and the yields in the variant Z are lower by 2.2%. On the basis of the above, we note that fortification with selenium does not have a significant effect on the height of the yield of fresh fruiting bodies in the first flush. For further research, it is advisable to verify the production potential of selenium enriched substrates under conditions of intensive production of edible mushrooms. Adebayoa et al. (2017) examined the flushes of the genus *Pleurotus*. In the case of *Pleurotus ostreatus* they found that the first flush represented 32.97% (121 g), the second 38.15% (140 g) and the third 28.88% (106 g) of the total yield 367 g. It is possible to assume that about 1/3 of the production potential was used in our conditions. In the next experiment, the production potential of the second and third flush should be evaluated.

Selenium content in the oyster mushroom fruiting bodies

The results of our experiments show that oyster mushroom is able to cumulate the inorganic form of sodium selenate, which was applied into the substrate in the form of a fortification solution. While lyophilized fruiting bodies in the control variant C in the first production period contained 0.116 μg.g^{-1} Se, in the variant Z fruiting bodies accumulated 699% more, i.e. 0.927 μg.g^{-1} Se. In each production period there was statistically confirmed the increasing accumulation of selenium in all variants, which was due to a higher concentration of fortification solution. The control variant C in the second production period contained 0.073 μg.g^{-1} Se, the variant Z accumulated 986% more Se (0.739 μg.g^{-1} Se). Similarly, on average, for both cultivation periods, the ability to accumulate selenium was statistically confirmed. We show in the Table 3 the average selenium content determined in lyophilized fruiting bodies of oyster mushroom in the first and the second production period.

The potential creation of a functional food by incorporating an inorganic selenium salt was described in 2008 by Falandysz. Our results are consistent with the

Table 2 Average yields of fresh fruiting bodies in the first flush in g

***Pleurotus ostreatus* KRYOS B**			
Variant	1. cultivation period	2. cultivation period	average
C	217.46 ±37.48a	367.09 ±46.36c	292.28 ±105.80a
X	255.78 ±43.84b	281.66 ±54.42a	268.72 ±18.30a
Y	261.44 ±31.05b	304.19 ±22.14ab	282.82 ±30.22a
Z	240.83 ±25.66ab	330.85 ±41.01bc	285.84 ±63.64a

Source: author
P <0.05 by LSD ANOVA
Explanatory notes: C – 0.0 mg.dm^{-3} Se; X – 0.5 mg.dm^{-3} Se; Y – 1.0 mg.dm^{-3} Se; Z – 2.0 mg.dm^{-3} Se according to Means and 95.0. Percent LDS Test. The values in the columns with different letters are significantly different from each other

Table 3 Average selenium content in lyophilized fruiting bodies in μg.g^{-1}

Pleurotus ostreatus KRYOS B			
Variant	1st cultivation period	2nd cultivation period	average
C	0.116 ±0.041a	0.073 ±0.006a	0.094 ±0.036a
X	0.437 ±0.069b	0.198 ±0.030b	0.318 ±0.132b
Y	0.443 ±0.069b	0.536 ±0.096c	0.489 ±0.094c
Z	0.927 ±0.185c	0.658 ±0.108d	0.793 ±0.202d

Source: author
Explanatory notes: C – 0.0 mg.dm^{-3} Se; X – 0.5 mg.dm^{-3} Se; Y – 1.0 mg.dm^{-3} Se; Z – 2.0 mg.dm^{-3} Se according to Means and 95.0. Percent LDS Test. The values in the columns with different letters are significantly different from each other

findings of the author. The ability of oyster mushroom to cumulate selenium was statistically demonstrated in both cultivation periods under model conditions. Falandysz (2008) reports that the concentration of selenium in fruiting bodies of frequently consumed edible mushrooms ranges from <1–20 μg Se.g^{-1} dry weight of fruiting bodies. However, this claim is inconsistent with our findings. The reality can be explained by the diverse chemical composition of the growing substrates. When cultivating mushrooms on crop residues from agricultural production from geographic locations with selenium contaminated soils, its built-up content is significantly higher in these substrates and hence also in mushrooms. The good availability of the thus incorporated selenium has been confirmed by Da Silva et al. (2012) and Rayman et al. (2007).

Bhatia et al. (2013) found that the content of selenium in saprophytic mushrooms grown on commonly available wheat straw with moderately low selenium content (according to Oldfield, 1999; Spadoni et al., 2007) is at the level of wild mushrooms, i.e. 0.12–3.4 μg Se.g^{-1} weight of the dried mushrooms *Pleurotus ostreatus*. The claim is consistent with our results. According to Kalac (2009) and Falandysz (2008), this value is similar to the selenium content of the commonly sold button mushrooms. Likewise, Da Silva et al. (2012), Estrada et al. (2009) and Wang et al. (2005) in their papers reported that mushrooms of the genus *Pleurotus* are able to accumulate selenium well. We fully agree with the statements, and the fact is confirmed in our model experiment.

Cubadda et al. (2010) investigated the ability of edible mushroom *Pleurotus florida* to cumulate selenium. They found that this mushroom is able to quickly mobilize and accumulate selenium from the substrate. Fruiting bodies yielded in the control variant without enrichment with selenium contained 0.17 μg Se.g^{-1} in the dry mass, while the fruiting bodies growing on the substrate enriched with large amount of inorganic selenium contained 800 times more Se (141 μg Se.g^{-1}) in a sample of dried mushrooms. The authors do not detail the concentration level of the used fortification solutions, but their findings correspond to the conclusions of our work.

Gąseckaa et al. (2015) reported that the concentration of selenium in the control samples of oyster mushroom fruiting bodies (without added selenium) was 2.54 ±0.22 μg Se.g^{-1} dry weight in their experiment. This assertion is inconsistent with our results, because the samples presented in the control variant of our experiment contain 2 602% less selenium (0.094 μg Se.g^{-1}) in the dry matter. This feature is probably caused by the diversity of the growing substrates, i.e. by growing on the substrates rich in selenium. The authors note that the next addition of selenium into the substrate led to an increase its accumulation in fruiting bodies. It follows that by increasing the selenium content in the substrate, the ability of its accumulation with an edible fungi increase. However, it should be pointed out that the accumulation potential can vary greatly between species and strains of mushrooms.

Conclusion

In this work there was verified the possibility of fortification of the world's third most-cultivated fungus with selenium, which is an essential element in small quantities. In the first step, an optimal lignocelluloses substrate for the production of oyster mushroom was chosen, which is suitable for easy handling, is well-storable and has a high sorption capacity. In the second step there was verified the ability of oyster mushroom to colonize the agar nutrient media at selected selenium concentration levels. It was confirmed that none of the selected solution concentrations was lethal to oyster mushrooms. The main experiment showed that the fortification of the cultivation substrate of oyster mushroom in the first flush had no negative effect on yields of the fresh fruiting bodies. On the contrary, it was found that fortified substrates initiated fruiting bodies production, thus shortening the time required for growing. Final analyzes confirmed that oyster mushroom has a high potential for selenium accumulation. It can therefore serve as a tasty, biologically active foodstuff with a positive effect on human health of wide population.

Acknowledgement

The work was supported by VEGA project No. 1/0087/17.

References

ADEBAYOA, E.A. – OLOKEA, J.K., – AZEEZA, M.A., – OMOMOWOA, I.O. 2017. Assessment of the genetic diversity among ten genotypes of *Pleurotus* (oyster mushroom) using nutrient and mineral compositions. In Scientia Horticulturae, vol. 166, 2017, pp. 59–64. http://dx.doi.org/10.1016/j.scienta.2013.12.010

BEELMAN, R.B. – ROYSE, D.J. 2006. Selenium enrichment of *Pleurotus cornucopiae* (Paulet) Rouant and *Grifola frondosa* (Dicks: Fr.) S.F. gray mushrooms. In Int J Med Mushr, vol. 8, 2006, pp. 1–8.

BERNE, S. – POHLEVEN, J. – VIDIC, I. – REBOLJ, K. – POHLEVEN, F. – TURK, T. – MAČEK, P. – SONNENBERG, A. – SEPČIC, K. 2007. Ostreolysin enhances fruiting initiation in the oyster mushroom (*Pleurotus ostreatus*). In Mycological Research, vol. 111, 2007, pp. 1431–1436.

BHATIA, P. – AURELI, F. – D'AMATO, M. – PRAKASH, R. – CAMEOTRA, S.S. – NAGARAJA, T.P. – CUBADDA, F. 2013. Selenium bioaccessibility and speciation in biofortified *Pleurotus* mushrooms grown on selenium-rich agricultural residues. In Food Chemistry, vol. 140, 2013, no. 1–2, pp. 225–30. http://doi.org/10.1016/j.foodchem.2013.02.054

CUBADDA, F. – AURELI, F. – CIARDULLO, S. – D'AMATO, M. – RAGGI, A. – ACHARYA, R. 2010. Changes in selenium speciation associated with increasing tissue concentrations of selenium in wheat grain. In Journal of Agricultural and Food Chemistry, vol. 58, 2010, no. 4, pp. 2295–2301.

DA SILVA, M.C.S. – NAOZUKA, J. – DA LUZ, J.M.R. – DE ASSUNCAO, L.S. – OLIVEIRA, P.V. – VANETTI, M.C.D. 2012. Enrichment of *Pleurotus ostreatus* mushrooms with selenium in coffee husks. In Food Chemistry, vol. 131, 2012, no. 2, pp. 558–563.

DOMONDON, D.L. – HE, W. – DE KIMPE, N. – HOFTE, M. – POPPE, J. 2004. b-Adenosine, a bioactive compound in grass chaff stimulating mushroom production. In Phytochemistry, vol. 65, 2004, pp. 181–187.

ESTRADA, A.E.R. – LEE, H.J. – BEELMAN, R.B. – JIMENEZ-GASCO, M.D. – ROYSE, D.J. 2009. Enhancement of the antioxidants ergothioneine and selenium in *Pleurotus eryngii* var. *eryngii* basidiomata through cultural practices. In World Journal of Microbiology & Biotechnology, vol. 25, 2009, no. 9, pp. 1597–1607.

FALANDYSZ, J. 2008. Selenium in edible mushrooms. In Journal of Environmental Science and Health Part C-Environmental Carcinogenesis & Ecotoxicology Reviews, vol. 26, 2008, no. 3, pp. 256–299.

FAO/WHO. 2002. Human vitamin and mineral requirements. Report of a joint FAO/WHO consultation, Bangkok, Thailand. Food and Agriculture Organization of the United Nations (FAO).

GANDHI, U.H. – NAGARAJA, T.P. – PRABHU, S.K. 2013. Selenoproteins and their role in oxidative stress and inflammation. In Curr Chem Biol., vol. 7, 2013, pp. 65–73.

GĄSECKAA, M. – MLECZEK, M. – SIWULSKIB, M. – NIEDZIELSKIC, P. – KOZAKC, L. 2015. The effect of selenium on phenolics and flavonoids in selected edible white rot fungi. In LWT – Food Science and Technology, vol. 63, 2015, no. 1, pp. 726–731.

HEGEDŰS, O. – HEGEDŰSOVÁ, A. – JOMOVÁ, K. – VARGOVÁ, A. – ŠIMKOVÁ, S. 2006. Problematika obsahu a zachovania selénu pri pestovaní kultúrnych rastlín. In Chemické listy, vol. 100, 2006, pp. 731–732. ISSN 0009-2770.

HEGEDŰS, O. – HEGEDŰSOVÁ, A. – ŠIMKOVÁ, S. 2007. Selén ako biogénny prvok. Nitra : UKF, 2007, 76 p. ISBN 978-80-8094-168-0.

HEGEDŰS, O. – HEGEDŰSOVÁ, A. – ŠIMKOVÁ, S. – PAVLÍK, V. – JOMOVÁ, K. 2008. Evaluation of the ET-AAS and HG-AAS methods of selenium determination in vegetables. In J. Biochem. Biophys. Methods, vol. 70, 2008, pp. 1287–1291. ISSN 0165-022X.

CHOI, Z.W. 2004. Shelf cultivation of oyster mushroom. Oyster mushroom cultivation. In Mushroom Grower's Handbook 1, 2004, pp. 192–196.

JAKABOVÁ, S. – HEGEDŰS, O. – HEGEDŰSOVÁ, A. 2009. Effect of agronomic biofortification on selenium content in *Pisum sativum* L. In Acta fytotechnica et zootechnica, vol. 12, 2009, pp. 246–253. ISSN1335-258X.

JAKABOVÁ, S. – HEGEDŰS, O. – HEGEDŰSOVÁ, A. – VARGOVÁ, A. 2008. Biofortifikácia hrachu záhradného selénom. In Chemické listy, vol. 102, 2008, 753 p. ISSN 0009-2770.

KALAC, P. 2009. Chemical composition and nutritional value of European species of wild growing mushrooms: A review. In Food Chemistry, vol. 113, 2009, no. 1, pp. 9–16.

KOHRLE, J. – GARTNER, J. 2009. Selenium and thyroid. In Best Pract Res Clin Endocrinol, 2009, pp. 815–827.

KURTZMAN, R. 2014. El Porque y el como en el cultivo del hongo ostra: una Perspectiva Mundial, [online] 2014, Hacia un desarrollo sostenible del sistema de producción: Avances y perspectivas en el Siglo, [cit. 10.1.2018]. Dostupné na internete: http://www.cabdirect.org/abstracts/20113162462.html;jsessionid=BCD1FB845EC9AF78A3334D59DC34C38D. ISBN 970-9752-01-4.

LIN, Z. 2004. Grass (Juncao). Oyster mushroom cultivation. In Mushroom Grower's Handbook 1, 2004, pp. 192–196.

MAGAE, Y. 1999. Saponin stimulates fruiting of the edible Basidiomycete *Pleurotus ostreatus*. In Bioscience, Biotechnology and Biochemistry, vol. 63, 1999, pp. 1840–1842.

MANDEEL, Q. 2005. Cultivation of oyster mushrooms (*Pleurotus* spp.) on various lignocellulosic wastes. In World J. Microbiol. Biotechnol., vol. 21, 2005, pp. 601–607.

OLDFIELD, J.E. 1999. Selenium world atlas. Selenium-Tellurium Development Association.

OOI, V.E.C. 1996. Hepatoprotective effect of some edible mushrooms. In Phytotherapy Res., vol. 10, 1996, pp. 536–538.

O'REILLY, P. 2011. Fascinated by Fungi, Fist Nature. [online] 2011. [cit. 10.1.2018]. Dostupné na internete: http://www.first-nature.com/fungi/pleurotus-ostreatus.php

POPPE, J. 2004. Agricultural Wastes As Substrates for Oyster Mushroom. In Mushroom Growers' Handbook, 2004, 11 p.

RALSTON, N.V. – RAYMOND, L.J. 2010. Dietary selenium's protective effects against methylmercury toxicity. In Toxicology, vol. 278, 2010, pp. 112–123.

RAYMAN, M.P. 2000. The importance of selenium to human health. In Lancet, vol. 356, 2000, no. 9225, pp. 233–241.

RAYMAN, M.P. 2002. The argument for increasing selenium intake. In Proceedings of the Nutrition Society, vol. 61, 2002, no. 2, pp. 203–215.

RAYMAN, M.P. – ANGUS, F. – GOENAGA-INFANTE, H. 2007. Bioavailability and speciation of selenium from selenium – enriched mushrooms. In Proceedings of the Nutrition Society, vol. 66, 2007, 55 p.

SPADONI, M. – VOLTAGGIO, M. – CARCEA, M. – CONI, E. – RAGGI, A. – CUBADDA, F. 2007. Bioaccessible selenium in Italian agricultural soils: Comparison of the biogeochemical approach with a regression model based on geochemical and pedoclimatic variables. In Science of the Total Environment, vol. 376, 2007, no. 1–3, pp. 160–177.

SUGIMOTO, H.H. – BARBOSA, A.M. – DEKKER, R.F.K. – CASTRO-GOMEZ, R.J. 2001. Veratryl alcohol stimulates fruiting body formation in the oyster mushroom, *Pleurotus ostreatus*. In FEMS Microbiology Letters, vol. 194, 2001, pp. 235–238.

UPADHYAY, R.C. – HOFRICHTER, M. 1993. Effect of phenol on the mycelial growth and fructification in some of basidiomycetous fungi. In Journal of Basic Microbiology, vol. 33, 1993, pp. 343–347.

WANG, J.C. – HU, S.H. – LIANG, Z.C – YEH, C.Y. 2005. Optimization for the production of water-soluble polysaccharide from *Pleurotus citrinopileatus* in submerged culture and its antitumor effect. In Appl. Microbiol. Biotechnol., vol. 67, 2005, pp. 759–766.

WERNER, A.R. – BEELMAN, R.B. 2002. Growing high-selenium edible and medicinal button mushrooms (*Agaricus bisporus* (J.Lge) Imbach) as ingredients for functional foods or dietary supplements. In Int J Med Mushrooms., vol. 4, 2002, pp. 167–171.

WONG, J.Y. – CHYE, F.Y. 2009. Antioxidant properties of selected tropical wild edible mushrooms. In J Food Comp Anal., vol. 22, 2009, pp. 269–277.

YILDIZ, S. – GEZER, E.D. – YILDIZ, U.C. – TEMIZ, A. – DIZMAN, E. 2006. Effects of different substrate combinations on mycelial growth of *Pleurotus ostreatus*. Proceedings of the Fifth International Conference on Mushroom Biology and Mushroom Products, Shanghai, PR China, 2006, 551 p.