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THE POPLAR SAPLINGS SURVIVAL IN RECLAIMED MINELAND DEPENDING ON CLONE AND ROOT TREATMENT

SUMMARY

The genus *Populus L.* is one of the promising energy plants for growing on marginal lands. To assess its potential under steppe conditions, growth morphological parameters of 9 hybrid poplar clones grown over two years on a mix of loess-like loam and red-brown clay have been studied. In the first year, the degree of the sapling survival and the intensity of development were explored. At the end of the year, two clones which showed the best results (Ijzer-5 and Robusta), were selected for further breeding and rearing. Researches of the second year were devoted to the effect of biological agents on the survival and growth of these two clones. The treatments with vermicomposting extract (VCE), trichodermin, mycorrhiza and mixture of these agents were applied. The experiment with poplar clones Ijzer-5 showed a positive effect of all bioagents on the growth morphological parameters. The increase of the length and diameter of an annual shoots, leaf area and total assimilation surface from 10 to 38% was revealed. The treatment with vermicomposting extract gave the best result. For clones Robusta, only three agents out of four had a positive effect. The rise in morphological parameters was at the level of 9-55%. The best results were noted in the experiment with a mixture of agents. Treatment with trichodermin caused an inhibitory action on most of the growth characteristics of the clone Robusta.

To obtain the wood thermal stability information a comparative thermogravimetric analysis of poplar wood samples grown on different soil types was carried out. A larger value of DTG at all stages was observed in a sample of poplar grown on sod podzolic soil. The difference in the value of the rate of mass loss is explained by the larger content of humus in sod podzolic soils, than in the phytomeliorated mix of rocks.

Keywords: poplar, reclaimed mineland, survival, growth parameters, biological agents, thermogravimetry.

INTRODUCTION

In the modern world the issue of renewable energy production is becoming more urgent. By this time, many agricultural plants are successfully grown as bioenergy crops. However, to obtain high yields of agricultural plants sufficiently

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fertile soils are needed, the stock of which is limited. Therefore, the most expedient is to search for bioenergy species that can successfully grow on marginal areas and produce sustained yields.

The genus *Populus* L. can be attributed to such plants. This is a fast-growing woody energy plant, which makes it possible to create high-productive plantations with a long service life. The energy poplar is predominately grown by two technologies: short rotation system and medium rotation system (Bouriaud *et al.,* 2015; Cizcova *et al.,* 2010). Such short- and medium rotation coppice systems the first harvests take place after 4-5 years of cultivation and subsequently every 2-3 year intervals. The poplar productivity on fertile soils can reach 20 t/ha. The life time of energy poplar plantation is 15-20 years. (Klasnja *et al*., 2012; Karacic *et al.*, 2006). There are poplar unpretentiousness data to the soil fertility and the possibility of its cultivation in marginal lands, although the biomass productivity in these cases is much less - from 6 to 11.5 t / ha. Nevertheless, it is noted that irrigation and fertilization contribute to yield increase. (Stolarski *et al.,* 2014; Benetka *et al.*, 2007). The genetic component of plants has a great importance in determining their adaptive potential, and success of growing in specific conditions. (Kutsokon *et al.,* 2014; Panacci *et al.,* 2009; Labrecque and Teodorescu, 2005). At the same time, demonstrable indicators of promising poplar clones can be growth morphological parameters, the assimilation surface area, the photosynthesis rate and overall productivity (Ma *et al.,* 2015; Andrasev and Roncevic, 2008; Marron *et al.*, 2007). In Ukraine, by this time there is a successful experience of hybrid poplar cultivating for bioenergy purposes under conditions of the Polissya and Forest-Steppe region (Shylin, 2016; Odarchenko and Maurer, 2016; Geletukha *et al.,* 2014). The availability issue of growing this crop in the steppe zone is still open and requires a thorough consideration.

Controlled pyrolysis of woody biomass is a major means for the production of gaseous or solid fuel or a source of raw materials for chemical synthesis. Thermal stability of wood is an important characteristic to the understanding this process (Slopiecka *et al.* 2011; Zhang *et al*, 2010). The matter of structural soil component influence on this parameter has been poorly studied and needs to be investigated.

The objective of this study was to estimate in the micro-field experiments the poplar saplings survival degree depending on clone and root treatment.

MATERIAL AND METHODS

This research was carried out under Ukraine steppe zone conditions in the land reclamation station of DSAEU (Dnipropetrovsk State Agrarian and Economic University) in the Pokrov city (south of Ukraine) for two years (2016-2017). At the first stage all 9 poplar clones saplings were grown in the sod podzolic soil at the Boyarska Forest Research Station of NULES (National University of Life and Environmental Sciences) situated in the north of Ukraine.

In the spring of 2016, cuttings of 9 hybrid poplar clones have been planted on experimental plots (Table 1).

Table 1: Objects and their parentage

Clonal names	**Parentage**	**Sex**
Blanc du Poitou	Populus × euroamericana (Dode) Guinier	M
Dorskamp	Populus × euroamericana	M
Ghoy	Populus deltoides Bartr. Ex Marsh × Populus nigra L.	M
Marilandica	Populus × euroamericana	F
Robusta	Populus nigra var. plantierensis × Populus deltoides ssp. angulata Henry	M
Heidemij	Populus × euroamericana	M
Ijzer-5	Populus × euroamericana	M
Tardif de Champagne	Populus × euroamericana	M
Vereecken	Populus nigra	M

In the first year, the survival degree of the saplings and their development intensity were studied. At the end of the year, the clones that showed the best results were selected for further reproduction and cultivation. Researches of the second year were devoted to the effect of biological agents on the survival and growth of the clones, which was picked out last year. The plot substrate in reclaimed mineland was a mixture of loess-like loam and red-brown clay, which had passed through a long-term phytomelioration stage. The humus content in the substrate is about 1.5% (Kharytonov, 2007). The ratio of humic and fulvic acids was 0.2-0.5, which indicates a weak humus accumulation and active destruction of the soil mineral part. The main minerals of rocks silty fraction consist of feldspar, calcite, hydro mica, montmorillonite, chlorite and kaolinite. The near reserve of mobile phosphorus is represented by its medium-accessible forms (Kharytonov and Resio Espejo, 2013). In the spring of 2017, four variants of the experiment were laid: treatment with vermicomposting extract (VCE), trichodermin, mycorrhiza and mixture of these three agents. The choice of these agents was justified by their role in improving the soil nutrition regime (Kharytonov et al., 2009). Before planting in the substrate, the saplings were soaked, and after planting, they were irrigated with an aqueous solution of VCE in a ratio of 1: 100. In the same way and in identical ratio the trichodermin preparation was used. In the variant with mycorrhiza, the roots of the saplings before planting were dipped into a suspension. The dilution was 1 g for two saplings. Growth indicators were assessed by morphometric parameters. The plant height and length of the annual shoots were measured by a tape measure, the shoot diameter by a caliper. The leaf area was determined by scanned image using a computer program AreaS 2.1. The dry weight of the leaf and the leaf mass per area (LMA) were identified as well.

To obtain the wood thermal stability information a comparative thermogravimetric analysis of poplar wood samples grown on different soil types was carried out. The analysis was performed using the derivatograph Q-1500D of the "F. Paulik-J. Paulik-L. Erdey" system. Differential mass loss and heating effects were recorded. The results of the measurements were processed with the software package supplied with the device. Samples of annual wood were analyzed dynamically at a heating rate of 10 ° C / min in an air atmosphere. The mass of samples is 100 mg. The reference substance was aluminum oxide. The received data were analyzed statistically using the software package StatGraphics Plus5 with all tests of significance being made at a type 1 error rate of 5%.

RESULTS AND DISCUSSION

The survival percentage of 9 poplar clone saplings planted in 2016 was very different between varieties (Figure 1).

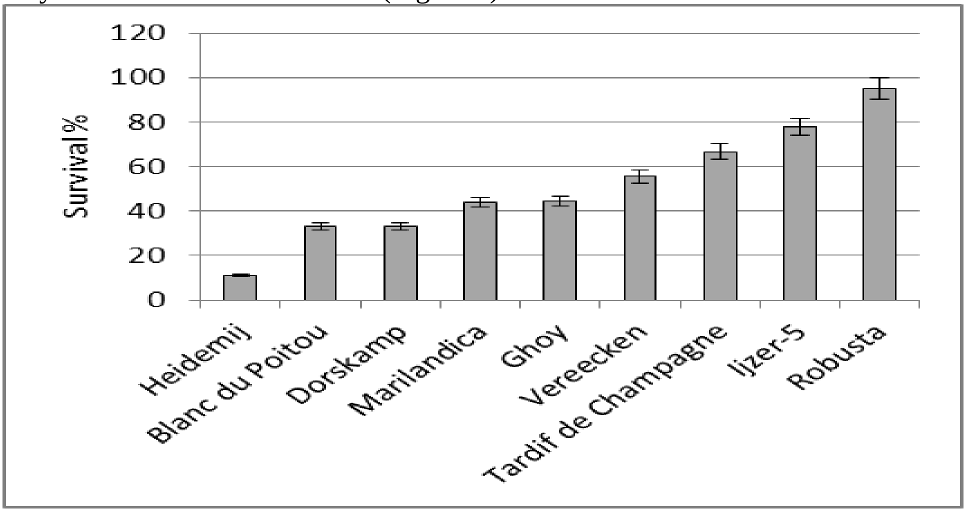

Figure 1. Survival of poplar clones on marginal soils, %.

The worst indicators were observed for the clone Heidemij - only 11%. Clones Tardif de Champagne, Ijzer-5 and Robusta showed a high level of survival (70, 80 and 95%, respectively). For the rest clones, this index varied in the range of 33-55%. During the growing season processes of plant growth and development passed in the best way for the clones Ijzer-5 and Robusta (Figure 2). By the end of the year the average height of these plants was 80-93 cm, and some specimens reached 170 cm. Clone Dorskamp also showed good growth rates, but bad survivability does not give grounds for the expediency of its further cultivation on marginal soils. The clone Tardif de Champagne, despite the good sapling survival, showed a low growth rate and therefore also lacks a good potential. Thus, according to the results obtained in the first year of cultivation, two clones - Ijzer-5 and Robusta - were evaluated as the most promising and selected for further research. Researches of the second year were devoted to the effect of biological agents on the survival and growth of these two clones. It was revealed that the sapling survival rate of both clones in the control, experiments with vermicomposting extract, mycorrhiza and a mixture of agents was practically the same and amounted to 87-93%.

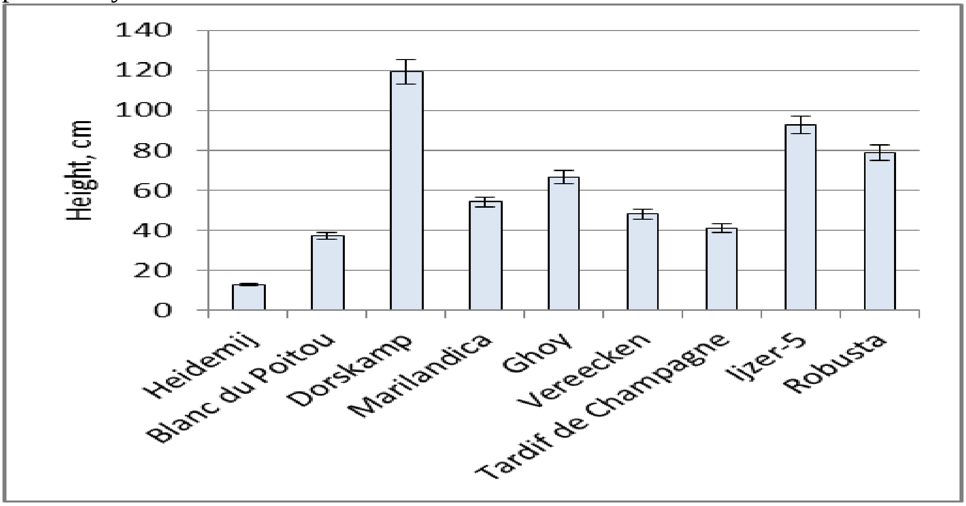

Figure 2. The height of poplar clones at the end of the first year grown on reclaimed mineland

Treatment with trichodermin had a supressive action, as a result of which the survival of clones Ijzer-5 was 73%, and of clones Robusta was even lower - 66.7%. The year 2017 was more drought-ridden than the year 2016. The total amount of precipitation for March-October was only 260 mm against 383 mm in 2016. This affected the experimental plants. Indeed, growth rates were lower than in the previous season. For example, the length of an annual shoots did not overtopped 60 cm. Treatment of clones Ijzer-5 with biopreparations promoted growth acceleration of all experimental specimens by 10-19%. The clone Robusta responded to the influence of biopreparations by growth intensification from 8.5 to 46%. Only treatment with trichodermin had no effect on this parameter (Figure 3).

Measurements of the annual shoot diameter showed that in the clone Ijzer-5 it is 22-30% higher than in the clone Robusta in the control plot and experiments with vermicomposting extract, mycorrhiza and trichodermin, and 4.5% less in the experiment with the mixture of agents. Treatment with biopreparations stimulated the activity of annual shoot lateral meristems in all experimental variants in both clones. The treatment with vermicomposting extract gave the best result for the clone Ijzer-5, and for clone Robusta in the experiment with a mixture of agents (Figure 4).

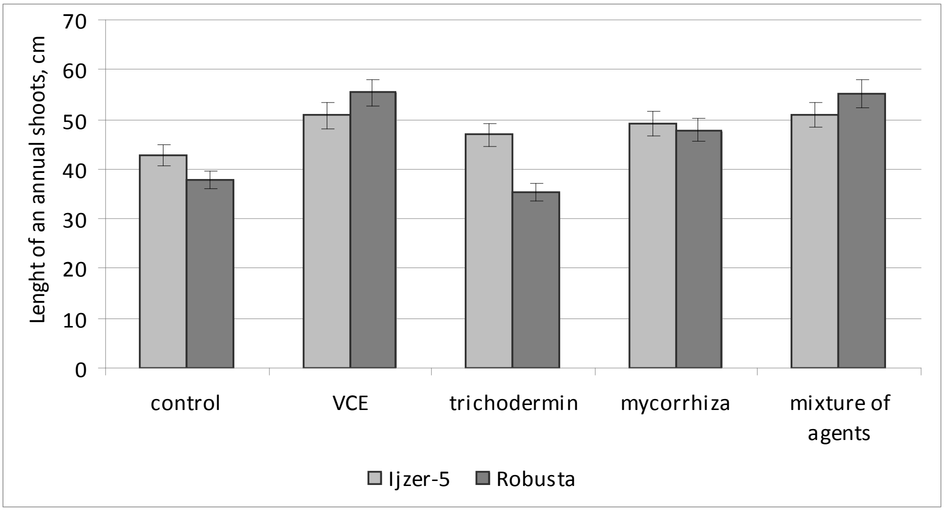

Figure 3. The length of an annual shoots of poplar clones grown on reclaimed mineland in 2017

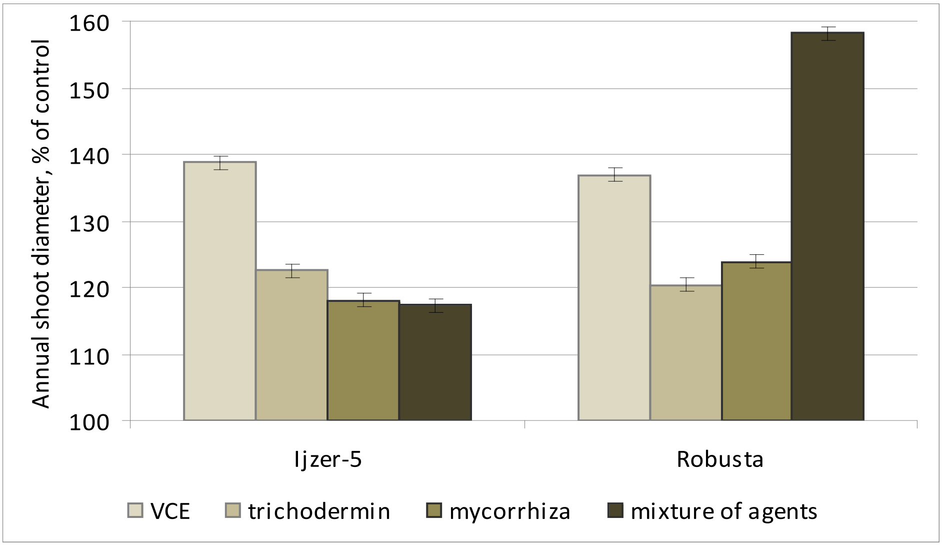

Figure 4. Diameter of annual shoots of poplar clones grown on reclaimed mineland in 2017, % of control

For clone Ijzer-5 an increase of the leaf area in all experiment variants was observed from 19.5 to 38%. The treatment with trichodermin had the greatest impact. In clone Robusta, quite the contrary, trichodermin caused a decrease in leaf area by 25% compared to the control. In other variants, an increase of this parameter was noted, but less intense than for clone Ijzer-5, only by 13.5-20.5% (Figure 5). At the same time, clone Robusta showed a higher degree of increase of the total assimilation surface area (from 20 to 55%) compared to clone Ijzer-5 (from 20 to 32%). Treatment with trichodermin was an exception. This agent had a stimulating effect only on the clone Ijzer-5 plants, whereas in the clone Robusta the total assimilation surface area decreased by 52% compared to the control. One of the attribute among the leaf structural organization is the leaf mass per area (LMA), which is the ratio between leaf dry mass and leaf area. LMA is closely correlated with the photosynthesis intensity, potential growth rates and ecological flexibility (Pugliell *et al.,* 2015; Poorter *et al.,* 2009; Wright *et al.,* 2002). Factors such as light, CO_2 concentration, water supply and mineral nutrition can significantly influence the LMA. However, since in this study these factors were the same in all variants of the experiment, it is possible to trace the impact of biopreparations on the LMA.

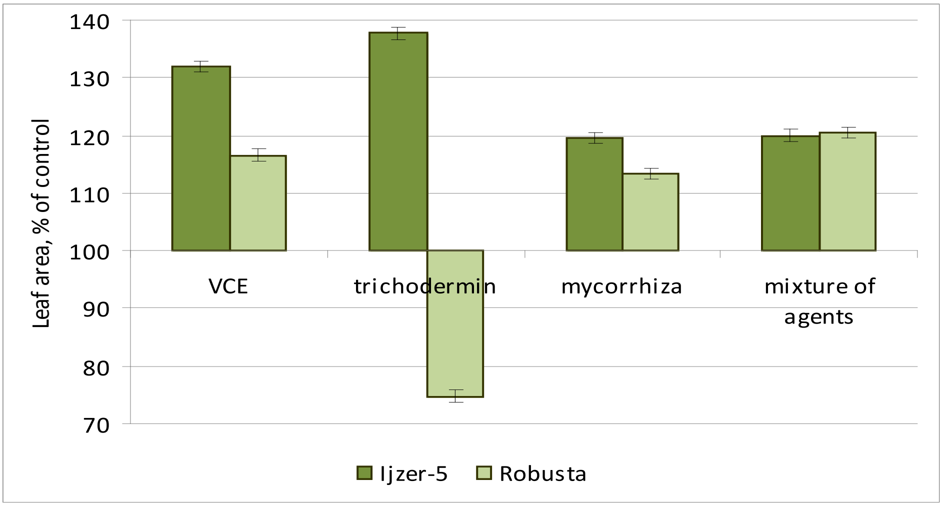

Figure 5. Change in the leaf area of poplar clones under the influence of biopreparations, % of control.

Comparison of control samples showed that LMA of the clone Ijzer-5 was 18.5% more than those of clone Robusta. Treatment with biopreparations led to an increase in this parameter for both clones in all experiment variants. However, it was insignificant for clone Ijzer-5 (6-13%), and stronger for clone Robusta (from 17 to 48%). There is a positive linear correlation between the LMA value and the leaf dry mass (Figure 6). Increase in leaf dry mass lead to increase in LMA. It can be assumed that the growth of LMA is due to the increase in mesophyll volume by formation of more quantity of structural and functional photosynthesis elements. Thus, in plants that have undergone treatment with biopreparations, photosynthetic processes are more intense. This is indirectly confirmed by their more vigorous growth and development.

The comparative thermogravimetric analysis of wood samples of poplar clones Ijzer-5, grown on plant meliorated mix of rocks and sod podzolic soil was carried out. Two curves obtained due to differential thermogravimetry (DTG) estimation are shown in the figure 7.

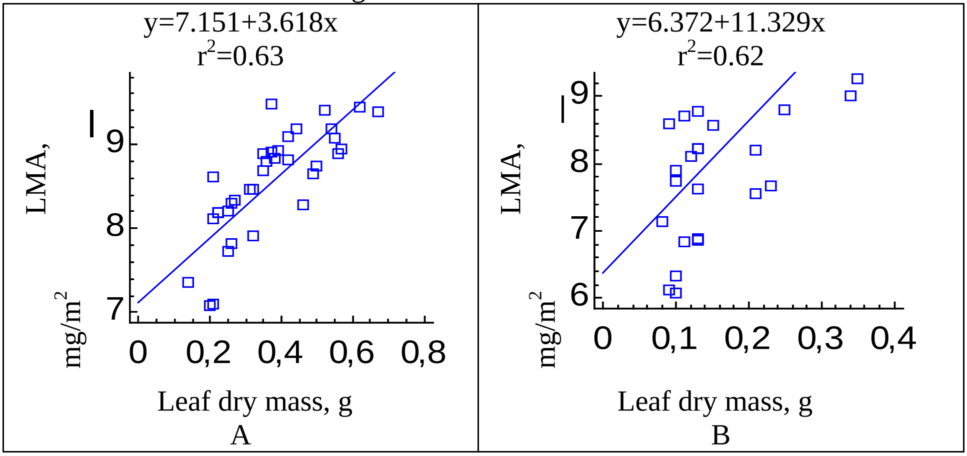

Figure 6. Relationship between LMA and leaf dry mass. Lineare regression has been calculated for the clones Ijzer-5 (A) and Robusta (B), $p \leq 0.01$

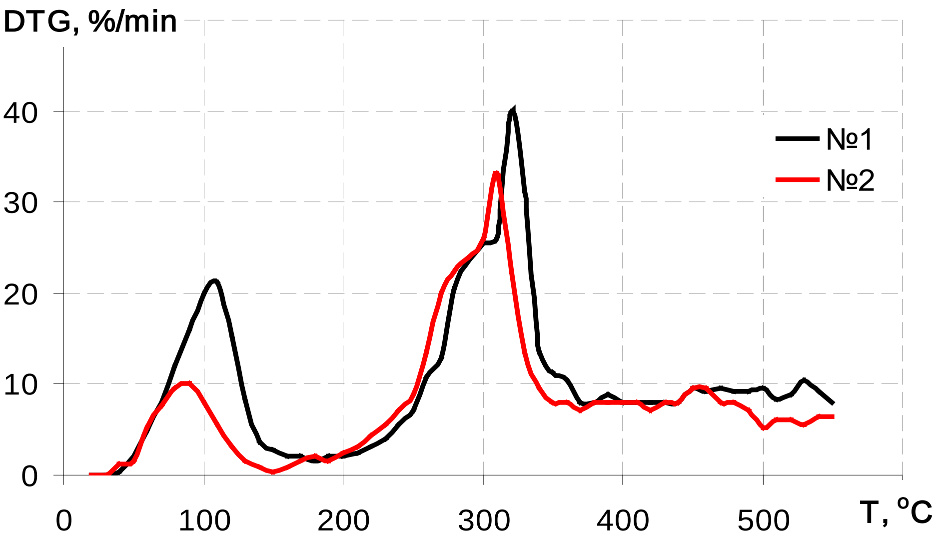

Figure 7. The results of thermogravimetric analysis of wood samples of poplar clone Ijzer-5, grown on sod podzolic soil and reclaimed mineland.
(№1 – sod podzolic soil, №2 - reclaimed mineland)

It is known that thermal decomposition of wood takes place in several stages. At the first stage of heating the wood, extraction of moisture, water adsorption and removal of volatile components take place. Further mass loss is related to hemicellulose, cellulose and lignin decomposition. At the last stage, the thermal destruction of lignin is completed and the combustion of coal formed during the thermal decomposition takes place (Loskutov *et al*, 2015; Muller-

Hagedorn *et al.*, 2003). In this study, it is distinguished three temperature ranges for the combustion of woody biomass of the poplar clones Ijzer-5 as well . The first stage of thermal destruction proceeds in a range from approximately 40°C to 150°C. The second interval is in the temperature range from 200°C to 300°C. The third stage is characterized by the highest combustion rate in the range from 300°C to 350°C. A larger value of DTG at all stages was observed in a sample of poplar grown on sod podzolic soil (1.2 times). Apparently, the difference in the value of the rate of mass loss is explained by the larger content of humus in sod podzolic soils, in comparison with the phytomeliorated mix of rocks.

CONCLUSIONS

Thus, marginal soils, together with low water supply under the steppe zone conditions, require searching for poplar clones which can to ensure high growth potential and plant biomass productivity. As a result of the research, only two clones proved to be promising for growing in such conditions. The experiment with poplar clone Ijzer-5 showed a positive effect of all bioagents on the growth morphological parameters. The treatment with vermicomposting extract gave the best result. For clone Robusta the best results were noted in the experiment with a mixture of agents. Treatment with trichodermin caused an inhibitory action on most of the growth parameters. And so there do not appear to be sufficient reason to use this preparation as individual agent for growing poplar clone Robusta. Nevertheless, in a mixture with vermicomposting extract and mycorrhiza, it has a significant positive effect.

The comparative thermogravimetric analysis of wood samples of poplar clone Ijzer-5 showed that DTG indexes were larger in poplars grown on sod podzolic soil. The difference in the value of the rate of mass loss is explained by the larger content of humus in sod podzolic soils, than in the phytomeliorated mix of rocks.

REFERENCES

Andrasev S., Roncevic S. 2008. Developmental characteristics of selected black poplar clones (section Aigeros). Lesnicky casopis – Forestry Journal. 54(1):5-12

Benetka V., Vratny F., Salkova I. 2007. Comparison of the productivity of Populus nigra L. with an interspecific hybrid in a short rotation coppice in marginal areas. Biomass and Bioenergy, 31(6):367-374.

Bouriaud L., Duduman M.L., Danila I.C., Olenici N., Biris I.A., Ciornei I., Barnoaiea I., Maciuca A., Savin A., Grosu L., Mutu M., Nichiforel L., Bouriaud O., Danila G., Avacaritei D., Roibu C. 2015. How to evaluate the sustainability of short-term cultures for biomass production? An application from ne Romania. Agriculture & Forestry, 61(4):7-22.

Cizkova L., Cizek V., Bajajova H. 2010. Growth of hybrid poplars in silviculture at the age of 6 years. Journal of Forest Science, 56:451-460.

Geletukha G., Zheliezna T., Tryboi O. 2014. Prospects for the growing and use of energy crops in Ukraine. UABio Position Paper No 10. 30p.

Karacic A., Weih M., 2006. Variation in growth and resource utilisation among eight poplar clones grown under different irrigation and fertilisation regimes in Sweden. Biomass and Bioenergy, 30:115-124.

Kharytonov M. 2007. Geochemical assessment of reclaimed lands in the mining regions of Ukraine. NATO ARW Soil chemical pollution, risk assessment, remediation and security. Springer.Printed in the Netherlands, p.57-60.

Kharytonov M., Loza I., Garmash S., Pfeiffer D. 2009. Prerequisites for Tomato and Potato Ecological Farming in Ukrainian Steppe. IOBC/WPRS. Integrated Control in Protected Crops, Mediterranian Climate. Chania, Crete, Greece, 49:25-30.

Kharytonov M.M., Resio Espejo J.M. 2013. Prospects of the Nikopol manganese basin rocks using for land reclamation. Gruntoznavstvo, 14 (1-2):78-86.

Klasnja B., Orlovic S., Galic Z. 2012. Energy potential of poplar plantation in two spacing and two rotation. Sumarski list, CXXXVI:161-167.

Kutsokon N.K., Jose Ah., Holzmueller E. 2014. A global analysis of temperature effect on Populus plantation production potential. American Journal of Plant Science, 6:23-33.

Labrecque M., Teodorescu T. 2005. Field performance and biomass production of 12 willow and poplar clones in short-rotation coppice in southern Quebec (Canada). Biomass and Bioenergy, 29.1:1-9.

Loskutov S.R., Shapchenkova O.A., Aniskina A.A. 2015. Thermal analysis of wood of the main tree species of Central Siberia. Siberian Journal of Forest Science, 9: 17-30 (in Russian).

Ma H., Dong Y., Chen Zh., Liao W., Lei B., Gao K., Li Sh., An X. 2015. Variation in the growth traits and wood properties of hybrid white poplar clones. Forests, 6:1107-1120.

Marron N., Dillen SY., Ceulemans R. 2007. Evaluation of leaf traits for indirect selection of high yielding poplars. Environmental and Experimental Botany, 61:103-116.

Muller-Hagedorn M., Bockhorn H., Krebs L., Muller U., 2003. A comparative kinetic study on the pyrolysis of three different wood species. Journal of Analytical and Applied Pyrolysis, 68-69: 231-249.

Odarchenko I., Maurer V. 2016. "Stump" type of poplar plantation management in Polissya region of Ukraine. Scientific Herald of NULES of Ukraine. Series: Forestry and decorative gardening, 238:169-175 (in Ukrainian).

Panacci E., Bartolini S., Covarelli G. 2009. Evaluation of four poplar clones in a short rotation forestry in Central Italy. Italian Journal of Agronomy, 4:191-198.

Poorter H., Niinemets U., Poorter L., Wright I.J., Villar R. 2009. Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis. New Phytologist, 182:562-588.

Puglielli G., Crescente M.F., Frattaroli A.R., Gratan L. 2015. Leaf mass per area (LMA) as a possible predictor of adaptive strategies in two species of Sesleria (Poaceae): analysis of morphological, anatomical and physiological leaf traits. Annals Botanic Fennici, 52(1-2): 135-143.

Shylin I.S. 2016. Some features of the state and height of poplar trees cultivars in an engraftment phage on the plantation of Volyn Polissya and Opillya. Scientific Bulletin of UNFU, 26(1):122-128 (in Ukrainian).

Slopiecka K., Bartocci P., Fantozzi F. 2011.Thermogravimetric analysis and kinetic study of poplar wood pyrolisis. Applied Energy, 97:491-497.

Stolarski M.J., Krzyzniak M., Szczukowski S., Tworkowski J., Bienick A. 2014. Short rotation woody crops grown on marginal soil for biomass energy. Pollish Journal of Environmental Studies, 23(5):1727-1739.

Wright I.J., Westoboy M., Reich P.B. 2002. Convergence towards higher leaf mass per area in dry and nutrient-poor habitats has different consequences for leaf life span. Journal of Ecology, 90:534-543.

Zhang L., Xu C., Champagne P., 2010, Overview of recent advances in thermo-chemical conversion of biomass. Energy Conversion and Management, 51(5): 969-982.