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Ecology of soil algae cenoses in Norway maple plantation in the recultivated territory of the Western Donbas (Ukraine)

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The problem of the degradation of land ecosystems and their underlying basis – the soil – has a global character. In some regions of Ukraine, such as the Western Donbass, it becomes particularly topical. The damaged areas formed during coal mining are restored through reclamation. One of its directions is forest reclamation. Soil algae constitute an active autotrophic part of the microbiota. They are connected with all its autotrophic, heterotrophic components and with the soil. They play a great role in the accumulation and transformation of organic matter, contributing to the creation of soil fertility. This explains the importance of algae in the process of restoration of damaged soils. Algae participate in the formation of primary products for primary consumers of such soil saprophages as two-bipartite petioles, woodlice, earthworms, collembola, oribatei. These animals act as a natural soil-protecting biological factor, as well as the factor of naturalization of soils in the restoration of damaged areas. They cause redistribution of algae communities composition as a result of their selective eating, thus affecting the number of their communities. The selection of soil samples and forest litter has been carried out in the plantations of Norway maple in the experimental-production site of forest reclamation in the territory of the Western Donbas (Ukraine). The structure of the domination of algae complexes, the vital forms of the representatives of the coenoses of soil algae in the plantation of *Acer platanoides* L. on various stratigraphic variants of piled edaphotopes – on a variant with a potentially fertile terrain (non-humous loess loam) and on several chernozem variants with different stratigraphy has been studied. The representatives of green algae (*Chlorophyta*) predominate in the investigated re-cultivated area in the plantations of Norway maple. The participation of green algae in the composition of soil algae groupings shows the sylvatizative role of the tree plantations in the restored territories. In the plantations of Norway maple on the various stratigraphic variants of piled edaphotopes, an increase in the number of species from 8 in the area with the fill of loess loam up to 15 in a chernozem variant with a half-meter layer of sand has been noted. In general, for maple plantations on chernozem fills, a larger number of species (from 10 to 15) has been observed compared to the maple plantation on the loess loam fill. On the one hand, the small species variety indicates very rough conditions for the existence of soil algae flora, on the other hand, the appearance and occurring of species characteristic of forest ecosystems, indicates the processes of their naturalization in the re-cultivated territories.

Key words: environment rehabilitation; forest recultivation; artificial edaphotopes; ecosystem services; Norway maple; soil algae

Introduction

One of the urgent problems of the modern ecology is the development of approaches to the conservation and rational use of biological diversity and ecosystem productivity in anthropological-technological environment, in particular in the process of coal mining, which causes the destruction of soil and vegetation cover, reduction of flora and fauna species diversity, deterioration of soil fertility (Faly et al., 2017; Chakravarty, 2012; Klymenko et al., 2017). In some cases, anthropological-technological pressure on natural ecosystems manifests itself more acutely, to the full extent of their degradation and the formation of an "industrial desert" in their place, which can be represented in the form of mine dumps that are constantly exposed to wind and water erosion. In this case, the toxic components contained in the mountain dumps fall into aquatic ecosystems, soil and atmosphere, negatively affecting biota, human habitat (Benbrahim et al., 2004) and as a result reduce people's health potential (Lykholat et al. 2016). Therefore, in the coal mining regions the problem of optimizing the environmental situation prevails at present (Mbaya, 2013).

To reduce the negative impact of technological genesis on the environment, a number of measures are being taken to preserve and restore the soil and vegetation cover. One of the solutions to this problem is forest reclamation – a system of measures for forest breeding on rock dumps and other lands damaged in the process of mineral deposits development (Ibarra and de las Heras, 2005; Chibrik et al., 2016).

Soil algae are an indispensable component of land ecosystems. They form an active part of the microflora connected with complex interactions, both with all its components, and with the proper soil and higher plants, and take variable participation in the soil processes (Maltseva, 2007; Maltsev, 2013; Scherbina et al., 2014; Maltsev et al., 2017a, 2017b, 2017c; Shcherbyna et

al., 2017 et al.). The role of algae in the accumulation and transformation of the organic matter, favourable for the creation of soil fertility, is great. (Shtina and Gollerbah, 1976; Maltseva, 2007). They enrich the soil with nitrogen by utilizing the free nitrogen of the atmosphere. Blue-green algae capable of fixing atmospheric nitrogen are an important source of biogenic elements entry into the soil (Maltsev, 2015; Maltseva et al., 2017; Yarovyi et al., 2017). Besides, the soil algae release into the environment a spectrum of biologically active substances, vitamins, and various mucus that promotes the gluing of separate mineral particles of the substrate and the formation of the future soil structure (Gollerbah and Shtina, 1969; Sirenko and Kondrateva, 1999, Shekhovtseva and Maltseva, 2015; Maltsev and Konovalenko, 2017), and also serve as an anti-erosive barrier (Dubovik, 1995). In addition, they are highly resistant to unfavourable environmental factors (Gollerbah and Shtina, 1969; Maltseva et al., 2008), which allows them to colonize various artificial substrates (Gaylarde et al., 2000; Crispim et al. 2003; 2004 ; Srispim and Gaylarde, 2004; Rindi and Guiry, 2004; Uher et al., 2005; Karsten et al., 2007; Rindi; 2007; Hallmann et al., 2011) and substrates of technogenic origin (Maltseva et al., 2009; Maltseva and Chayka, 2011; Maltseva and Posrednikova, 2011; Maltseva and Baranova, 2014).

Their functioning relate mainly to providing such ecosystem services as increasing soil fertility and nutrient cycling. The benefits of such a forest ecosystem determine the significance of this group of organisms, the value of which greatly increases in the present conditions of climate change in the direction of dryness and temperature rise, especially in semiarid climatic zones (Lykholat et al., 2017).

Together with other green plants, the algae participate in the formation of primary products for primary consumers, in particular, soil saprophages such as two-bipartite petioles, woodlice, earthworms, collembola, oribatei. They participate in improving and maintaining the ecological quality of the soil (Kul'bachko et al., 2011, 2015), cause redistribution of algae groupings due to their selective eating (Shtina and Gollerbah, 1976).

The algae play a great role in the processes of restoration of damaged soils. The very fact of algae occurring together with other representatives of the zoomicrobiotic complex in the substrate of mine dumps indicates the initial stage of their overgrowing followed by the accumulation of primary organic matter in them. The peculiarities of the formation of pioneer algae communities on damaged soils are presented in a number of papers (Maltseva et al., 2009; Maltseva and Chayka, 2011; Maltseva and Posrednikova, 2011; Maltseva and Baranova, 2014; and others). An important aspect in the study of ecosystems formed on damaged soils is the organization of monitoring. Since 1990, the study of the soil algae (Maltseva and Cherevko, 1994; Maltseva, 1996, 2006) is being carried out in the experimental site of the reclamation located in the minefield of the mine “Pavlohradska”. The long-term observation allows obtaining the valuable information on the changes occurring in the algae communities from the moment of their formation to the communities that have undergone a relatively long stage of the ecotopic and phytocoenotic selection in the conditions of artificial ecotopes and phytocoenoses created during reclamation.

The aim of our study has been to identify the features of the phytocoenotic organization of soil algae groupings in the plantation of Norway maple (*Acer platanoides* L.) in the area of forest reclamation of the Western Donbas.

Material and methods

The material has been collected in the site of forest reclamation in the Western Donbas territory (Dnipropetrovsk region, Pavlohrad district) in the plantation of Norway maple (*Acer platanoides* L.). This experimental-production site for reclamation is located in the minefield zone of the mine “Pavlogradska” (48°33'32"N, 35°59'13"E) and is represented by five stratigraphic variants of piled edaphotopes with different thickness of reclamation layers (Fig. 1). On the biological stage of this site reclamation, tree and shrub species were planted, in particular, Norway maple – a deciduous tree plant of the Soapberry family (*Sapindaceae*). It is a popular decorative species for recreational areas, as well as for forestry.

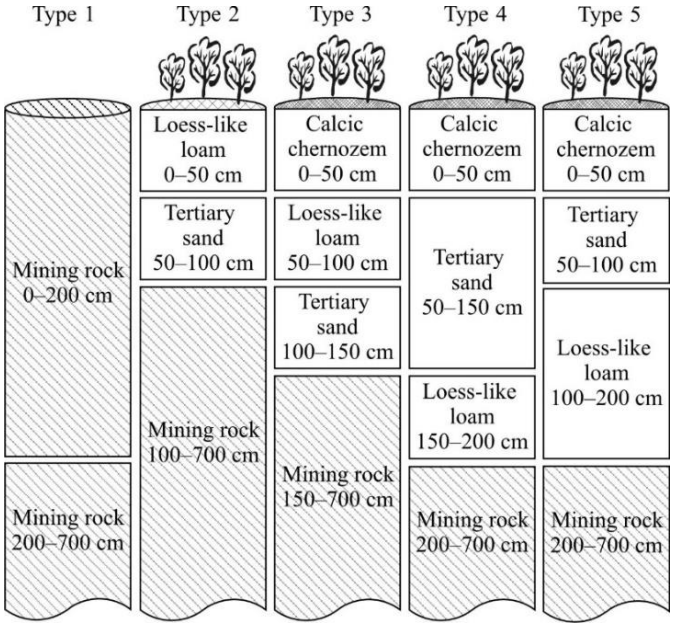

Fig. 1. Stratigraphic structure of piled soils of the forest reclamation site

To determine the representatives of the algae flora the samples were taken from the litter and layers of soils 0–5 cm, 5–10 cm, 10–15 cm. The replication of soils sampling was three-stage. Under the laboratory conditions, soils were transferred to the sterile Petri dishes and in a humidified state they were being held for 12 hours with light and dark phases alternation. On the surface of soils there were laid the sterile glasses, on the underside of which the algae developed. The cultures were screened in 2–3 weeks (Kuzyahmetov and Dubovik, 2001). The systematic structure was established on the basis of I. Yu. Kostikov's and his co-authors' system (Kostikov et al., 2001). The classification of algae life forms was conducted according to Shtina and Gollerbah (1976). The data were processed by means of the Excel application package.

Results and discussion

The composition of the algae groupings in various stratigraphic variants of the piled soil in the plantation of Norway maple on each stratigraphic variant of the reclamation has its own peculiarities. On the second (non-chernozem) variant (the upper half-meter layer of loess loam) 8 species of algae belonging to five departments were found. The largest number of species of soil algae (3 species) was shown by representatives of *Chlorophyta* (38%). The department of *Cyanophyta* is represented by two species (23%), and the departments of *Xanthophyta, Bacillariophyta, Eustigmatophyta* – respectively, by one species each (13%). The algae flora is dominated by green algae, characteristic of forest ecosystems. This speaks for the processes of sylvatization occurring in this biogeocoenosis.

The nature of the vertical distribution of algae along the soil horizons gives the most complete picture of the peculiarities of formation of algae groupings. Green algae are noted in the litter and in the soil layer of 5–10 cm, while blue-green ones, most characteristic of steppe biogeocoenoses, are recorded in the litter and layers of soil 0–5, 10–15 cm. The representatives of yellow-green algae are found only in the soil layer 0–5 cm, diatoms – at a depth of 0–5 and 5–10 cm, and eustygmatophytic – 0–5 and 10–15 cm.

Considering the structure of domination of these stratigraphic variant algae complexes (Fig. 2), it should be noted that in the litter the representatives of *Chlorophyta* (75%) dominate, *Cyanophyta* accounts for 25%.

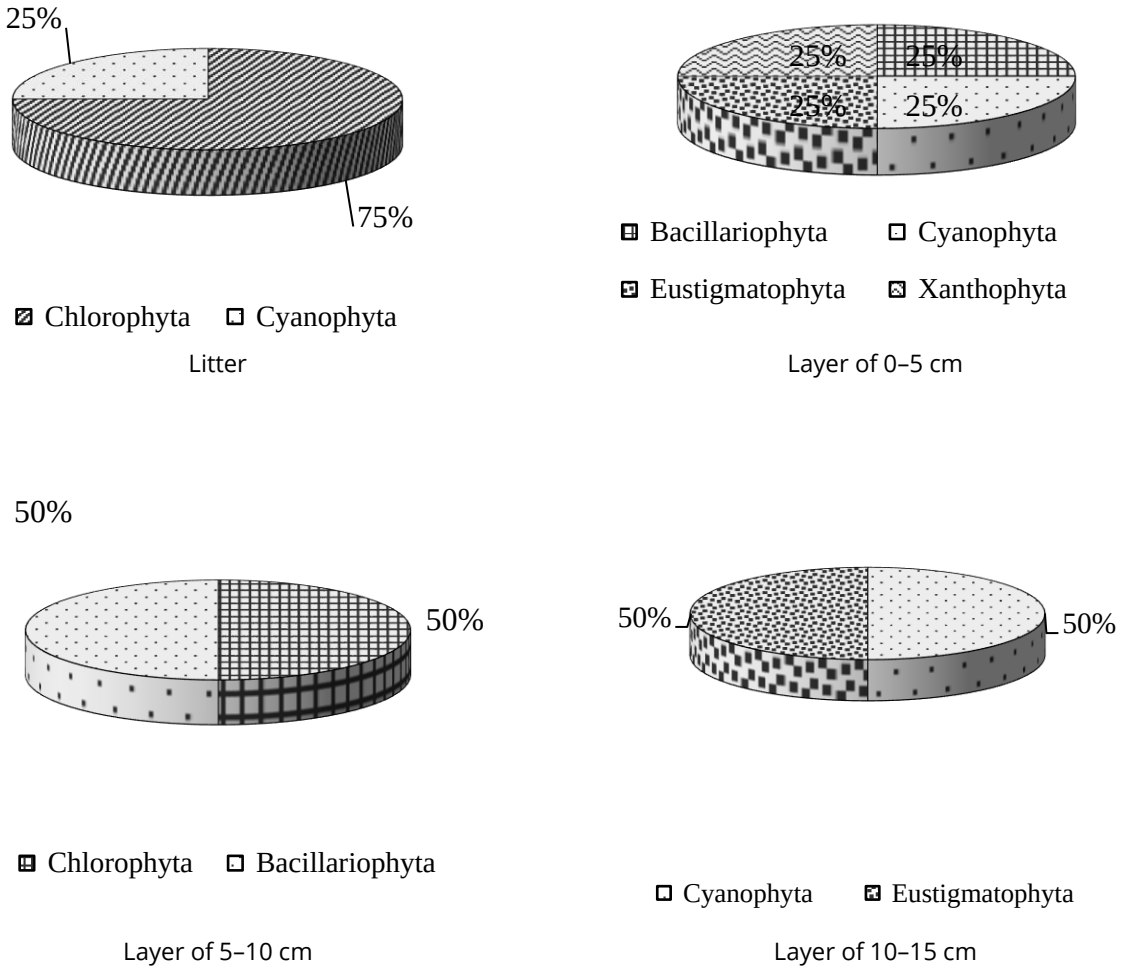

Fig. 2. Distribution of algae flora representatives in the litter and soils of the second stratigraphic variant of forest reclamation site (variant with a fill of loess loam, 0–50 cm) in the plantation of Norway maple

In the uppermost layer of soil of 0–5 cm, one species of *Xanthophyta, Cyanophyta, Bacillariophyta, Eustigmatophyta* representatives (25%, respectively) was found. The representatives of *Bacillariophyta* and *Chlorophyta* (50%) predominate at a depth of 5–10 cm. In the 10–15 cm layer, *Cyanophyta* and *Eustigmatophyta* represent 50% respectively.

An important characteristic of the algae groupings is their ecological structure. In general, in the investigated plantation of Norway maple of the second stratigraphic variant of forest reclamation, *Ch*-forms (58%) are most widely represented by unicellular and colonial green algae, and by yellow-green ones partially. The ratio of representatives of *N*-, *P*-, *B*-life forms is the same (14%, respectively). Compared to the earlier studies of algae composition (Maltseva et al., 2006), the emergence of diatoms algae species is noted. Usually they are noted on the lattermost stages in the formation of the soil algae coenosis in damaged areas.

On the third (chernozem) variant of the piled soils in the plantation of Norway maple (upper half-meter layer of ordinary chernozem on the vein of loess loam) 10 species of soil algae belonging to the *Cyanophyta* (5 species – 56%), *Chlorophyta* (2 species – 22%), *Eustigmatophyta* (1 species – 11%), *Bacillariophyta* (1 species – 11%) have been registered. Unlike the second variant of the piled soils, the representatives of blue-green algae, algae groupings, which are characteristic of steppe biogeocoenoses, prevail. At the same time, the number of their species increases by 2.5 times in comparison with the second variant of the fill. The amount of green algae is reduced by 1.5 times. The ratio of representatives of diatoms and eustygmatophyte algae, as in the previous variant of the fill, remains unchanged.

If in the piled loess loam (the second stratigraphic variant), the representatives of *Chlorophyta* are noted only in the litter and in the soil layer of 5–10 cm, then in the maple litter of the third variant they are absent, but found in the soil layers of 5–10 cm and 10–15 cm (Fig. 3). The representatives of *Cyanophyta* and *Chlorophyta* are absent in the litter, but are present at a depth of 0–15 cm. The representatives of eustigmatophytes are found in the litter, the soil layer of 0–5 cm and 5–10 cm, while the diatoms are in the litter and at the depth of 5–10 cm.

In the litter, the ratio of the representatives of *Eustigmatophyta* and *Bacillariophyta* is the same – 50% each (Fig. 3). In the soil layer of 0–5 cm, the representatives of *Cyanophyta* (67%) predominate, *Eustigmatophyta* accounts for 33%. The representatives of *Chlorophyta* dominate at the depth of 5–10 cm, they account for 40%. The ratio of representatives of *Cyanophyta, Eustigmatophyta, Bacillariophyta* is respectively 20% each. In the soil layer of 10–15 cm, the representatives of *Cyanophyta* prevail – 60%. *Chlorophyta* accounts for 40%.

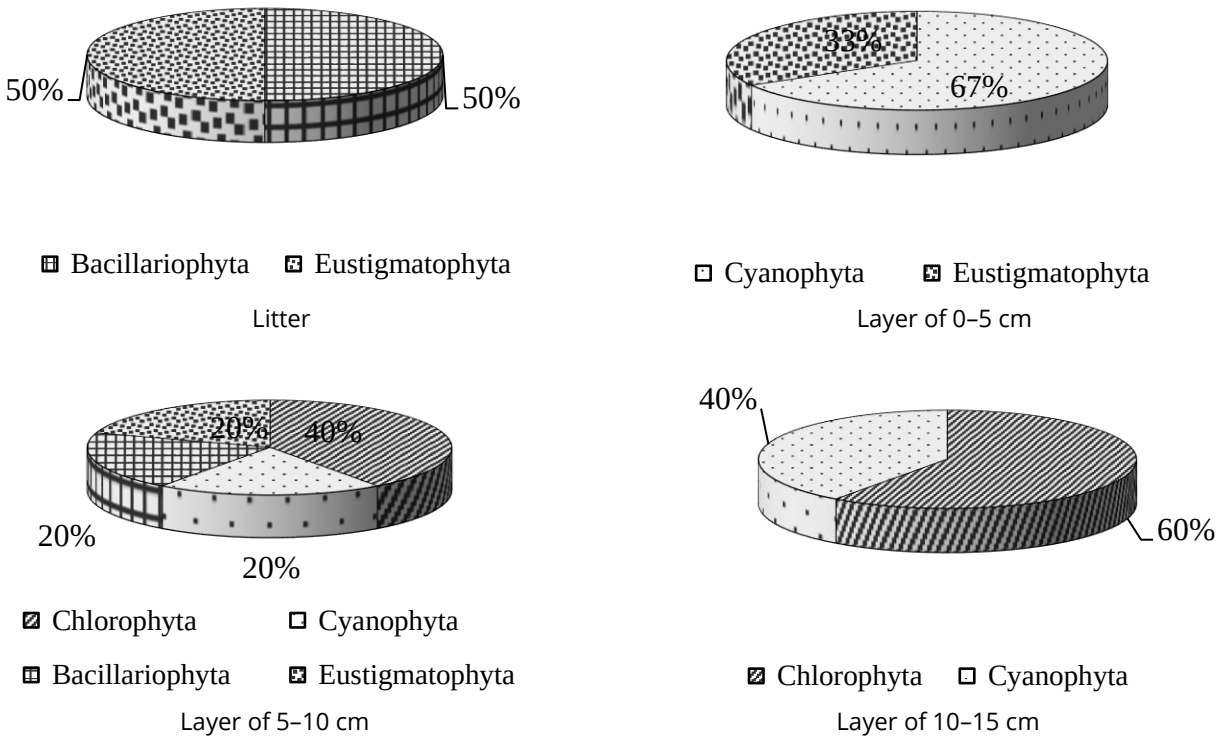

Fig. 3. Distribution of algae flora representatives in the litter and soils of the third stratigraphic variant of the forest reclamation site (humous layer of ordinary chernozem (0–50 cm) on the vein of loess loam (50–100 cm) in the plantation of Norway maple

In general, in the investigated plantation of Norway maple of the third (chernozem) stratigraphic variant of forest reclamation, the soil algae of the *Ch*-form accounts for 40%, this is 1.5 times less than in the second variant of the fill. The part of soil algae representatives in the *N*-form increases by 2.1 times, the one of the *P*-form increases by 1.4 times, the one of the *B*-form is reduced by 0.7 time in comparison with the second variant, respectively.

For the fourth (chernozem) variant of the piled soils in the plantation of Norway maple (upper half-meter layer of ordinary chernozem in a meter vein of sand) is characterized by an increase in the number of species of soil algae flora up to 11, with the number of departments becoming smaller. Algae groupings are represented by *Chlorophyta* (58%), *Cyanophyta* (33%),

Eustigmatophyta (8%). The predominance of green algae as part of the algae coenosis was remarked earlier (Maltseva and Cherevko, 1994; Maltseva et al., 2006).

In the fourth variant, unlike the previous variants, the representatives of *Chlorophyta* are present in the litter and in all investigated soil layers, *Cyanophyta* – at the depth of 0–10 cm, *Eustigmatophyta* are found only in the soil layer of 10–15 cm (Fig. 4).

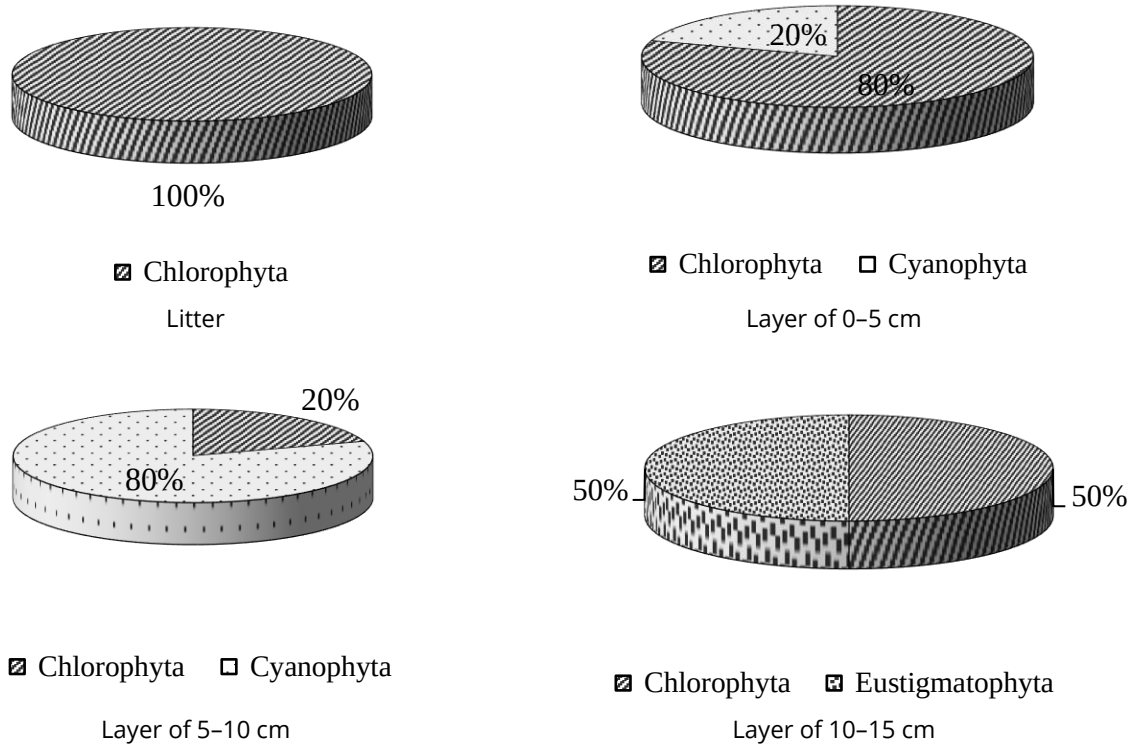

Fig. 4. Distribution of algae flora representatives in the litter and soils of the fourth stratigraphic variant of the forest reclamation site (humous layer of ordinary chernozem (0–50 cm) on the vein of sand (50–150 cm) in the plantation of Norway maple

Only the representatives of *Chlorophyta* (4 species, 100%) predominate in the litter on the investigated variant of the fill (see Fig. 4). In the soil layer of 0–5 cm the representatives of *Chlorophyta* (80%) dominate, while *Cyanophyta* represent only 20%. At the depth of 5–10 cm of soil, the part of representatives of *Chlorophyta* accounts for 20%, and *Cyanophyta* – 80%. In the soil layer of 10–15 cm, the ratio of *Chlorophyta* and *Cyanophyta* is the same – 50% each. The presence of representatives of the green algae, characteristic of forest ecosystems, in all the layers of soils, indicates the process of sylvatization in this maple plantation.

In general, among the life forms of soil algae in the investigated plantation of Norway maple of the fourth (chernozem) stratigraphic variant of forest reclamation, as in the previous variants, the representatives of the *Ch*-form dominate while the percentage of the *N*- and *P*-forms representatives does not change. The representatives of the *H*-form appear, this form is represented by organisms unstable to drought and light, but at the same time finding optimal conditions for existence in this variant.

The fifth (chernozem) variant of piled soils in the plantation of Norway maple (upper half-meter layer of ordinary chernozem on a half-meter vein of sand) is characterized not only by the maximum species richness of green algae in comparison with the previous variants – 15 species. In general, the representatives of *Chlorophyta* account for 53%, *Cyanophyta* – 20%, *Xanthophyta* – 13%, *Eustigmatophyta* – 7%, *Bacillariophyta* – 7%.

The representatives of green algae are found in the litter and soil layer of 0–10 cm, the blue-green ones – In the soil layers of 0–5 and 10–15 cm, the yellow-green and diatomaceous ones – at the depth of 10–15 cm, eustygmatophytic ones – in the litter and soil layer of 5–10 cm (Fig. 5).

In the litter of this variant, the representatives of *Chlorophyta* (87%) predominate, *Eustigmatophyta* ones account only for 13% (see Fig. 5), which is typical for the composition of forest litter algae (Maltsev et al., 2017c). For the upper soil layer of 0–5 cm, the ratio of *Chlorophyta* and *Cyanophyta* is the same – 50% each. The representatives of *Chlorophyta* (67%) predominate at the depth of 5–10 cm. The part of *Eustigmatophyta* is 33%. The representatives of *Chlorophyta* are absent in the 10–15 cm soil layer, it contains the representatives of *Cyanophyta* and *Xanthophyta* – 40% per each and *Bacillariophyta* – 20%.

In general, the representatives of the *Ch*-form prevail (53%) in the plantation of Norway maple of the fifth (chernozem) stratigraphic variant of forest reclamation, as in all previous variants. The part of *R*- and *B*-forms representatives accounts for 7% per each, and *H*- and *N*-forms account for 20% and 13%, respectively.

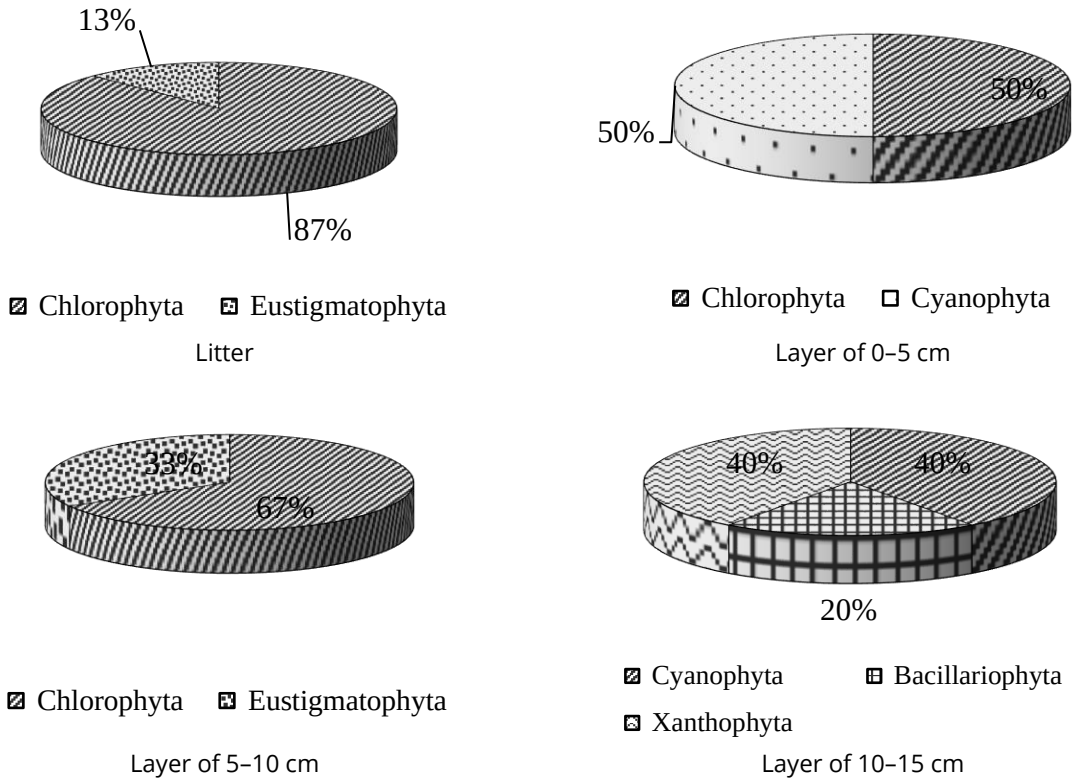

Fig. 5. Distribution of algae flora representatives in the litter and soils of the fifth stratigraphic variant of the forest reclamation site (humous layer of ordinary chernozem (0–50 cm) on the vein of sand (50–100 cm) in the plantation of Norway maple

Species richness, taxonomic variety of departments, prevailing of *Ch*-form representatives practically in all soil layers in the maple plantation of the fifth variant speaks for favourable ecological conditions of existing in this man-made forest ecosystem.

Conclusions

The representatives of green algae predominate on the investigated reclaimed area in the forest plantation of Norway maple. At the same time, yellow-green, blue-green, eustygmatophyte and diatomic algae are also found in less number. The participation of green algae in the composition of soil algae groupings shows the sylvatizing role of the tree plantations in the reclaimed territories. Consequently, for the existence of the soil algae flora, which is a potential source for the saprophages nutrition, the optimal conditions are created in the forest reclamation site on the chernozem variants of the fill in comparison with the variant of the loess loam where the fewer species of algae are observed. Thus, the soil algae contribute to the naturalization of artificial edaphotopes of forest plantations on reclaimed lands.

References

Benbrahim, K.F., Ismaili, M., Benbrahim, S.F. & Tribak A. (2004). Land degradation by desertification and deforestation in Morocco. Sécheresse, 15(4), 307–320.

Chakravarty, S., Ghosh, S.K., Suresh, C.P., Dey, A.N. & Shukla G. (2012). Deforestation: causes, effects and control strategies. In: Global Perspectives on Sustainable Forest Management, Dr. Dr. Clement A. Okia (Ed.), InTech, doi: 10.5772/33342

Chibrik, T.S., Lukina, N.V., Filimonova, E.I., Glazyrina, M.A., Rakov, E.A., Maleva, M.G. & Prasad, M.N.V. (2016). Biological reclamation of mine industry deserts: Facilitating the formation of phytocoenosis in the middle Ural region, Russia (pp. 349-418). In: Prasad, M.N.V. (Ed). Bioremediation and Bioeconomy. Elsevier. doi: http://doi.org/10.1016/B978-0-12-802830-8.00016-2

Crispim, C.A. & Gaylarde, C.C. (2004). Cyanobacteria and biodeterioration of cultural heritage: a review. Microbial Ecology, 49(1), 1–9. doi: 10.1007/s00248-003-1052-5

Crispim, C.A., Gaylarde, C.C. & Gaylarde, P.M. (2004). Biofilms on church walls in Porto Alegre, RS, Brazil, with special attention to cyanobacteria. International Biodeterior & Biodegradation, 54, 121–124. doi: doi.org/10.1016/j.ibiod.2004.03.001

Crispim, C.A., Gaylarde, P.M. & Gaylarde, C.C. (2003). Algal and cyanobacterial biofilms on calcareous historic buildings. Current Microbiology, 46(2), 79–82. doi: 10.1007/s00284-002-3815-5

Dubovik, I.E. (1995). Vodorosli erodirovannyh pochv i algologicheskaia otsenka pochvozashitnyh meropriiatii [Algae of eroded soils and algological evaluation of soil-protection measures]. Publ. Bashkir State University, Ufa (In Russian).

Faly, L.I., Kolombar, T.M., Prokopenko, E.V., Pakhomov, O.Y. & Brygadyrenko, V.V. (2017). Structure of litter macrofauna communities in poplar plantations in an urban ecosystem in Ukraine. Biosystems Diversity, 25(1), 29–38. doi: 10.15421/011705

Gaylarde, P.M. & Gaylarde, C.C. (2000). Algae and cyanobacteria on painted buildings in Latin America. International Biodeterior & Biodegradation, 46(2), 93–97. doi: 10.1016/S0964-8305(00)00074-3
Gollerbah, M.M. & Shtina, E. A. (1969). Pochvennyie vodorosli [Soil algae]. Nauka, Leningrad. (In Russian).
Hallmann, C., Rüdrich, J., Enseleit, M., Friedl, T. & Hoppert, M. (2011). Microbial diversity on a marble monument-a case study. Environmental Earth Sciences, 63(7–8), 1701–1711. doi: doi.org/10.1007/s12665-010-0772-3
Ibarra, J.M.N. & de las Heras M.M. (2005). Open-Cast Mining Reclamation (pp. 370-376). In: Forest Restoration in Landscapes: Beyond Planting Trees. Mansourian, S., Vallauri, D., Dudley, N. (Eds.). In cooperation with WWF International, Springer, New York.
Karsten, U., Schumann, R. & Mostaert, A. (2007). Aeroland algae growing on man-made surfaces. In: Seckbach J. (eds). Algae and Cyanobacteria in Extreme Environments. Cellular Origin, Life in Extreme Habitats and Astrobiology, vol 11. Springer, Dordrecht. doi: doi.org/10.1007/978-1-4020-6112-7_32
Klymenko, G., Kovalenko, I., Lykholat, Y., Khromykh, N., Didur, O. & Alekseeva, A. (2017). The integral assessment of the rare plant populations. Ukrainian Journal of Ecology, 7(2), 201–209. doi: 10.15421/2017_37
Kostikov, I.Iu., Romanenko, P.O., Demchenko, E.M., Dariienko, T.M., Mykhailiuk, T.I., Rybchynskyi, O.V., Solonenko, A.M. (2001). Vodorosti gruntiv Ukrainy (istoriia ta metody doslidzhennia, systema, konspekt flory) [Soil algae of Ukraine (history and methods of research, system, checklist of flora)]. Fitosotsiotsentr, Kyiv.
Kul'bachko, Y., Loza, I., Pakhomov, O., Didur, O. (2011). The Zooecological Remediation of Technogen Faulted Soil in the Industrial Region of the Ukraine Steppe Zone (pp. 115-123). In: Behnassi, M., Shahid, S., D'Silva, J. (Eds). Sustainable Agricultural Development. Springer, Dordrecht. doi: https://doi.org/10.1007/978-94-007-0519-7_7
Kul'bachko, Y.L., Didur, O.O., Loza, I.M., Pakhomov, O.E. & Bezrodnova, O.V. (2015). Environmental aspects of the effect of earthworm (Lumbricidae, Oligochaeta) tropho-metabolic activity on the pH buffering capacity of remediated soil (steppe zone, Ukraine). Biology Bulletin, 42(10), 899–904. doi: https://doi.org/10.1134/S1062359015100088
Kuzyahmetov, G.G. & Dubovik, I.E. (2001). Metody izucheniia pochvennyh vodorosley [Methods for studying soil algae]. Publ. Bashkir State University, Ufa (In Russian).
Lykholat, T., Lykholat, O. & Antonyuk, S. (2016). Immunohistochemical and biochemical analysis of mammary gland tumours of different age patients. Cytology and Genetics, 50 (1), 32–41. doi: https://doi.org/10.3103/S0095452716010072
Lykholat, Y.V., Khromykh, N.A., Ivan'ko, I.A., Matyukha, V.L., Kravets, S.S., Didur, O.O., Alexeyeva, A.A. & Shupranova, L.V. (2017). Otsinka i prohnoz invaziinosti deiakykh adventyvnykh roslyn za vplyvu klimatychnykh zmin u Stepovomu Prydniprov'i [Assessment and prediction of the invasiveness of some alien plants in conditions of climate change in the steppe Dnieper region]. Biosystems Diversity, 25(1), 52–59. doi: 10.15421/011708
Maltsev, E.I. (2013). Ekolohichni osoblyvosti alhouhrupovan lisovykh pidstylok zaplavnykh dibrov stepovoi zony Ukrainy [Ecological features of algae groupings in forest litter of floodplain oak woods in steppe area of Ukraine]. Gruntoznavstvo, 14(1–2), 70–77. (In Ukrainian).
Maltsev, E.I. (2015). Vliyanie raznyih shtammov roda *Nostoc* Vaucher ex Bornet et Flahault na rost i razvitie *Pisum sativum* L. [The influence of Nostoc Vaucher ex Bornet et Flahault strains on growth and development of *Pisum sativum* L.]. Ukrainian Journal of Ecology, 5(3), 148–154. doi: 10.7905/bbmspu.v5i3.993
Maltsev, Y.I. & Konovalenko, T.V. (2017). New finding of green algae with potential for algal biotechnology, Chlorococcum oleofaciens and its molecular investigation. Regulatory Mechanisms in Biosystems, 8(4), 532–539. doi: 10.15421/021782
Maltsev, Y.I., Didovich, S.V. & Maltseva, I.A. (2017*a*). Seasonal changes in the communities of microorganisms and algae in the litters of tree plantations in the Steppe zone. Eurasian Soil Science, 50(8), 935–942. doi: 10.1134/S106422931706005
Maltsev, Y.I., Maltseva, I.A., Solonenko, A.N. & Bren, A.G. (2017*b*). Use of soil biota in the assessment of the ecological potential of urban soils. Biosystems Diversity, 25(4), 257–262. doi: 10.15421/011739
Maltsev, Y.I., Pakhomov, A.Y. & Maltseva, I.A. (2017*c*). Specific features of algal communities in forest litter of forest biogeocenoses of the Steppe zone. Contemporary Problems of Ecology, 10(1), 71–76. doi: 10.1134/S1995425517010085
Maltseva, I.A. & Cherevko, S.P. (1994). Gruntovi vodorosti rekultyvovanykh zemel Prysamar'ia Dniprovskoho (Ukraina) [Soil algae of the reclaimed lands in Prisamarie Dniprovske (Ukraine)]. Ukrainian Botanical Journal, 51(2/3), 144–148. (In Ukrainian).
Maltseva, I.A. & Baranova, O.O. (2014). Vodorosli tehnogennyh ekotopov zhelezorudnogo proizvodstva [Algae of technogenic ecotopes of iron-ore industry]. Algologiia, 24(3), 350–353. (In Russian).
Maltseva, I.A. & Chayka, N.I. (2011). Pochvennyie vodorosli otvala ugolnoy shahty Donetskoi oblasti [Soil algae of the coal mine in Donetsk region]. Biological Bulletin of Bogdan Khmelnitskiy Melitopol State Pedagogical University, 1(3), 45–54. (In Russian).
Maltseva, I.A. & Posrednikova, A.V. (2011). Vyvchennia alhoflory derevnykh nasadzhen rekultyvovanoho vuhilnoho vidvalu shakhty Sviato-Serafimivska (Donetska oblast) [The algae flora investigation within tree plantations of the reclaimed coal dump of Svyato-Serafimivska mine (Donetsk region)]. Chornomorskyi Botanical Journal, 7(2), 187–193. (In Ukrainian).
Maltseva, I.A. (1996). Pochvennyie vodorosli lesnyih nasazhdeniy na rekultivirovannyih shahtnyih otvalah Zapadnogo Donbassa [Soil algae of forest plantations on reclaimed mine dumps of Western Donbas]. Ekologiia ta noosferologiia, 2(3–4), 129–133. (In Russian).
Maltseva, I.A. (2006). Riznomanittia gruntovykh vodorostei lisovykh rekultyvatsiinykh ekosystem pivdnia Ukrainy [Variety of soil algae of forest reclaimed ecosystems in the South of Ukraine]. Ekologiia ta noosferologiia, 17(1–2), 46–50. (In Ukrainian).
Maltseva, I.A. (2007). Gruntovi vodorosti u funktsionalnii strukturi bioheotsenoziv [Soil algae in the functional structure of biogeocoenoses]. Gruntoznavstvo, 8(3–4), 71–79. (In Ukrainian).

Maltseva, I.A., Adamenko, Yu.P., Dzhoglo, T.I., Pysanets, Z.G. & Maltsev Ye.I. (2008). Vplyv nadlyshku pliumbumu i kuprumu na gruntovi vodorosti [Influence of lead and copper surplus on the soil algae]. Ekologiya ta noosferologiya, 19(1–2), 134–137. (In Ukrainian).
Maltseva, I.A., Baranova, O.O. & Maltsev, E.I. (2009). Alhouhrupovannia bioheotsenoziv landshaftno-tekhnohennykh system Kryvorizhzhia [Algae groupings of biogeocoenoses of landscape-technogenic systems of Kryvorizhia]. Visnyk Zaporizkoho derzhavnoho universytetu, 2, 20–23. (In Ukrainian).
Maltseva, I.A., Kotok, I.A. & Pasko, K.S. (2006). Doslidzhennia gruntovoi alhoflory rekultyvatsiinykh lisovykh nasadzhen [The investigation of soil algae flora of reclaimed forest plantations]. Journal of Kharkiv National Agrarian University, Series Biology, 1, 128–134. (In Ukrainian).
Maltseva, I.A., Maltsev, Y.I. & Solonenko, A.N. (2017). Soil Algae of the Oak Groves of the Steppe Zone of Ukraine. International Journal on Algae, 19(3), 215–226. doi: 10.1615/InterJAlgae.v19.i3.20
Mbaya, R.P. (2013). Land degradation due to mining: the gunda scenario. International Journal of Geography and Geology, 2(12): 144–158. doi: 10.18488/journal.10/2013.2.12/10.12.144.158
Rindi, F. & Guiry, M.D. (2004). Composition and spatial variability of land algal assemblages occurring at the bases of urban walls in Europe. Phycologia, 43(3), 225–235. doi: doi.org/10.2216/i0031-8884-43-3-225.1
Rindi, F. (2007) Diversity, distribution and ecology of Green Algae and Cyanobacteria in urban habitats. In: Seckbach J. (eds) Algae and Cyanobacteria in Extreme Environments. Cellular Origin, Life in Extreme Habitats and Astrobiology, vol 11. Springer, Dordrecht. doi: https://doi.org/10.1007/978-1-4020-6112-7_34
Scherbina, V.V., Maltseva, I.A. & Solonenko, A.N. (2014). Peculiarities of postpyrogene development of algae in steppe biocenoses at Askania Nova Biospheric National Park. Contemporary problems of ecology, 7(2), 187–191. doi: doi.org/10.1134/S1995425514020140
Shcherbyna, V.V., Maltseva, I.A., Maltsev, Y.I. & Solonenko, A.N. (2017). Post-pyrogenic changes in vegetation cover and biological soil crust in steppe ecosystems. Regulatory Mechanisms in Biosystems, 25(4), 633–638. doi: 10.15421/011797
Shekhovtseva, O.G. & Maltseva, I.A. (2015). Physical, chemical, and biological properties of soils in the city of Mariupol, Ukraine. Eurasian Soil Science, 48(12), 1393–1400. doi: doi.org/10.1134/S1064229315120145
Shtina, E.A. & Gollerbah, M.M. (1976). Ekologiia pochvennyh vodorosley [Ecology of soil algae]. Nauka, Moscow. (In Russian).
Sirenko, L.A. & Kondrateva, N.V. (1999). Rol Cyanophyta v prirode (obzor) [The role of Cyanophyta in the nature (review)]. Algologiia, 3(1), 1–15. (In Russian).
Uher, B., Aboal, M. & Kovacik, L. (2005). Epilithic and chasmoendolithic phycoflora of monuments and buildings in South-Eastern Spain. Cryptogamie Algologie, 26(3), 275–308.
Yarovyi, S.O., Arabadzhi, L.I., Solonenko, A.M., Bren, O.G., Maltsev, Y.I. & Matsyura, A.V. (2017). Diversity of Cyanoprokaryota in sandy habitats in Pryazov National Natural Park (Ukraine). Ukrainian Journal of Ecology, 7(2), 91–95. doi: 10.15421/2017_24

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