Influence of Forest Vegetation on Organic Matter Composition after Restoration of Mining Spoils in the Town of Pernik

Vania Kachova
Forest Research Institute – Bulgarian Academy of Sciences
Bulvd. "Kliment Ohridski" 132, Sofia, 1756, Bulgaria
Corresponding Author: Vania Kachova, e-mail: vania_kachova@abv.bg
Received: 9 September 2020 *Accepted: 1 March 2021*

Abstract

Three tree species are studied: coniferous plantation of black pine / *Pinus nigra* Arn./ and deciduous: birch / *Betulla alba* L./ and ash / *Fraxinus pennsylvanica* Marsh/, on the territory of Baikusheva neighborhood in Pernik, near the mine "M. Tolbuhin ", after performed 45 years ago reclamation. The accumulation of organic matter in the mining spoil and humus composition are analysed. High amounts of org.C are found under all three types of woody plants (tC% = 3.65 ÷ 9.50 in top layers 0-20cm). This is also due to the presence of large amounts of coal carbon particles in the substrate. Humus accumulation is more pronounced under deciduous species and especially under the newly studied species of *Fraxinus pennsylvanica* Marsh (Humus% = 11.42 ÷ 16.38). But here the process of humification takes place to a lesser extent (~ 10 ÷ 16%). On the contrary, under the coniferous plantation of *Pinus nigra* Arn. is accumulated less org. C (tC% = 1.34 ÷ 3.65), but the humification processes are going in the highest degree (~ 18 ÷ 32%). However, this is also associated with the formation of the largest amounts of the more mobile parts of the organic matter: fulvic acids (Cf ~ 11% from tC). Among deciduous species under *Fraxinus pennsylvanica* Marsh, fulvic acids move in the range of the lowest values (4-5% of tC).

Key words: recultivation, organic carbon, humic and fulvic acids

Introduction

Mining activity is associated with the destruction of natural soil cover, transportation and deposition of soils in the form of huge heterogeneous masses of soil substrates - mining spoils. Restoring their ecological characteristics and recovering a good growing environment is an important and "hot" issue facing scientists for decades (Prokopiev, 1967; Donov et al., 1978; Banov et al., 1989; Zheleva et al., 2004; Atanassova et al., 2018; Simeonova et al., 2018; Nikova et al., 2019). It is generally believed that the best cost-effective and most applicable method is a phytoremediation (Henry et al., 2013; Deng et al., 2020). In this method with particular importance is the land-use type, kind of vegetation: forest, grass or agricultural plants (Banov, Marinova, 2016.). Forest vegetation is especially valuable in case of heavier pollution of the substrate and for building a high aesthetic value of the landscape with remediation applicability. In addition, with its deep roots and huge forest litter, the forest vegetation significantly and in depth improve the characteristics of the substrate (Gencheva and Filcheva, 1995). Here the question of the specificity of the species of forest-tree vegetation is important (Feng et al., 2019). Aboveground vegetation closely correlated with soil properties including soil organic carbon (Sun et al., 2019; Jobbagy, Jackson, 2000). Who are the best phytoremediators among forest-tree species remains an open question, for which there are not many studies (Gencheva and Filcheva, 1995). The influence of the species on the content and composition of the soil organic matter (SOM) is especially indicative. It is that driver of soil processes which is of main importance for biochemical characteristics of soil and especially of its quality. Afforestation affects the content of SOM and its composition (Zhiyanski et al, 2012) especially on substrates of mining activity (Bech et al., 2012; Sokolovska et al., 2014). Analyses of variance shows that all soil properties including pH, total C and total N influence by tree species (Zhiyanski et al, 2008).

In our country in the Pernik mining region, as one of the biggest in the country, these issues also arise. A number of scientists have worked here on the composition of mining substrates (Ivanov, 2007; Sokolovska et al., 2014; Hristov et al., 2015), contents and composition of SOM (Ivanov et al., 2007; Gencheva and Filcheva, 1995; Filcheva, 2000) and interaction of tree vegetation with soil`s substrates (Kolarov and Shishkova 1983; Gencheva and Filcheva, 1995; Ilinkin and Dimitrova, 2019). It is important to see the influence of forest-tree species on humus accumulation and the composition of humus over a longer period of time, as the age of the substrate is also a factor influencing soil formation processes (Ivanov, 2007).

The aim of the present study is to analyze the influence of *Pinus nigra Arn*., *Betula alba* L.and *Fraxinus pennsylvanica* Marsh on the accumulation and composition of organic matter in spoils from mining sites of Pernik.

The study has both confirmative character for the species *Pinus nigra* Arn, *Betula alba* L., but having in mind that it is made in a significantly older and unexplored substrate for this purpose, as well as the accumulation of new information regarding the species *Fraxinus pennsylvanica* Marsh.

Material and methods

The sample plots (SPs) are set on a reclaimed spoil in the area of Baikusheva mahala, about 200 m from the mine “M. Tolbuhin”, at the exit from Pernik to the right of the road Pernik - Breznik. The recultivation was carried out in the early 70's and the plantations are about 45 years old. There are 3 SPs under the different types of woody plants:

SP1 (sample plot 1) – under black pine /*Pinus nigra* Arn./ in the middle of the hill, in the presence of grass cover of cereals ~ 60%;

SP2 (sample plot 2) – under birch /*Betula alba* L./ at the bottom of the hill, in the presence of grass cover of cereals ~ 90%;

SP3 (sample plot 3) – under ash /*Fraxinus pennsylvanica* Marsh/ at the top of the hill, in the presence of grass cover of cereals ~ 30%;

Parents materials are represented mainly by marls, with impurities of black coal shale, as well as slag (Hristov et al., 2015). Sampling was performed in 3 layers: 0-20; 20-40; 40-60 cm. It is determined: pH – potentiometrically by pH-meter "Placitronic, MV 88" according ISO 10390, 2002; Total carbon (C%) and humus (%): by the Thurin method; Total nitrogen (N%): by the Keldal method – (Donov et al., 1974); the composition of humus by Kononova, Belchikova method (1961). This method consists of determination of total content of humic and fulvic acids with a mixed solution of 0.1N $Na_4P_2O_7$ and 0.1M NaOH; free acids and bound to the sesquioxides (R_2O_3) with 0.1M NaOH; aggressive fulvic acids with 0.05M H_2SO_4.

Results and Discussion

The results of the study of the main chemical properties of the spoil`s substrate under the different forest-tree species are given in Table 1..

With recultivation after mining activity is associated the changes in pH of substrate (Cardenas-Aguiar et al., 2020). All substrates of investigated SPs has pH in the range 7.05 ÷ 7.60 which defined substrates as neutral. This result coincides with the characteristics of most spoilss of the Pernik mining basin, found by Donov et al., (1978). In literature dominates opinion that more often vegetation restoration of mining sites could alleviate soil alkaline and in such way moderate accumulation of soil nutrients (Feng et al., 2019; Deng et al., 2020). In our cases acidity is stabilized around pH = 7. For tree species pH preferences vary between range 5.0-6.5 (Feng et al., 2019), which shows a slightly more alkaline reaction of investigated substrate from favorite of the species.

Table1. *Main characteristics of mining spoil in SPs*

SPs	Depth cm	pH	Humus%	C%	N%	C/N
under black pine /*Pinus nigra* Arn./						
SP1	0-20	7.05	6.29	3.65	0.17	21.47
	20-40	7.47	4.96	2.88	0.14	20.57
	40-60	7.60	2.32	1.34	0.08	16.75
under birch /*Betula alba*/						
SP2	0-20	7.23	11.32	6.91	0.28	24.68
	20-40	7.30	11.09	6.43	0.23	27.96
	40-60	7.34	10.09	5.86	0.20	29.30
under plain /*Fraxinus pennsylvanica*/						
SP3	0-20	7.26	16.38	9.50	0.35	27.14
	20-40	7.27	15.23	8.83	0.29	30.45
	40-60	7.31	11.42	6.62	0.25	26.48

The main indicator determining soil fertility for rehabilitated mining substrates is organic matter (Hristov et al., 2015). It plays an important role in soil formation processes in mining areas (Sokolovska et al., 2014). Tree species influence SOM, tN and C/N in top-soils 0-10cm (Zhiyanski et al., 2008). In our case, there is a significant and differentiated differences of the influence of tree species on the accumulation of humic substances in the substrate. The substrate in terms of humus content is defined as rich humu (Filcheva and Ilieva, 2014), and the one under ash /*Fraxinus pennsylvanica* Marsh/ as very rich in humus (humus > 15%). Main component in OM (organic matter) is OC (organic carbon) that plays crucial role in soil structure and fertility (Feng et al., 2019). The content of OC varies moderately to high under black pine /*Pinus nigra* Arn./ to very high under birch /*Betula alba* L./, and especially under ash /*Fraxinus pennsylvanica Marsh/* (OC > 5.9%). This high content of OM and OC in spoil is due to the availability of coal dust in the substrata, which is an inherited coal carbonized organic matter, and which is not related to the newly accumulated due to the decomposition of organic waste from tree species. The same effect of coal particles on tC is found by other authors studying the organic matter in mining spoils of Pernik (Donov et al., 1978; Gencheva and Filcheva, 1995; Ivanov et al., 2007; Sokolovska et al., 2014; Hristov et al., 2015). In our case however, having in mind that this is one and same mining spoil, which suggests a similar composition, including organic composition, and having in mind that the content of OM under coniferous species (black pine) is differentiated lower, we could talk about the influence of tree species on organic accumulation. Very high content of organic matter is found under deciduous tree vegetation in mining substrates from the vicinity of the studied spoil Hristov et al., (2015). Donov et al. (1978) for reclaimed spoils from Pernik found the highest accumulation of organic matter under birch /*Betula alba* L/.. The same was reported by Kolarov, Shishkova (1983). In our case, there is indeed a very high content of OM under birch, but especially high is the accumulation of organic matter under the newly studied species – ash /*Fraxinus pennsylvanica* Marsh/.

The content of tN follows the trend of tC. In the surface layers, the substrate under black pine is moderately stored with tN, but poorly stored at a depth of 20-40 cm (tN <0.15%). On the contrary, under birch it is well stocked with tN (0.2-0.25%). Very stocked with tN (> 0.25%) is the substrate below clear /*Fraxinus pennsylvanica* Marsh/. This increased values of tC and tN and accumulation of litter and root biomass accelerate formation of humus (Mukhopadhyaya et al., 2013).

The other tendency that can be observed is the reduction of content of tC and tN into depth. This speaks about advanced degree of soil-forming process, because there are other older data about heterogeneity in distribution of tC into depth in more younger substrates from Pernik (Gencheva and Filcheva (1995). In Pernik, under tree species is also observed elementary soil forming process under 5-10 years after recultivation of mining spoils (Prokopiev, 1967; Gencheva and Filcheva, 1995). In literature has data that soil-forming process can be observed after 10 years and could be stabilized after 20 years (Feng et al., 2019). After 45 years here we find such stabilization of soil forming processes.

The results of the analysis of the composition of the organic matter in investigated spoil in Pernik is given in Table 2. In fact the composition of humus represents the ratio between humic acids - more stable part of humus which shows his maturity, and fulvic acids - more reactive and mobile part of humus, which shows his lability. In all depths in all SPs we find bigger quantity of humic acids in comparison with fulvic acids. This could be sign of more advanced degree of humus-accumulation processes as well as favorable climatic conditions. A higher percentage of humic acids under black pine is seen compared to deciduous tree species, but this is due to the higher percentage of total carbon extracted with the pyrophosphate solution. Ths is a peculiarity, that the lowest percentage of fulvic acids (~ 5%) is observed under the newly studied deciduous species /*Fraxinus pennsylvanica* Marsh/. The other trend is the decreasing of humic acids towards the deeper layers. In relation with fulvic acids this tendency has exception – in SP2. We calculated also the ratio Ch / Cf, which defines the type of humus. The humus is of the fulvate type at Ch / Cf < 0.5, of the humate-fulvate type at Ch / Cf > 0.5, and of the humate type at Ch / Cf > 1 (Orlov, 1985).

Table 2. *Composition of organic matter*

SP	Depth cm	Organic C% Extracted with 0.1 M $Na_2P_4O_7$ + 0.1MNaOH			Ch / Cf	Organic C% Fractions of humic acids		Non extracted organic C % (humin)	"Aggressive" fulvic acids
		Extracted totally	Humic acids Ch	Fulvic acids Cf		Free or bounded with R_2O_3	Bounded with Ca		
under black pine /*Pinus nigra* Arn./									
SP1	0-20	1.34 36.71	0.76 20.82	0.44 12.50	1.72	100	0	2.32 63.56	0.12 3.28
	20-40	0.82 28.47	0.53 18.40	0.21 7.29	2.52	100	0	2.01 69.79	0.06 2.08
	40-60	0.66 49.25	0.44 32.84	0.15 11.19	2.93	100	0	0.78 58.21	0.07 5.22
under birch /*Betula alba* L./									
SP2	0-20	1.74 25.18	1.08 15.62	0.51 7.38	2.12	100	0	5.08 73.51	0.13 1.88
	20-40	1.48 23.07	0.95 14.77	0.40 6.22	2.38	100	0	4.97 77.29	0.14 2.17
	40-60	1.28 21.84	0.73 12.46	0.45 7.68	1.62	100	0	4.55 77.64	0.09 1.53
under plain /*Fraxinus pennsylvanica* Marsh/									
SP3	0-20	2.14 22.53	1.53 16.11	0.52 5.47	2.94	100	0	7.38 77.68	0.13 1.36
	20-40	1.48 16.76	0.97 10.99	0.43 4.87	2.26	100	0	7.35 83.24	0.09 1.02
	40-60	1.40 21.15	0.96 14.50	0.34 5.14	2.91	100	0	5.22 78.83	0.12 1.81

P.S. column 1, 2, 3, 4, 5, 6, 7 are given as a % to the weight of soil sample,
under line column 1, 2, 3, 4, 5, 6, 7 are given as a % to the total carbon (from table 1)

Gencheva, Filcheva (1995) studying the humus formation of the spoil "Teva" found that it proceeds differently under different types of phytocenoses, and under black pine they founf that the process is of the fulvate type. In our case, where we study a significantly older substrate, with a more advanced soil formation process, we find under black pine a humate type of humus formation, and the same is under deciduous tree plantations (Ch / Cf > 1) (Orlov, 1985).

Logically, the highest amount of "aggressive" fulvic acids is observed under the coniferous plantation of black pine (2 ÷ 5% from tC) compared to deciduous tree species. The lowest content of these most mobile organic acids is below ash /Fraxinus pennsylvanica Marsh/ where the percentage of Cf "aggressive" is moving ~ 1%.

For all layers humic acids is free or bounded with R2O3 sesquioxides and do not form stable complexes with Ca ions. This could due to the chemistry of parent materials and shows one more expressed mobility of OM towards deeper layers. On the contrary, for the mining spoils of the "Teva" mine, Gencheva and Filcheva (1995) found 100% bound to Ca ions.

The amount of non-extracted with pyrophosphate C% - so called "humin" is very high for all samples (63-83%). This is normal when studying mining spoils from Pernik, where the amount of coal fractions is too high (Ivanov, 2007). For soils under forest crops in urbanized parks Zhiyanski et al. (2012) calculate the degree of humification (Ch / tC) * 100% which is very weak (<10%), weak (10-20%) and medium (20- 30%). The degree of humification in the individual layers of the substrate from all SPs are given in Figs. 1.

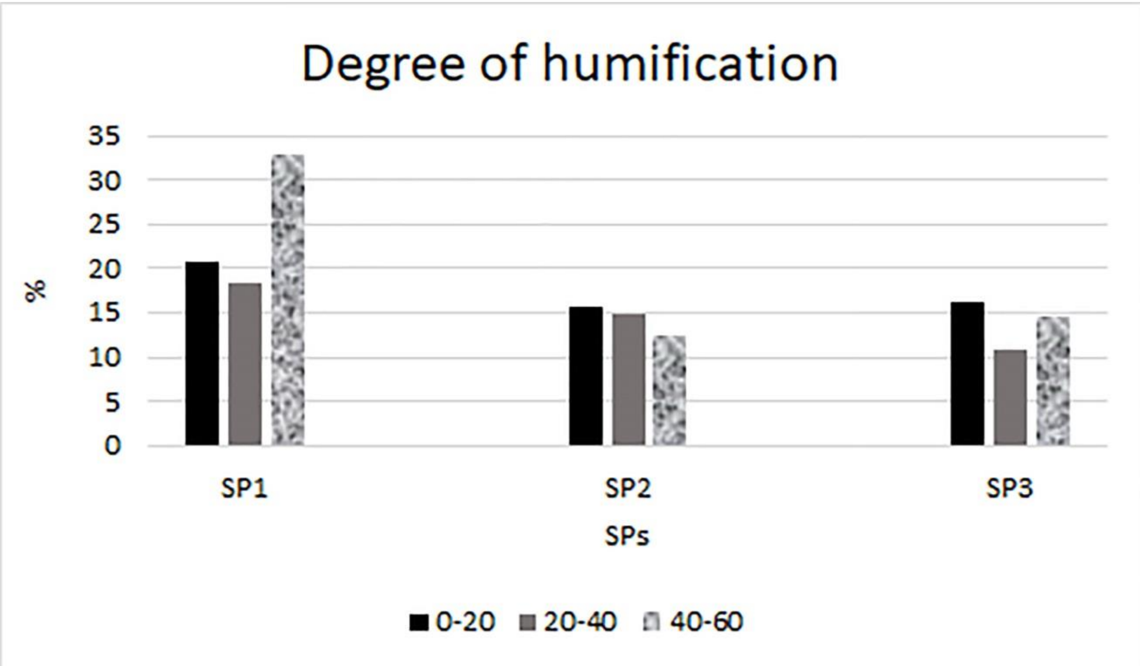

Figure 1. *Degree of humification in the spoils of investigated SPs*

The processes of humification take place with the highest degree under the coniferous plantation of black pine /*Pinus nigra* Arn./ Here, however, this is accompanied by a greater accumulation of more mobile fulvic acids. Under deciduous tree plantations, the degree of humification is lower, but nevertheless sufficient amounts of humic acids is accumulated, and less fulvic acids in comparison with coniferous plantation.

Conclusion

The current researches show that the processes of humus formation and humus accumulation in a mining spoil after a longer period of time from the conducted restoration (~ 45ys) take place differently under the different tree species. The largest amount of org.C accumulates under *Fraxinus pennsylvanica* Marsh. Although, under this plantation is the lowest degree of humification, in the substrate below it accumulate sufficient amounts of more stable humic acids, which have significantly high quantity in comparison with more mobile fulvic acids. Under the coniferous plantation of *Pinus nigra* Arn. although the rate of humification is the highest, it is associated with the formation of the largest amounts of fulvic acids, and therefore with a more labile composition of the newly formed humus in the mining substrate.

References

Atanasova, I., M. Banov, T. Shishkov, Z. Petkova, B. Hristov, P. Ivanov, E. Markov, I. Kirilov, M. Harizanova, 2018. Relationships between soil water repellency, physical and chemical properties in hydrophobic technogenic soils from the region of maritsa-iztok coal mine in Bulgaria. Bulgarian Journal of Agricultural Science, 24, 2: 10-17.

Banov, M., E. Filcheva, B. Hristov, 1989. Humus accumulation and composition of humus in reclaimed lands. Soil science and Agrochemistry, 4: 3-8. (in Bulgarian).

Banov, M., S. Marinova, 2016. Reclamation of Heaps of Solid Waste. – Ecological Engineering and Environmental Protection, 3: 23-31.

Bech, J., M. Sokolovska, M. Zhiyanski, E. Filcheva, N. Roca, 2012. Soil organic matter quality in a former mine site of NE Spain. Silva Balcanika, 13, 1: 30-37.

Cardenas-Aguiar, E., G. Suarez, J. Paz-Ferreiro, M.P.J. Askeland, A. Mendez, G. Gasco, 2020. Remediation of mining soils by combining Brassica napus growth and amendment with chars from manure waste. Chemosphere, 261 (2020) 127788, in press: www.elsevier.com/locate/chemosphere

Deng, J., X. Bai, Y. Zhou, W. Zhu, Y. Yin, 2020. Variations of soil microbial communities accompanied by different vegetation restoration in an open-cut iron mining area. Science of the Total Environment, 704, (2020), 135243 in press: www.elsevier.com/locate/scitotenv

Donov, V., Gencheva, S. & Yorova, K. 1974. Guidance on Soil Analysis, Sofia, Bulgaria: Zemizdat. p. 220. (in Bulgarian)

Donov, V., S. Gencheva, E. Geleva, N. Delkov, D. Pavlov, R. Milanov, 1978. Recultivation of Industrial Spoils. Zemizdat, Sofia, 166 p. (in Bulgarian).

Feng, Y. , J. Wanga, Z. Baia, L. Reading, 2019. Effects of surface coal mining and land reclamation on soil properties: A review. Earth-Science Reviews, 191: 12-25.

Filcheva, E., M. Noustorova, S. Gencheva, M. J. Haigh, 2000. Organic accumulation and microbial action in surface coal-mine spoils, Pernic, Bulgaria. Journal of Ecological Engeneering, 15, (1-2): 1-15.

Filcheva E., R. Ilieva. 2014. Soil organic matter of Bulgarian Chernozems. 17 th International Conference of IHSS, 1-5 September, Ioannina, Greece.

Gencheva, S., E. Filcheva, 1995. Organic matter composition in reclaimed lands from opencast mining. In: Proceedings from Sientific sessein "70 ys. Forestry education in Bulgaria", 7-9 April, Sofia, 3: 3-10. (in Bulgarian).

Henry, H., J. Burken, R. Maier, L. Newman, S. Jerald, L. Schnoor, W. Suk, 2013. Phytotechnologies – Preventing Exposures, Improving Public Health. International Journal of Phytoremediation, 15, 9: 889-899.

Hristov, B., T. Shishkov, V. Katchova, E. Atanassova, I. Atanassova, 2015. Basic chemical and physic-chemical characteristics of soils and substrates in the region of Pernik coal mine basin. International Conference "Soils and agrotechnology in the changing worlds" 11-15 May, Sofia.

Ilinkin, V., V. Dimitrova, 2019. Forestry Reforestation vs. Spontaneous Revegetation- Soil Changes in Coal Mining Spoil Heaps Across Bulgaria. Ecologia Balkanica, 11, 2: 25-36.

Ivanov, I., 2007. Soil forming processes in reclaimed lands from recovered landscapes from industryal activities with different waies of usage. PhD Thesis, Institute of Soil Sci, Agrotechnology and Plant Protection "N. Pushkarov, 156 p.(in Bulgarian).

Ivanov, I., E. Filcheva, M. Banov, 2007. Organic matter content in Reclamed lands after Mining Industry. Soil science, Agrotechnology and Ecology, XLI, 1: 27–30. (in Bulgarian).

Jobbagy, E., Jackson, R., 2000. The vertical distribution of soil organic carbon and its relation to climate and vegetation. Belowgr. Process. Glob. Chang. 10: 423-436. https://doi.org/10.1890/1051-0761(2000)010[0423:TVDOSO]2.0.CO;2.

Kolarov, D., R. Shishkova, 1983. Studies on phytosintetical activity of deciduous tree species growth after recultivation of "Maxim taban" in Pernik. Gorskostopanska nauka, XX, 6: 31-39. (in Bulgarian).

Kononova, M., N. Belchikova, 1961. Rapid method of mineral soil humus composition. Pochvovedenie, 10: 75-85. (in Russian).

Mukhopadhyaya, S., .S. Maitia, R Masto, 2013. Use of Reclaimed Mine Soil Index (RMSI) for screening of tree species for reclamation of coal mine degraded land. Ecological Engineerin, 57: 133-142.

Nikova, I., B. Hristov, N. Dinev, M. Hristova, 2019. Assessment of Soil Quality in a Copper Mining Region in Bulgaria. Ecologia Balkanica, 11(2): 13-23.

Orlov, D. C., 1985. Chemistry of soils. MGU, Moskva, 376 p. (in Russian).

Prokopiev, E., 1967. Landscaping of industrial regions. Zemizdat, Sofia, 144 p. (in Bulgarian).

Simeonova, T., M. Benkova, L. Nenova, I. Atanassova, 2018. Chemical Composition of Soil Solutions of Technosols from a Coal Mine Region in SouthEastern Europe. Bulgarian Journal of Soil Science, 3, 1: 4-12.

Sokolovska, M., M. Zhiyanski, E. Slavtcheva, N. Roca, J. Bech, 2014. General Characteristics of Organic Matter in Reclaimed Soils. 한국토양비료학회 학술발표회 초록집, 6: 509-509.

Sun, X., B. Li, F. Han, E. Xiao, Q. Wang, T. Xiao, W. Sun, 2019. Vegetation type impacts microbial interaction with antimony contaminants in a mining-contaminated soil environment. Environmental Pollution, 252: 1872-1881. (in Russian).

Zheleva, E., B. Bogdanov, M. Tsolova, 2004. New ecological and technical problems of reclamation of disturbed terrains from Maritza-Iztok coal mines. Management and Sustainable development, 1-2 (10), 323-328.

Zhiyanski, M., Kolev K., Sokolovska M., 2008. Tree species effect on soils from central Stara Planina Mountains. Forest Science, 4: 65-82.

Zhiyanski, M., M. Sokolovska, E. Filcheva, Y. Yordanov, 2012. Soil Organic Matter of Urban Forest Parks Journal of Agricultural Science and Forest Science, XI, 3: 21-26. (in Bulgarian).