Physico-chemical properties of lignite mine reclaimed soil formed under 19 different tree species in Sokolov, Czech Republic

Spasić M., Drábek O., Tejnecký V., Vacek O., Ing. Borůvka L.
Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, Prague 6 - Suchdol, Czech Republic
spasic@af.czu.cz, drabek@af.czu.cz, tejnecky@af.czu.cz, vacek@af.czu.cz, boruvka@af.czu.cz

Abstract: *Coal mining was, and still is, a very important part of Czech national economy. Since 1957, it has been compulsory for organizations which have been granted mining permissions to carry out restoration procedures after the mining is finished. The aim of this research was to compare the physico-chemical properties of reclaimed mine soil of Antonin locality in the Sokolov mining basin, Czech Republic, which was experimentally afforested between 1968 and 1972. 5 undisturbed soil samples were taken from each of the 20 homogeneous stands (100 samples in total) composed of 19 various tree species (10 broadleaved and 9 coniferous) and bulk and specific density, porosity, water retention capacities, pH, soil oxidizable carbon (SOC) and total levels of N, C and S were determined and compared. In most cases, forming of soils with better overall physical and chemical properties was noticed under the broadleaved species.*
Keywords*:* RECLAMATION; SOIL; LIGNITE; MINING; PHYSICAL PROPERTIES; CHEMICAL PROPERTIES; CARBON; DUMPSITES;

1. Introduction

Coal mining has been extensively used in the Czech Republic ever since the beginning of 19th century, and was and still is a very important part of the Czech national economy [1]. Due to vast areas being affected by open-cast mining, a Mining Act was imposed in 1957, stating that it's obligatory for the organization with the granted mining permission to carry out rehabilitation and restoration after the mining is finished [2]. Although many research results and expert recommendations in recent years concluded that technical reclamation is an expensive approach which diminishes biodiversity, and it should be avoided if possible, over the years, many coal mining sites have been subjected to this process, and subsequently revegetated. After the excavation process had ended, Antonin, a locality near the city of Sokolov, in the northwestern part of the Czech Republic, was experimentally afforested between 1968 and 1972 with different tree species, 19 of which were processed in this research. After more than 50 years have passed since the reclamation was performed, these stands have shown an observable process of soil formation underneath them, where, in most cases, there is a visible soil profile with distinguished A, B and C soil horizons. The main goal of this research was to determine the basic physical and chemical properties of the uppermost soil layer, and compare the results between the tree species encompassed within it.

2. Materials and methods

Soil samples used in this research were taken from 20 homogenous stands comprised of 19 different tree species, 10 of which are broadleaved (*Quercus* sp., *Fagus sylvatica*, *Carpinus betulus*, *Pyrus communis*, *Acer pseudoplatanus*, *Acer platanoides*, *Tilia cordata*, *Betula pendula*, *Alnus glutinosa* and *Ulmus glabra*), and 9 are coniferous (*Pinus nigra*, *Pinus sylvestris*, *Pinus uncinata* subsp. *uliginosa*, *Pinus strobus*, *Pinus contorta*, *Picea abies*, *Picea omorika*, *Pseudotsuga mensiesii* and *Larix decidua*). Two different *Tilia cordata* stands on different exposures and slope angles were examined in order to see the differences these changes might make. Undisturbed soil samples were taken from the organomineral A horizon using 100 cm^3 Kopecky steel cylinders. For statistical purposes, 5 scattered samples were taken from each stand, the total number of samples being 100. The sampling was done between 10th August and 9th November 2018.

The samples were gravimetrically measured for determination of moisture content and water capacities (fully saturated, 30 minutes from saturation, maximum capillary water capacity after 2 hours from saturation, and water retention capacity after 24 hours), as well as bulk density, using the methodology described by Valla et al. in 2008 [3]. The same methodology was used for determination of particle density and capillary and non-capillary porosity. Soil pH was measured in $CaCl_2$ solution according to SFU Soil Science Lab manual from 2011 [4] using "WTW pH7110" pH meter. Soil oxidizable carbon content was determined using the oxidimetric (Tyurin) method, and total contents of carbon, nitrogen and sulphur were determined using Thermo Scientific Flash 2000 NCS Analyzer.

The results were statistically processed using Statistica, with repeated measures ANOVA and Tukey's HSD test used on all sample groups.

3. Results and discussion

After analysing the bulk densities, it was noticed that the samples from lime, beech and pear stands have shown the smallest values (the average values varied between 0.7-0.8 g/cm^3). 10 other species have not shown significant statistical differences, with the average values varying from 0.840-0.950 g/cm^3, whereas hornbeam, birch, Norway spruce, larch, black pine and Scots pine have shown the greatest bulk density values (0.969-1.092 g/cm^3). Particle densities have shown a similar trend, where lime and pear had the smallest values (2.17 and 2.22 g/cm^3, respectively), and Scots pine had the greatest (2.489 g/cm^3), with other species being in between and showing no significant statistical differences among each other. Soil samples taken from beech, lime and pear stands have also shown the greatest porosity, both non-capillary and capillary, whereas spruce, birch and larch have had the smallest values.

Water retention results have shown that elm, spruce, alder, both maple stands and oak stand samples have shown higher water retention levels all the way from fully saturated, to 24 hours later. The average values of these samples varied from 61.59% for fully saturated to 46.11% after 24 hours from saturation, whereas the values of the Weymouth pine, Lodgepole pine, hornbeam and one of the lime stand samples varied between 43.67 (fully saturated) and 28.28% (after 24h), making these samples the least capable in terms of water holding ability. These results are graphically depicted in Fig. 1.

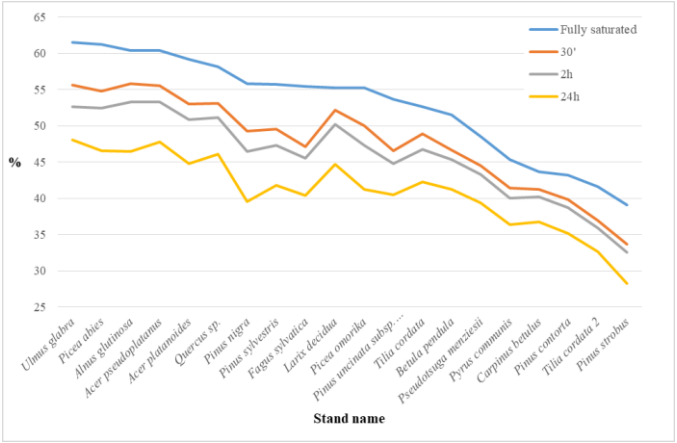

Fig. 1 *– Water retention properties of the samples from the 20 studied stands*

Average pH values of the studied soil samples varied between 5.33 and 7.07. As expected, the lowest values belong to Weymouth pine and Norway spruce (5.33 and 5.43, respectively), followed by hornbeam (5.84). The highest value belongs to black pine (7.07), followed by Scots pine, Norway maple, Scots elm and larch (6.94-6.72). Omorika and alder stands samples have had yet somewhat smaller values (6.49 and 6.48), while the samples from the other 10 stands, ranging in pH values from 5.95 to 6.43, have shown no significant statistical differences among each other. These results are graphically presented in Fig. 2.

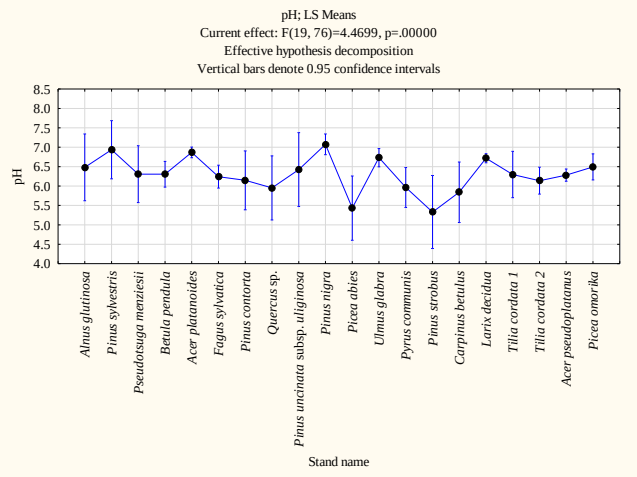

Fig. 2 *– Average pH of the studied samples*

Analysis of oxidizable carbon (SOC) content has shown no significant statistical differences between the samples, although the mean values vary from 4.62% for Scots pine, to 9.94% for Weymouth pine. One of the lime samples, pear and Sycamore maple have also shown somewhat higher values. The total carbon levels have shown a similar trend to the oxidizable carbon, with, as expected, few per cents more, and the total C values varied from 5.52% for Scots pine to 13.84% for Weymouth pine. In the latter (total C) case, these two species have shown statistical differences among each other, while the others have shown no statistical differences.

Total nitrogen mean values varied between 0.24% for Scots pine and 0.67% for pear samples, and the difference between coniferous and deciduous species was much more noticeable. Soil samples from all coniferous stands have shown an average total nitrogen value of less than 0.35%, while samples from broadleaved stands ranged from 0.36 to 0.67%. The samples with the highest N content are pear, lime and Sycamore maple, followed by Scots elm, another lime and oak. Total average N levels of the studied samples are shown in Fig. 3.

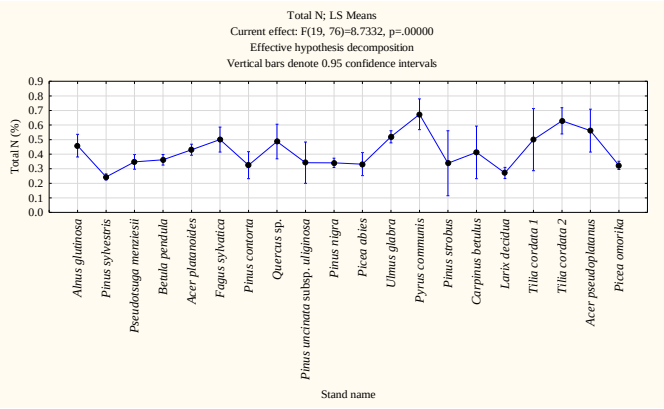

Fig. 3 *– Average total N levels of the studied samples.*

Range of average total sulphur content varies from 0.16% for Weymouth pine to 0.42% for Norway maple. The highest S levels (0.42-0.34%) were noticed in both of the maple stands, black pine, elm, and Douglas fir. Weymouth pine, hornbeam, alder and spruce have shown the smallest values (less than 0.22%).

By comparing the results of all the analyses performed in this research, and taking the stands that have shown significant statistical differences in consideration, it can be noticed that both maple stands, elm, pear and lime have shown the best overall physical and chemical properties that are generally considered favourable (low average bulk and particle density, higher porosity and water retention values, higher pH, and higher carbon, nitrogen and sulphur values). Some of these species (maples, lime and elm) have also previously been described as favourable because of their ability to produce the highest quality humus [5], along with alder and hornbeam. Broadleaved species such as these have also been noticed to support better conditions for edaphon development than conifers [5], which further reinforces their applicability on reclamation sites. The depth of the formed A horizon was also usually several times greater in broadleaved stands, compared to coniferous ones. The most noticeable differences between coniferous and broadleaved species were observed when total nitrogen levels were analysed and compared. When comparing the two lime stands, in most cases it was noticed that the results from the one on greater slope (9.4°) are more favourable than the one on minor slope (2.7°). On the other hand, out of the broadleaved stands, hornbeam (*Carpinus betulus*) has not shown very favourable results in several of the aforementioned categories. Although sometimes showing satisfying results in some of the categories, most of the samples from coniferous stands have shown drastically less favourable soil properties. Coniferous species that have proven to have the least favourable properties were Weymouth pine (*Pinus strobus*) and Scots pine (*Pinus sylvestris*).

Planned further research related to soil texture, structure, stability of structural aggregates, available nutrients and potentially toxic elements should provide us with more information on the influence of these species on the quality of the soil formed underneath the stands and the overall soil properties. Besides that, litter bag decomposition experiments are also planned, as well as some more complex chemical and biological analyses.

3. Conclusions

Having in mind all of the mentioned analyses performed on these samples, it can be stated that the species which are the most suitable for soil development of lignite reclaimed mine sites in Central European region, in terms of physical and chemical properties, are maples (both *Acer pseudoplatanus* and *Acer platanoides*), Scots elm (*Ulmus glabra*), pear (*Pyrus communis*) and lime (*Tilia cordata*). On the contrary, species such as hornbeam (*Carpinus betulus*), Weymouth pine (*Pinus strobus*) and Scots pine (*Pinus sylvestris*) have shown the least favourable physico-chemical soil properties.

4. References

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