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INFLUENCE OF FERTILIZATION ON MICROBIAL ACTIVITIES, SOIL HYDROPHOBICITY AND MINERAL NITROGEN LEACHING

WPŁYW NAWOŻENIA NA AKTYWNOŚĆ MIKROORGANIZMÓW, HYDROFOBOWOŚĆ GLEBY ORAZ WYPŁUKIWANIE AZOTU MINERALNEGO

Abstract: This work presents the analysis of the influence of compost and reclamation substrate addition and mineral fertilizers application on leaching of mineral nitrogen, microbial activities, soil hydrophobicity and plant biomass production. To demonstrate the effect of compost, reclamation substrate and mineral nitrogen (N_{min}) addition on above parameters, the pot experiment was performed. As a model crop, *Deschampsia caespitosa* L. was used and cultivated for 63 days in climate chamber. The leaching of N_{min} was measured by application of ion exchange discs, soil hydrophobicity was determined based on the values of saturated hydraulic conductivity (K_{sat}) and microbial activity was expressed as basal (*BR*) and substrate induced respiration (*SIR*). Four variants (V1-V4) with different doses of fertilizers were prepared: V1 - control without addition of fertilizers; V2 - this variant of experiment was prepared as mixture of compost and arable land in ratio 7:3; V3 - 90 g/m^2 of mineral fertilizers NPK (in the ratio 1:1:1) were applied there and into V4, dose 30 g of compost were applied. The significant differences ($P < 0.05$) in the detection of N_{min}, values of K_{sat} and *SIR* were found. The highest decrease of mineral nitrogen leaching was observed by the simultaneous applications of compost (V4) to arable soil, about 50% in comparison with the variant V4 (application of mineral fertilization) and about 10% in comparison with the control. Variants with addition of compost (V2 and V4) showed higher values than variants without, which were measured at three stages (before application of N_{min} - 12 days after establishment of the experiment; after application of N_{min} - 34 days; at end of the experiment - 63 days). During the experiment, two types of respiration were measured: *BR* and *SIR*. The significant differences in *SIR* were found between variants with addition of compost and variants without. The SIR (cumulative production of CO_2) was higher about 25% in variants V2 and V4 compared to variants V1 and V3. The highest values of K_{sat} were found in variants with addition of compost. Conversely, the lowest value of K_{sat} was detected in variant with addition of N_{min}. Low values of K_{sat} indicate an increased level of hydrophobicity.

Keywords: compost, reclamation substrate, microbial activity, mineral nitrogen, soil hydrophobicity

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Introduction

Soil is a natural resource that is not renewable in a historical time scale. Soil is the first link in the food chain determines the chemical composition of plants, and finally the health of humans and animals [1]. Soil erosion is a natural phenomenon and has occurred throughout geological history. However, human activities have increased erosion rates. This human influenced process is termed accelerated erosion [2]. Erosion is a major factor for soil degradation which causes irreversible effects.

Today in many parts of Eastern Europe the soil cover was significantly damaged by erosion processes [2]. Significant erosion influence on soil cover due to human impact started in medieval times [3]. Soil erosion, leaching of nutrients and soil fertility depletion are one of the key threats to soil in both industrialized countries (developed) and in developing countries. These problems include increasing application of mineral fertilizers, decrease in addition of organic materials such as manure or organic waste compost into arable land and cultivation on marginal and fragile lands [4-6].

Soil has been perceived by human beings as a source of building materials and as the medium for farming, ergo the lowest component of the food chain. However, from an environmental point of view, soil should be perceived as an ecosystem, the quality of which is influenced positively or negatively by the mutual interaction of individual (animate and inanimate) components. For that reason, soil has to be considered an animate, dynamic and vitally important part of the ecosystem [7].

Within an environmental and sustainable agricultural policy, reduction of soil erosion must be a priority. Erosion causes damage not only to cultivated soils, but it also affects water quality and is responsible for sediment transport, causing many off-site problems such as mud floods. Hereafter, we only consider water erosion occurring in cultivated areas, excluding erosion of river banks and mountain areas, as well as mass movements that result from different factors and processes [8].

Currently modern agriculture is faced with the question of how to resolve these issues. These problems can be solved only by changes in the farming. The basis of all changes in modern (intensive) agriculture should be to achieve sustainable arable soil. Sustainable arable soil is the cornerstone of sustainable agriculture. This new way of agricultural management represents a different approach to farming on arable soil. Sustainable agriculture aims to increase soil organic matter content, support microbial activity and improve soil physical a chemical parameters [9].

The fundamental change is to increase the content of soil organic matter in arable soil using organic substances. Organic matter (substances) can be applied as manure, crop residues, compost or reclamation substrates that are suitable for highly degraded soil [4, 5].

A significant problem is the price of these materials and their application. For example, the decline in livestock production and the cultivation of monoculture instead of forage in the Czech Republic is the main reason for the lack of organic residues; these are necessary to increase the content of soil organic matter in the Czech Republic. Thus, in the second half of the nineties farmers started to look for compensation and found it in the form of a compost.

Compost, the main product of composting, may be defined as the stabilized and sanitized product of organic matter decomposition [9]. Czech farmers' lack of interest to use compost as organic fertilizer caused that the compost producers can start to use more for the preparation of reclamation substrates [10]. Application of compost (from vegetable, fruit, garden and organic waste) and reclamation substrate that is made from it has positive influence on soil fertility, soil properties (chemical and physical) and microbial activity [9, 11]. This positive influence is possible due to the chemical composition and structure of the compost. More than 80% of the total nitrogen content is in organic compounds together with carbon. Available carbon and nitrogen is source of energy for microorganisms, thus this energy can be subsequently used for the processing of nitrogen. Consequently, nitrogen is fixed in the bodies of soil microorganisms and during their life cycle nitrogen is progressively released into the rhizosphere of cultivated crops. Positive influence of compost on soil structure is based on the content of the solid fraction (>5 mm), which in combination with organic substances makes a prerequisite for increasing the ability of water retention and creation of capillary pores [4, 5, 9]. These facts are very important for achieving the optimum soil properties and thus cost-effective production of cultivated crops.

Therefore, the influence of compost and reclamation substrate addition as well as mineral fertilizer addition on selected parameters was studied. The hypothesis arguing that the compost addition has better positive effect on plant growth, microbial activities, the leaching of mineral nitrogen from arable soil and soil hydrophobicity than the reclamation substrate addition and mineral fertilizer application was tested. This paper presents the results of a laboratory experiment.

Objectives of this study were: (i) to determine and compare the effect of compost, reclamation substrate and mineral nitrogen addition on microbial activity; (ii) to determine and compare the effect of compost, reclamation substrate and mineral nitrogen addition on soil hydrophobicity and leaching of mineral nitrogen from arable soil; (iii) to identify the influence of the above fertilizing substances on soil fertility - production of plant biomass.

Material and methods

The experiment was carried out in plastic experimental containers (Fig. 1) of a diameter of 10 cm and a height of 11 cm filled up with arable soil collected from protection zone of underground drinking water source Březová nad Svitavou, where annual climatic averages (1962-2012) are 588.47 mm of precipitation and 7.9°C mean annual air temperature.

Each experimental container was filed with 550 g of arable soil (with or without the addition of compost and mineral fertilizer). Soil sampling was carried out on 25th November 2013 in accordance with the Czech National Standard ČSN ISO 10 381-6. Compost (C_p) was obtained from the Central Composting Plant in Brno. Samples of C_p were taken on 27th November 2013 in accordance with the Czech National Standard ČSN EN 46 5735. Samples were sieved (grid size of 2 mm) and stored in a thermostat at a temperature of 4°C. The experimental containers were filed with soil samples on 25th February 2014. *Deschampsia caespitosa* was used as a model plant to determine the effect of compost, reclamation substrate addition and the application of mineral nitrogen on plant production. Individual plants (seedlings) for the experiment were pre-cultivated from a formerly single clump of grass. Pre-cultivated seedlings were kept for one month. Before transplanting, both aboveground and underground parts of seedlings were reduced to the same size.

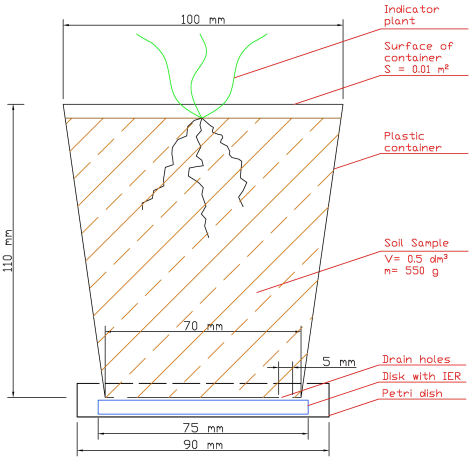

Fig. 1. Experimental container

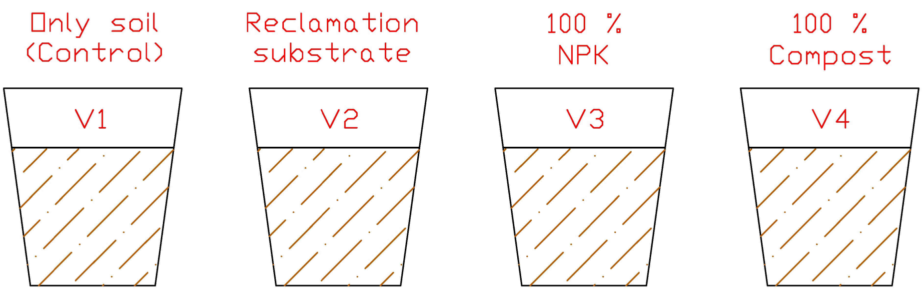

Fig. 2. Distribution of laboratory experiment (percentages represent the proportion of the applied recommended dose of NPK and compost; precise doses of fertilizers are listed above)

The experiment was conducted in the period from 25th February to 28th April 2014 (63 days). During the whole experiment, plants were kept in a climate chamber at 22°C with a day length of 16 hours and a light intensity of 300 μmol/m·s.

Four variants (V1-V4) of the experiment with different doses of fertilizers (C_p, RS and GSH) were prepared. All used fertilizers are registered for agriculture use in the Czech Republic (under Fertilizers Law). GSH (mineral fertilizer containing N, P, K and S in the ratio 10:10:10:13) and special type of C_p - Black Dragon (BD) were used, because these types are registered by Ministry of Agriculture - Central Institute for Supervising and Testing in Agriculture (GSH-NPK reg. no: 2007 and C_p reg. no.: 3372). Each variant had four repetitions: V1 - control was conducted without the addition of fertilizers. V2 - this variant of the experiment (reclamation substrate) was prepared as a mixture of compost and arable soil in ratio 7:3. As for variant V3, only mineral fertilizer was used (GSH). One hundred percent of recommended dose of mineral fertilizer was applied here (90 mg·m^{-2} of GSH). Within variant V4 a 30 g dose of compost was applied (recommended dose in accordance with the Czech National Standard ČSN EN 46 5735 - 50 Mg·ha^{-1}). This dose represents one hundred percent of recommended dose of compost.

Measurement of leached mineral nitrogen

Mineral nitrogen (N_{min} = NH_4^+-N and NO_3^--N) that leached from the experimental containers was captured by special discs with mixed IER (Ion Exchange Resin). Discs were located under each experimental container. The discs were made from plastic (PVC) tubes. Each disc was 75 mm in diameter and 5 mm thick. From both sides of each disc, nylon mesh was glued (grid size of 0.1 mm). Mixed IER (CER - Cation Exchange Resin and AER - Anion Exchange Resin in ratio 1:1) were then placed into the inner space of annular flat cover [12].

After the termination of the Ion Exchange Resin experiment, quantification of N_{min} trapped by the mixed IER (resin) was performed. At first the disks were dried at laboratory temperature (18.5°C) for one week. After 7 days dry IERs were removed from individual discs and divided by the variants (V1, V2, V3, and V4). Subsequently, captured N_{min} was extracted from IER using 100 cm^3 of 1.7 M NaCl. N_{min} that was released by NaCl was determined by distillation-titration method according to Peoples et al [13]. The value of N_{min} was calculated as the sum of the detected ammonium and nitrate forms. The results obtained from the analyses of IER were expressed in mg of N_{min} per m^2 (surface of experimental containers - $mg \cdot m^{-2}$).

Index of nitrogen availability - ammonium production during waterlogged incubation

Ammonium production during waterlogged incubation was used to determine the amount of N which was stored in the microbial biomass. In this method that was carried out by Bundy & Meisinger [14], soil N availability is estimated from NH_4^+-N produced during a seven-day waterlogged incubation. The method is based on the determination of difference between the original and final content of NH_4^+-N. This difference is appropriate to the amount of nitrogen that was previously stored in the original microbial biomass before the incubation. The only anaerobic as well as facultative anaerobic thermopiles (these bacteria constitute a minority in the original soil environment) can survive these extreme conditions of waterlogged incubation at 40°C. Organic N from original microorganisms is mineralized during the incubation and accumulated as NH_4^+-N [12, 14]. The method of nitrogen availability index consists of two parts.

The first part (A) is used to determine the content of NH_4^+-N and NO_3^--N before incubation. NO_3^--N is determined to find out how many N_{min} was in soil. This parameter is very important in evaluating the amount of N_{min} that escaped from the soil. The second part (B) is used to determine the content of NH_4^+-N, which is floated out of the microbial cell. In part A 20 g of soil sample (from each variant and repetition) and 100 cm^3 of 2 M KCl (two molar solution of potassium chloride) were placed into incubation bottle and shaken for 60 min. After shaking, suspension was filtered and concentration of NH_4^+-N and NO_3^--N was performed by distillation-titration method according to Peoples et al [13]. In the second part (B) 20 g of soil sample (from each variant and repetition) and 50 cm^3 of distilled water were placed into incubation bottle. After 7^{th} day of incubation at 40°C, 50 cm^3 of 4 M KCl were added and the sample was shaken for 60 min. After shaking, suspension was filtered and concentration of NH_4^+-N was performed according to the same method as before the incubation [12, 14].

The results obtained from the determination of mineral nitrogen (NH_4^+-N and NO_3^--N before incubation) and ammonia nitrogen (after incubation) were expressed in mg of N_{min} per kg and in mg of NH_4^+-N per kg of soil.

Determination of basal and substrate induced respiration

Basal respiration (BR) was determined by measuring the CO_2 production from soils incubated in serum bottles for 24 hours. Field moist soil (15 g) was weighed into each of three 120 cm^3 serum bottles. Bottles were sealed with butyl rubber stoppers and incubated at 25°C. After 3 and 24 hours a 0.5 cm^3 sample of the internal atmosphere in each bottle was analyzed by gas chromatography (Agilent Technologies 7890A GC System equipped with a thermal conductivity detector). Respiration was calculated from the increase in CO_2 during the 21 h incubation period. At the end of the measurements, the total headspace volume for each replicate bottle was determined by measuring the volume of water required to fill the bottle. The measured amounts of CO_2 were corrected for the gas is solved in the liquid phase. The results are expressed per gram of dry soil and hour [15].

Substrate induced respiration (SIR) was determined by measuring the CO_2 production from soils incubated in serum bottles for 4 hours after the addition of glucose. Field-moist soil (5 g) was added to three replicate serum bottles as described for the determination of BR in the previous paragraph, and 2 cm^3 of a glucose solution was added to each bottle (4 mg C/g of dry soil). Bottles were sealed with butyl rubber stoppers, and soils were incubated at 25°C. After 2 and 4 hours a 0.5 cm^3 sample of the internal atmosphere was analyzed by gas chromatography (see previous paragraph). SIR was calculated from the CO_2 increase during the 4 h incubation period. The bottles were further processed as described for BR measurement [15].

Determination of hydraulic conductivity

Saturated hydraulic conductivity (K_{sat}) was calculated based on the measured volume of water that infiltrated into the soil (infiltration). Cumulative infiltration was measured using Mini-Disk Infiltrometer (MDI) according to Robichaud et al [16]. The measurement is based on the recording of the infiltrated volume of water over the time. High soil hydrophobicity slows water infiltration (hydraulic conductivity is lower) and conversely. Therefore, K_{sat} may indicate a degree of soil hydrophobicity. This was confirmed also by Robichaud et al, Doerr et al, and Buczko et al [16-18].

The calculation of K_{sat} was performed by Šindelář et al, Lichner et al, and Lichner et al [19-21]. K_{sat} was calculated by the modified formula (1), originally Zhang [22]:

$$K_{sat} = C_2 / A_2 \tag{1}$$

where C_2 [m·s^{-1}] is the function of the soil water content θ and suction (h_0) [cm], A_2 is dimensionless coefficient.

This parameter was determined by Van Genuchten equations, which were described by Zhang [22].

Statistical analysis

Differences in the amount of leached mineral nitrogen, index of nitrogen availability, respiration and hydraulic conductivity were analyzed by one-way analysis of variance

(ANOVA) in combination with the Tukey´s test. All analyses were performed using Statistica 10 software.

Results and discussion

Leaching of mineral nitrogen

Leaching of mineral nitrogen from arable soils is a major threat for the quality of drinking water from underground sources in the Czech Republic. The most dangerous are nitrates. These compounds are very mobile in the soil as they have a negative charge, whereas soil sorption complex has minimal affinity for negatively charged particles.

Figure 3 indicates significant differences in the leaching of N_{min} in particular variants. The highest detection of N_{min} (V3 = 78.42 mg·m^{-2}) was recorded for the variant without C_{org} addition. Conversely, the lowest detection of N_{min} (V4 = 37.19 mg·m^{-2}) was found in variant with C_p addition in comparison with control, reclamation substrate and the variant, where mineral nitrogen was applied. Increased value of N_{min} losses in variant V2 was caused by a high dose of compost (12 fold higher dose in comparison with recommended dose). The values of N_{min} in variant V4 indicate a positive effect of C_p addition on leaching from arable soil. Diaz et al [9] state that during the production of compost microbial activity is developing and this activity continues after the application of compost. Moreover, according to Schimel and Bennett [23] microbial activities in soil are necessary for the utilization of nitrogen in soil.

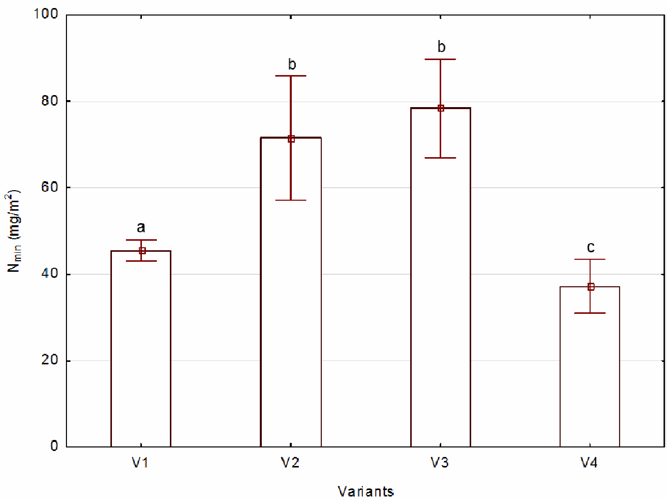

Fig. 3. Detection of mineral nitrogen (mean values ± standard error, $n = 4$, different letters indicate a significant differences at the level 0.05 - ANOVA, $P < 0.05$)

The compost addition has a positive effect on the leaching of N_{min}, because it contains carbon and two forms of nitrogen (mineral and organic). Carbon is a source of energy for microbial activities and nitrogen is the cornerstone for the construction of their bodies. More than 85-90% of total nitrogen is in organic form and is therefore immobile in soil and can be slowly degraded by soil microorganisms. This results in increased functionality of organic-mineral sorption complex and thus in increased capacity for the retention of soil environment for mineral nitrogen [4, 9, 24].

Table 1

Content of N_{min} in soil samples

Variants	N_{min} [mg/kg]	±SE	Mean differences
V1	20.40	1.58	a,b
V2	21.56	0.82	a,b
V3	17.46	2.01	a
V4	27.84	2.44	b

Mean values ± SE (standard error), $n = 4$. Different letters indicate a significant differences at the level 0.05 - ANOVA $P < 0.05$

The amount of mineral nitrogen in arable soil that was determined according to Bundy and Meisinger [14] is an important indicator of soil fertility. For complete results of N_{min} content see Table 2. The Table shows how values of N_{min} content increase in variants with the addition of C_p (V2 and V3). The stockpile of N_{min} was larger in variant V4 compared to V3.

Data presented in Table 1 indicated positive effect of C_p application on soil fertility - content of nutrients (N_{min} - consisting of NO_3^--N and NH_4^+-N) in soil. The highest content of N_{min} was recorded for variant V4 with recommended dose of C_p. Conversely, the lowest content of N_{min} was measured in variants with N_{min} addition. Nevens and Reheul, and Weber et al [11, 24] confirm that the application of C_p contributes to an increase of N_{min} content in soil, because C_p contains organic matter, which is decomposed by soil microorganisms to NH_4^+-N and subsequently to NO_3^--N. Moreover, C_p contains carbon, so that microorganisms had sufficient source of energy for processing available organic nitrogen. Consider Figure 3 and Table 1, which show a relationship between values of N_{min} leaching and values of N_{min} content. These values confirm that recommended dose of C_p has a positive effect on the increase of N_{min} content and its retention in soil, which is a prerequisite for increasing soil fertility.

Ammonium production during waterlogged incubation

Ammonium N (NH_4^+-N) production during waterlogged incubation indicates the amount of NH_4^+-N in microbial biomass, but does not indicate microbial activities in soil [14]. Amounts of NH_4^+-N, which was released from microbial biomass, are summarized in Table 2. These data do not show significant differences among individual variants.

Table 2

Index of nitrogen availability

Variants	NH_4^+-N [mg/kg]	±SE	Mean differences
V1	35.13	2.19	a
V2	40.93	2.30	a
V3	32.81	2.59	a
V4	34.71	0.70	a

Mean values ± SE (standard error), $n = 4$

Basal and substrate indicated respiration

According to previous researches, soil microorganism controls soil respiration and nitrogen mineralization [25]. Silva et al found that microbial and actinomycete populations were positively correlated with gross mineralization and ammonium consumption rates [26]. Muller et al used barometric process separation (BaPS) techniques to indicate that soil microorganism affected soil respiration [27]. Additionally, soil respiration and nitrogen mineralization are also influenced by many environmental factors including soil hydrology, soil texture, and soil aggregate [25]. Moreover, it is widely reported that soil temperature can significantly impact microbial species, quantity, and activity which determine these soil processes [25].

Soil respiration is one of the most important indicators of microbial activity in the soil [15, 28, 29]. Soil respiration is attributed to a wide range of microorganisms, such as fungi, bacteria, protozoa and algae. Moreover, the soil fauna contributes significantly. Generally, the microbial contribution to the total release of CO_2 (excluding root respiration) is thought to be about 90%, compared to 10% released by the fauna. Although fungal biomass often dominates microbial biomass the relation fungi vs. bacteria with respect to respiration may vary considerably, due to, for example, type of ecosystem or soil management. To complete the picture, plant roots also contribute between 12 and 30% to the total release of CO_2 through respiration in the field [29]. The above stated confirm the importance of respiration for the assessment of soil quality.

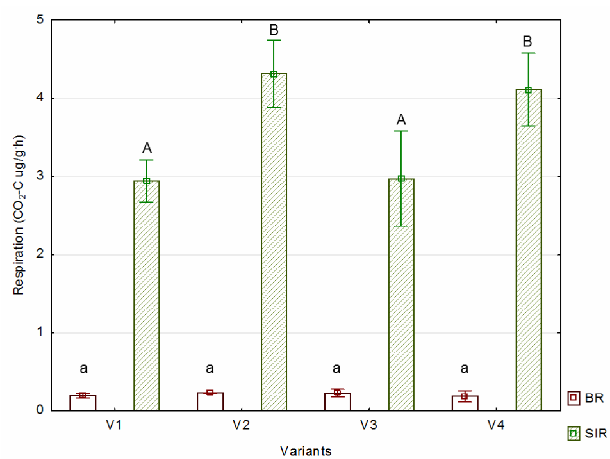

Fig. 4. Basal and substrate induced respiration (mean values ± standard error, n = 4, different letters indicate a significant differences at the level 0.05 - ANOVA, $P < 0.05$)

During the experiment, two types of respiration were measured: *BR* and *SIR*. The values of both respirations are presented in Figure 5. Significant differences were found only in *SIR*, *BR* was at the same level for all variants. This situation is not surprising because respiration was measured after the termination of the experiment, at a time when the activity reached its peak. According to Bloem et al [29] BR is the steady rate of respiration in soil, which originates from the turnover of organic matter. And SIR (method) is based on the detection of a respiratory response of soil microorganisms on supply of glucose. Thus, only glucose-responsive and active organisms are measured.

SIR is more important for the assessment of compost and mineral nitrogen addition on microbial activities and thus the soil properties. The highest values of SIR were found in variants V2 (4.31 µg/g·h) and V4 (4.11 µg/g·h). Conversely, the lowest values were detected in variants without compost (V1, V2). These data indicated that the addition of C_p has a positive effect on soil quality. Borken et al [28] confirmed that the application of compost has a positive effect on *SIR* and thus on microbial activities.

Small letters indicate a significant difference ($P < 0.05$) among individual variants in BR and different uppercase letters indicate a significant difference ($P < 0.05$) among individual variants in *SIR*.

Plant biomass production

After 63 days, on 28th April 2014, indicator plant was harvested and it production is the main indicator of compost and mineral nitrogen addition on plant production for individual variants. Production of aboveground and underground biomass is presented in Figure 6. Significant differences were found only in production of aboveground biomass (*AB*). The highest production of *AB* was found in variant V1 ($P < 0.05$) and the lowest production of *AB* was detected in variant V3. In addition, the production of AB was lower than the production in V1, but higher than in V3.

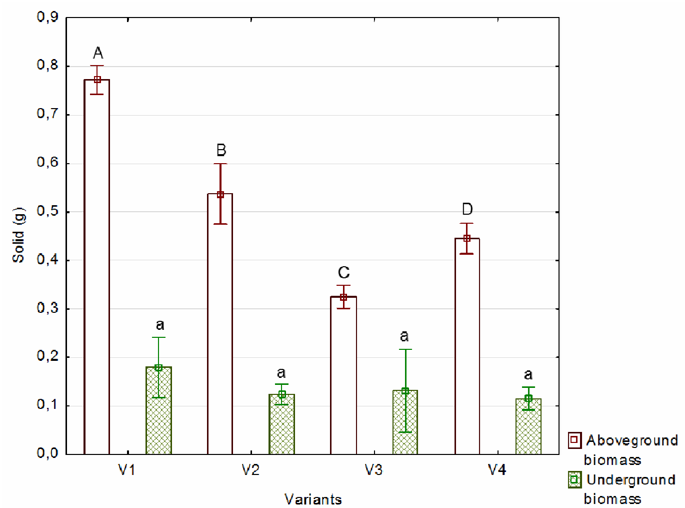

Fig. 5. Production of plant biomass (mean values ± standard error, $n = 4$, different letters indicate a significant differences in production of above and underground biomass among individual variants at the level 0.05 - ANOVA, $P < 0.05$)

These results indicate that the application of C_p had a greater effect on plant growth than the application of mineral nitrogen, which was applied in variant V3. The significant differences between control variant and variants with the addition of compost could be due to phytotoxicity or worse quality of C_p. Aslam et al, Tiquia and Himanen and Hänninen

[30-32] draw attention to the danger of phytotoxicity of compost, which can be caused by raw input, a mistake in the manufacturing process or its excessive applications. Increasing the dose of C_p could cause phytotoxicity of reclamation substrate and thus reduced production of *AB*. Conversely, recommended dose of C_p was applied in variant V4 and this type of C_p (Black Dragon) had already been successfully tested [10, 12, 33] and each time its positive effects on plant biomass production have been demonstrated. There is a presumption that the sample taken of C_p contained fewer nutrients than samples used in previous experiments. Despite this fact, this type of C_p applied in V3 had a positive effect on soil fertility in comparison with other variants. The highest values of SIR, content of N_{min} in soil and the lowest value of leaching of N_{min} were found here.

Different uppercase letters indicate a significant difference ($P < 0.05$) among individual variants in production of aboveground biomass and different small letters indicate a significant difference ($P < 0.05$) among individual variants in underground biomass.

Hydraulic conductivity

Soil water repellency is a widespread phenomenon, which affects infiltration as well as soil water retention and plant growth. It can be responsible for enhanced surface runoff, erosion and preferential flow. Due to this high relevance, a great number of studies have been conducted on possible causes of water repellency and point to a variety of factors causing and influencing repellency [16, 17].

Doerr et al, Buczko et al, and Robichaud et al [16-18] confirmed that soil hydrophobicity has direct impact on water infiltration into soil. The ability of the soil to accept water can be expressed as (saturated) hydraulic conductivity K_{sat}. Therefore, K_{sat} may be used to determine the degree of hydrophobicity of the soil.

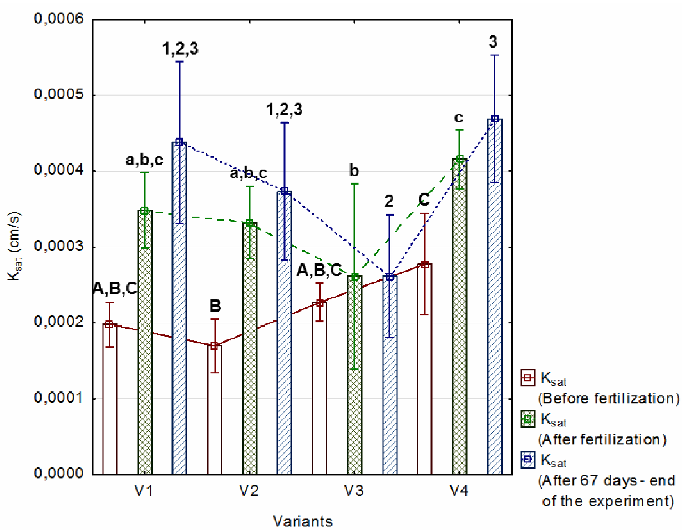

Fig. 6. Impact of compost addition and mineral nitrogen application on saturated hydraulic conductivity (mean values ± standard error, $n = 4$, different letters indicate a significant differences in K_{sat} among individual variants at the level 0.05 - ANOVA, $P < 0.05$)

The values of K_{sat} were calculated based on the measured volume of water (cumulative infiltration) which were measured in three periods: (a) before the application of mineral fertilizer into variant V3 (12 days after the establishment of the experiment), (b) after the application of mineral fertilizer (34 days after the establishment of the experiment) and (c) at the end of the experiment (63 days following the establishment of the experiment). Figure 6 displays the values of K_{sat} for three periods. In each period, the highest values of K_{sat} were found in variant V4. Furthermore, these values were significantly ($P < 0.05$) higher than values in variant V3 (addition of N_{min}) in the last two periods. This fact is very important for the authors because it confirms the premise that the application of C_{org} has a positive effect on soil hydrophobicity and soil properties in terms of a longer period of time, but the authors stress that the experiment was conducted in specific conditions and it should be repeated as a field and laboratory experiment. Considering values of K_{sat} in variant V2 (the application of reclamation substrate), these values were higher than values in variant V3, but these differences are insignificant.

Diaz et al, Walker and Bernal, and Lakhdar et al [9, 34, 35] confirm a positive effect of compost addition on the development of soil biota and on physical and chemical properties of soil. Therefore, the application of C_p had an influence on leaching of mineral nitrogen and the values of hydraulic conductivity.

Different uppercase letters indicate a significant difference ($P < 0.05$) among individual variants in the first period, different small letters indicate a significant difference among individual variants in the second period and different numbers indicate a significant difference among individual variants in the third period.

Conclusions

Our experiment showed the potential benefits of compost and reclamation substrates application. Based on these results, we can conclude the addition of compost (separately or as reclamation substrate) has a positive effect on microbial activity and decrease leaching of mineral nitrogen from the soil. Moreover, the content of compost (organic matter) has directly affected soil hydrophobicity, which is very important for stability of soil aggregates. For these comparisons, we may draw the following conclusions. There are great differences between arable soils with addition of compost and arable soils without, as it was expected. Compost has a positive impact on the soil environment and thus on soil properties: content of organic matter in soil, soil fertility, microbial activities etc. This positive effect is manifested in all variants of experiment where compost was applied. The authors are aware that the experiment was conducted under laboratory conditions and it should be repeated as a field-experiment.

Acknowledgments

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WPŁYW NAWOŻENIA NA AKTYWNOŚĆ MIKROORGANIZMÓW, HYDROFOBOWOŚĆ GLEBY ORAZ WYPŁUKIWANIE AZOTU MINERALNEGO

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Abstrakt: W pracy przedstawiono analizę wpływu kompostu, substratu rekultywacyjnego oraz zastosowanie nawozów mineralnych na wymywanie azotu mineralnego, działalności mikroorganizmów, hydrofobowość gleby i produkcję biomasy roślinnej. W celu zbadania efektu wykorzystania kompostu, substratu rekultywacyjnego oraz azotu mineralnego (N_{min}) został przeprowadzony eksperyment w doniczkach. Jako modelowa roślina została wykorzystana *Deschampsia caespitosa* L, którą hodowano przez 63 dni w komorze klimatycznej. Wymywanie N_{min} zostało zmierzone przy zastosowaniu tarcz jonowymiennych, hydrofobowość gleby określono na podstawie wartości przewodnictwa nasyconego hydraulicznego (K_{sat}), a aktywność mikrobiologiczną wyrażono jako podstawową (*BR*) oraz wskaźnik oddychania podłoża (*SIR*). Wykorzystano cztery próbki (V1-V4) o różnych dawkach nawozów: V1 - kontrola bez dodatku nawozu, V2 - mieszanka kompostu oraz gleby w stosunku 7:3, V3 - 90 g/m^2 nawozu mineralnego NPK (w stosunku 1:1:1) oraz V4 - dawka 30 g kompostu. Stwierdzono znaczne różnice (P < 0,05) w badaniu N_{min}, wartości K_{sat} oraz *SIR*. Największy ubytek azotu mineralnego zaobserwowano podczas jednoczesnej aplikacji kompostu (V4) do gleby uprawnej, około 50% w porównaniu z próbką V4 (zastosowanie nawożenia mineralnego) i około 10% w porównaniu z kontrolą. Próbki z dodatkiem kompostu (V2 i V4) wykazywały wyższe wartości niż próbki bez kompostu, co zostało zmierzone w trzech etapach (przed zastosowaniem N_{min} - 12 dni po rozpoczęciu eksperymentu, po zastosowaniu N_{min} - 34 dni oraz na koniec eksperymentu - 63 dni). Podczas eksperymentu respiracja była mierzona: *BR* oraz *SIR*. Wyraźne różnice w SIR zostały zaobserwowane pomiędzy próbkami z dodatkiem kompostu oraz próbkami bez dodatku kompostu. SIR (skumulowana produkcja CO_2) była wyższa o około 25% w próbkach V2 oraz V4 w porównaniu z próbkami V1 oraz V3. Najwyższe wartości K_{sat} zaobserwowano w przypadku próbek z dodatkiem kompostu. Wartość najniższą K_{sat} zaobserwowano dla próbek bez dodatku N_{min}. Niskie wartości K_{sat} wykazują zwiększony poziom hydrofobowości.

Słowa kluczowe: kompost, substrat rekultywacyjny, działalności mikroorganizmów, azot mineralny, hydrofobowość gleby