EFFECT OF INCREASED DOSES OF COMPOST TO PREPARE RECLAMATION SUBSTRATE ON SOIL RESPIRATION AND CONTENT OF MINERAL NITROGEN IN THE SOIL

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Abstract: This paper deals with the effect of increased doses of compost in reclamation substrate on soil respiration and content of mineral nitrogen in soil. To demonstrate the effect of increased doses of compost (300 % of recommended dose) on soil respiration and content of mineral nitrogen in soil, the pot experiment was performed. Five variants with the same doses of compost and different doses of mineral organic fertilizers were prepared. The highest respiration was determined in variant with compost addition. And the highest content of mineral nitrogen was found in variant with only addition of mineral fertilizers. These results point to the positive effect of higher doses of compost on microbial activity in the soil and the availability of soil nutrients.

Keywords: compost, respiration, mineral nitrogen, arable land, soil fertility

1 Introduction

Modern agriculture is facing many problems: decline of soil fertility, compaction of soils, and contamination of water sources, which have different causes.
In many countries throughout the world, agricultural soils are being degraded at an alarming rate by wind and water erosion, salinization, nutrient depletion and desertification (Abdel-Sabour & Al-Seoud, 1996). This is due to the lack of organic matter in the soil (SOM). These problems can be solved only by a change of farming systems. The fundamental change is to increase the content of organic matter in the soil.
Abdolahi et al. (2013), Naeth & Wilkinson (2013) and Diaz et al. (2007) state the compost is a source of organic matter and nutrients for soil microorganisms. Moreover, compost has positive effect on soil properties (content of nutrients, soil structure etc.).
In agriculture, the main positive aspect of compost use is probably related to the sustainability of this practice. To society as a whole, the production of compost gives the opportunity of closing the cycles of nutrients (Diaz et al., 2007).
Quality of soil organic matter is the cornerstone of sustainable agriculture. To maintain a productive and sustainable agricultural system, agricultural soils must be managed as an ecological system using diverse plants and organisms, to provide a suitable energy flux and nutrient cycling, to prevent nutrient and soil loss and to provide pest and disease control (Franco & De Faria, 1997). Therefore, it is necessary to use waste organic matter obtained after harvest.
The transformation of fresh OM into compost is carried out mainly for three reasons: (1) to overcome the phytotoxicity of fresh non-stabilized OM; (2) to reduce the presence of agents (viruses, bacteria, fungi, parasites), that are pathogenic to man, animals and plants to a level that it does not further constitute a health risk, (3) to produce an organic fertilizer or a soil conditioner and to recycle organic wastes and biomass (Diaz et al., 2007).
Diaz et al. (2007), Tandy et al. (2011), Abdolahi et al. (2013) and Naeth & Wilkinson (2013) confirm positive effect of compost and addition of reclamation substrates made from it on soil fertility. This positive effect is based on chemical composition of compost, because more than 80 % of the total nitrogen content in compost is organic. This form of nitrogen is very suitable for microorganisms so it can be used for further development of soil microbial communities. Development of soil microorganisms is very important for plant growth and for the retention of nitrogen in soil.
In the present paper, effect of increased doses of compost to prepare reclamation substrate on soil respiration and content of mineral nitrogen in soil samples was tested. This research was conducted with soil samples from the protection zone of underground drinking water source “Březová nad Svitavou”. This protection zone is located in the northern part of the Czech-Moravian highland and aims to protect this source against contamination by pollutants. Unfortunately, this protection is not effective proven by increase of the mineral nitrogen concentration in the drinking water from this area. It is caused by excessive application of mineral fertilizers in the second half of the 20[th] century. Excessive use of mineral fertilizers caused disruption to soil microbial complex. At present, this microbial complex is disrupted by atmospheric deposition containing nitrogen.
Hypothesis, which claims that increased addition of compost stimulates growth of soil microbial communities, was tested. This paper presents the results of a laboratory experiment, carried out by the Department of Microbiology. The aim was to detect the consequences of the high amount of compost application (300% of recommended dose) on soil respiration and content of mineral nitrogen in soil samples.

2 Materials and methods

The present experiment is sub-section of a larger experiment, which was focused on monitoring the impact of increased doses of compost on soil phytotoxicity, leaching of mineral nitrogen from arable soil, soil pH and conductivity.

2.1 Experimental design

Cumulative production of carbon-dioxide (CO_2) and concentration of mineral nitrogen (N_{min}) were determined in soil samples, which were removed from pot experiment after 35 days.
Fifteen experimental containers with same proportions were used for the experiment (see Figure 1).

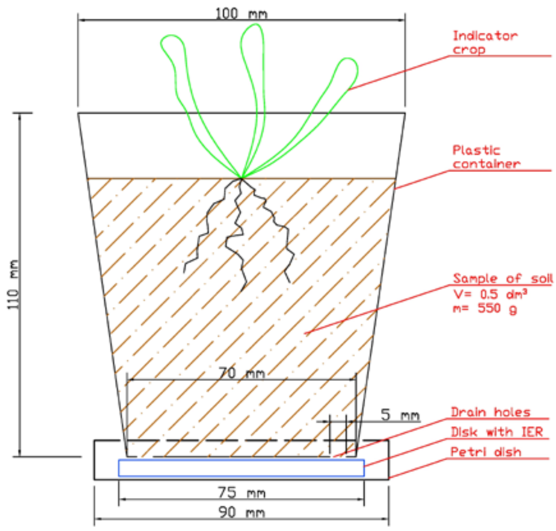

Fig. 1 Experimental container

These containers were filled with 550 g of soils with or without the addition of compost and mineral fertilizers. Soil samples were removed on the 10[th] of November 2012 from field in the protection zone of underground drinking water source “Březová nad Svitavou” in accordance with ČSN ISO 10 381-6. Compost samples were taken on the 30[th] of November 2012 from the company “CKB a.s” in accordance with ČSN EN 46 5735.

Special type of organic waste compost (Black Dragon – BD) was used for the experiment. BD is registered for agriculture use in the Czech Republic. BD was applied into the experimental containers together or without organic (Lignohumat Type B - LGB) and inorganic (mineral fertilizers GSH) fertilizers.
These fertilizers are also registered and Elbl et al. (2013) defines these fertilizers as follows: Lignohumat is a product of chemical transformation of lignosulfonate. This material is completely transformed into the final product: solution containing 90 % of humic salts (humic and fulvic acids in the ratio 1:1). GSH is a common mineral fertilizer containing N, P, K and S in the ratio 10:10:10:13.
Before the establishment of the experiment, samples of compost and soil were sieved through a sieve (grid size of 2 mm). After the end of the experiment, soil sampling was done from rhizosphere of the model plant. These soil samples were sieved again through a sieve (grid size of 2 mm) and then used for the determination of the N_{min} content and production of CO_2.

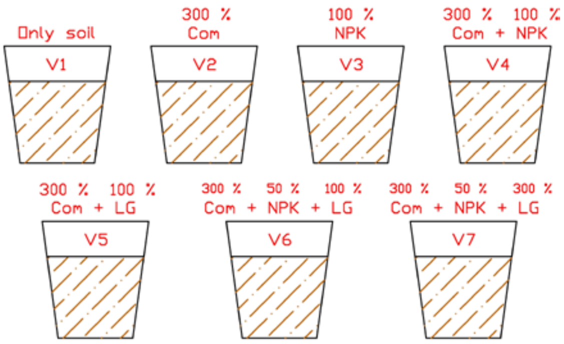

Fig. 2 Distribution of the laboratory experiment

Seven variants of experiment were performed (see Figure 2). Individual variants of experiment in detail: V1 – control variant (only soil) without addition of compost or another fertilizer. Into variants V2, V4 – V7, doses 90 g of compost were applied. This dose of compost is three times greater in comparison with the recommended dose in accordance with ČSN EN 46 5735 (50 Mg ha^{-1}). In conversion, this dose represents 150 Mg ha^{-1}. These variants (V4 – V7) were further complemented by: V4 – application of 90 g m^{-2} GSH; V5 – application of 50 ml m^{-2} of LG B; V6 – application of 50 ml m^{-2} of LG B + 45 g m^{-2} GSH (50 % of the recommended dose); V7 – 150 ml m^{-2} LG B (300 % of the recommended dose) + 45 g m^{-2} GSH. Furthermore, variant 3 (V3) was fertilized with only mineral fertilizer. Dose of 90 g m^{-2} GSH (100 % of the recommended dose) was applied in this variant.

2.2 Determination of N_{min} in soil samples

The amount of N_{min} in soil samples was determined by distillation-titration method after extraction with 2 M KCl .
This method was described by Bundy & Meisniger (1994). The content of N_{min} was performed by extraction with 2 M KCl. Extraction was realized in sealed glass containers. From each replication (V1 a, b, c; V2 a, b, c; V3 a, b, c etc.), 20 g of soil was collected. This sample was inserted into glass containers and shook for 60 minutes with 2 M KCl. After shaking, the determination of N_{min} was performed by distillation and titration method according the Peoples et al. (1989).
The results were expressed in mg of N_{min} per kg of soil.

2.2 Determination of cumulative CO_2 production

Cumulative CO_2 production (respiration) was measured using soda lime granules according Keith & Wong (2006). Soda limes granules consist of NaOH and $Ca(OH)_2$ and about 13-18 % of absorbed water. Water is required for chemical absorption of CO_2 in the form of Na_2CO_3 and $CaCO_3$. Carbonate formation is reflected in weight gain of granules. Weight gain of soda lime must be measured on oven-dried granules so that differences in water content of the initial batch of soda lime and water absorption during exposure do not interfere with measured weight gain of CO_2 (Keith & Wong, 2006; Elbl et al., 2013).
Soil samples (20 g) from each repetition of individual variants (V1, V2 etc.) were inserted into the 1000 ml airtight bottles. Glass beaker with 4.52 g of soda lime was inserted into each airtight bottle on metal tripod. This amount of soda lime is 0.06 g cm^{-2} of soil surface in airtight bottle. Before application, soda lime was dried at 105 °C for 14 h. After 24 h incubation, soda lime was dried again at same conditions and weighted with an accuracy of four decimal places. Control of measurements was ensured by creating blank samples. These samples represented soda limes that were placed into the same airtight bottles (V = 1000 ml) without soil. Soda lime was dried and weighed the same way as the previous ones.
The results of cumulative CO_2 production were expressed in g of C m^{-2} day^{-1} and calculated by the modified formula, which was adjusted according Keith & Wong (2006):

$$\text{Soil } CO_2 \text{ efflux (g C m}^{-2}\text{ day}^{-1}) = \left\{\frac{\text{sample weight gain (g) - mean blank weight gain (g)} \times 1.69}{\text{chamber area (m}^2)}\right\} \times \left[\frac{24\text{ h}}{\text{duration of exposure (h)}}\right] \times \left[\frac{12}{44}\right]$$

2.2 Statistical analysis

The measured values of cumulative CO_2 production and content of N_{min} in soil samples were analyzed by one-way analysis of variance (ANOVA) in combination with Tukey´s test. All data were analyzed in Statistica 10 software. Graphic processing of measured data was performed in Microsoft Excel 2010.

3 Results and discussion

3.1 Content of N_{min} in soil samples

Content of mineral nitrogen (consisting of NH_4^+-N and NO_3^--N) in the rhizosphere soil is an important indicator of threats to soil by nitrogen saturation.

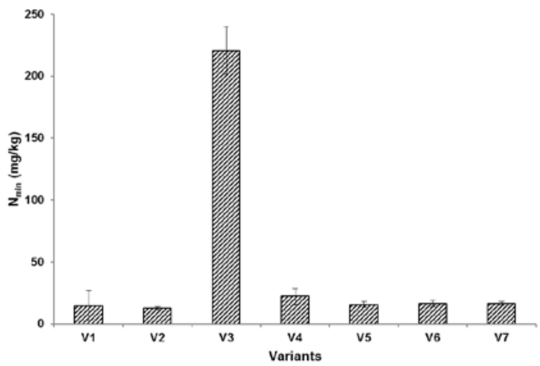

Fig. 3 Content of N_{min} in rhizosphere soil (mean values ± standard error are shown, n = 3)

The above Figure 3 shows a significant difference ($P<0.05$) between variant "V3" and other variants. The highest content of N_{min} was found in this variant (220.64 mg/kg). Conversely, the lowest content of N_{min} was measured in variant "V2" (12.53 mg/kg). Only mineral fertilizer was applied in V3 and only compost was applied into V2-V7, V1 was a control sample.
Various scientific works (Chalhoub et al., 2002; Nevens & Reheul, 2003; Weber et al., 2007; Diaz et al., 2007) confirm that application of compost has a positive impact on the availability of organic nitrogen in the soil. The content and availability of mineral nitrogen is then mainly influenced by microbial activity, because the SOM is firstly decomposed into ammonia nitrogen and subsequently to nitrate nitrogen. These beneficial effects are limited by time by mineralization of soil organic matter.

After application of compost, SOM was decomposed into ammonia nitrogen by microorganisms and it is quickly adopted by plants. Effect of organic matter content and microbial activity in the disclosure of ammonium nitrogen was demonstrated by Rennenber et al. (2009).

Application of mineral fertilizers increased the content of mineral nitrogen in the soil, but it the nitrogen was not used (see Figure 3) for development of microbial communities due to absence of organic matter. For comparison, consider data in the Table 1. The highest amount of mineral nitrogen was found in variant with the lowest production of CO_2. Data in the Table 1 show how productions of CO_2 increase in variant with compost addition. The relationship between content of N_{min} in soil and CO_2 production was analyzed by regression analysis. This analysis confirmed possible relationship between both parameters (R = 0.5967; P < 0.004; F = 10.5103). This situation was caused by the presence of organic carbon and organic nitrogen in the compost. Positive effect of compost application on microbial activities in soil was confirmed by Weber et al. (2007) and Leroy et al. (2007).

3.2 Cumulative CO_2 production

Soil respiration is an important component of terrestrial carbon cycling and can be influenced by many factors that vary spatially (Martin & Bolstad, 2009). Soil respiration was determined as cumulative CO_2 production during 24 h incubation and it expresses activity of microorganisms.

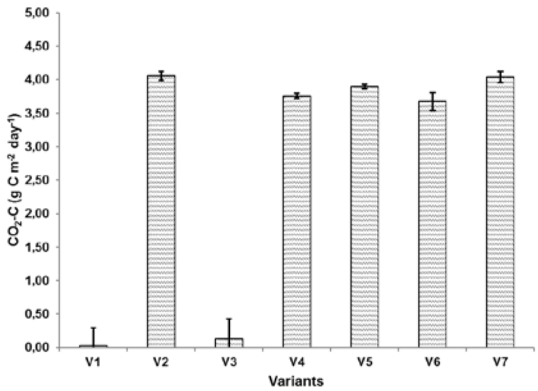

Fig. 4 Cumulative CO_2 production (mean values ± standard error are shown, n = 3)

The above Figure 6 shows the measured values of cumulative CO_2 production in g of C per m^{-2} day^{-1}. Graph shows how values increase in variant with compost addition compared to variants without (V1 and V3). From the graph, we can see that the respiration reaches a peak at the variant with compost addition (V2 = 4.0576 g m^{-2} day^{-1}). Conversely, the lowest value were detected in variants without compost (V1 = 0.026 g m^{-2} day^{-1} and V3 = 0.1329 g m^{-2} day^{-1}). The decline of respiration can perhaps be explained by the fact that variants without compost did not contain enough nutrients for soil microorganisms. This was confirmed by Borken et al. (2002).

Table 1 Production of CO_2 and N_{min} content in rhizosphere soil

Variants	N_{min} (mg/kg)	±SE	CO_2 (g C/m^2 day)	±SE
V1	14.61	11.88	0.02	0.02
V2	12.53	1.12	4.06	0.07
V3	220.64	19.33	0.13	0.29
V4	22.17	6.53	3.76	0.03
V5	15.65	2.27	3.90	0.03
V6	16.32	2.68	3.67	0.13
V7	16.40	1.65	4.03	0.08

Microorganisms need mainly organic carbon in the form of soil organic matter for their development. The organic carbon (C_{org}) is a source of energy. Martin & Bolstad (2009) confirm influence of C_{org} content on soil respiration. Positive influence of compost addition on content of soil nutrients, which are necessary for soil microorganisms, was confirmed by Naeth & Wilkinson (2013).

Conclusions

Our experiment with increased doses of compost showed the potential positive effects. Increased dose of compost can have a positive effect on cumulative CO_2 production and on the use of nitrogen in the soil. The significantly highest respiration was determined at variants with compost addition compared to variant without compost addition. Based on the results of content of mineral nitrogen in the soil, we conclude the positive effect of

Literature

1. ABDEL-SABOUR, M. F. & M. A. ABO EL-SEOUD. Effects of organic-waste compost addition on sesame growth, yield and chemical composition. *Agriculture, Ecosystems and Environment*. 1996, vol. 60, no. 2-3, pp. 157-164. ISSN: 01678809.
2. ABDOLLAHI, L., P. SCHJONNING, S. ELMHOLT & L. J. MUNKHOLM. The effects of organic matter application and intensive tillage and traffic on soil structure formation and stability. *Soil and Tillage Research*. 2014 (in press), vol. 136, pp. 28-37. ISSN: 0167-1987.
3. BORKEN, W., A. MUHS & F. BEESE. Application of compost in spruce forest: effect on soil respiration, basal respiration and microbial biomass. *Forest Ecology and Management*. 2002, vol. 159, no. 1-2, pp. 49-58. ISSN: 0378-1127.
4. BUNDY L. G. & J. J. MEISINGER. *Nitrogen availability indices – Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties*. Madison: SSSA Book Series, 1994.
5. DIAZ, L. F., M DE BERTOLDI & W. BIDLINGMAIER. *Compost science and technology*. Boston, MA: Elsevier, 2007, 364 p. ISBN 00-804-39600-8.
6. CHALHOUB, M., P. GARNIER, Y. COQUET, B. MARY, F. LAFOLIE & S. HOUT. Increased nitrogen availability in soil after repeated compost applications: Use of the PASTIS model to separate short and long-term effects. *Soil Biology and Biochemistry*. 2013, vol. 65, pp. 144-157. ISSN: 0038-0717.
7. KEITH, W. & S. C. WONG. Measurement of soil CO_2 efflux using soda lime absorption: both quantitative and reliable. *Soil Biology and Biochemistry*. 2006, vol. 38, no. 5, pp. 1121-1131. ISSN: 0038-0717.
8. LI-PING, W., Q. KUI-MEI, H. SHI-LONG & F. BO. Fertilizing reclamation of arbuscular mycorrhizal fungi on coal mine complex substrate. *Procedia Earth and Planetary Science*. 2009, vol. 1, no. 1, pp. 1101-1106. ISSN: 1878-5220.
9. LEROY, B. L. M. M., L. BOMMELE, D. REHEUL, M. MOENS & S. D. NEVE. The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: Effects on soil fauna and yield. *European Journal of Soil Biology*. 2007, vol. 43, no. 2, pp. 91-100. ISSN: 1164-5563.
10. MARTIN, J.G & P.V. BOLSTAD. Variation of soil respiration at three spatial scales: Components within measurements, intra-site variation and patterns on the landscape. *Soil Biology & Biochemistry*. 2009, vol. 41, no. 3, pp. 530-543
11. NAETH, M. A. & S. R. WILKINSON. Can we build better compost? Use of waste drywall to enhance plant growth on reclamation sites. *Journal of Environmental Management*. 2013, vol. 129, no. 15, pp. 503-509. ISSN: 0301-4797.
12. NEVENS, F. & D. REHEUL. The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: nitrogen availability and use. *European Journal of Agronomy*. 2003, vol. 19, no. 2, pp.189-203. ISSN: 1161-0301.
13. PEOPLES, M. B., A. W. FAIZAH, B. RERKASEM & D. F. HERRIDGE. *Methods for evaluating nitrogen fixation by modulated legumes in the field*. Canberra: Australian

Centre for International Agricultural Research, 1989, 81 p. ISBN 09-495-1190-0.

14. RENNENBERG, H., M. DANNENMANN, A. GESSLER, J. KREUZWIESER, J. SIMON & H. PAPEN. Nitrogen balance in forest soils: nutritional limitation of plants under climate change stresses. *Plant Biology*. 2009, vol. 11, pp. 4-23. ISSN: 14358603.
15. TANDY S., H. L. WALLACE, D. L. JONES, M. A. NASON, J. C. WILLIAMSON & J. R. HEALEY. Can a mesotrophic grassland community be restored on a post-industrial sandy site with compost made from waste materials? *Biological Conservation*. 2011, vol. 144, no. 1, pp. 500-510. ISSN: 0006-3207.
16. WEBER, J., A. KARCZEWSKA, J. DROZD, M. LICZNAR, E. JAMROZ & A. KOCOWICZ. Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste compost. *Soil Biology and Biochemistry*. 2007, vol. 39, no. 6, pp. 1294-1302. ISSN: 0038-0717.

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