Comparison of mineral nitrogen leaching in lysimetric and laboratory experiment with different types of fertilization

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Abstract: Compost can influence soil fertility and plant health. At the same time compost can play an important role in the nitrogen cycle and it can influence leaching of mineral nitrogen from soil to underground water.
This paper deals with the influence of compost addition and mineral nitrogen fertilizer on leaching of mineral nitrogen in the laboratory pot experiment and field lysimetric experiment - twenty one lysimeters were filed with topsoil and subsoil collected in the area of protection zone of underground source of drinking water - Březová nad Svitavou.
There are large 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.

Key-Words: compost, mineral nitrogen leaching, carbon, fertilization

Introduction

Application of compost in agriculture is very desirable worldwide. In the Czech Republic, compost is the most often used to improve soil structure and increase the content of soil organic matter.

The advantages of the use of organic wastes such as compost as fertilizers are evident. Their use would reduce the consumption of commercial fertilizers which need in their production high cost and energy [11]. Compost amendment improves physical, chemical and biological properties of soils, in particular by increasing available nutrients mainly in the organic soil fractions [4, 5] and there is evidence that application of organic amendments to soils could also reduce soil mineral N [13]. Many studies have reported that addition of a high C, low N organic amendment to soil can stimulate microbes to take up the available N from their environment for their own growth, in a process known as immobilisation [1, 6, 10]. Also, the application of compost increases the plant cover and stimulates soil microbial growth and activity [11, 12]. On the other hand, if the compost is applied in high doses it can negatively influence desirable groups of microorganisms, reduce yield of crops, increase leaching of nutrients [4].

Leaching of mineral nitrogen (consisting of NH_4^+-N and NO_3^--N) from arable land is a major threat to the quality of drinking water from underground reservoirs in the Czech Republic [6]. In the present paper, effect of compost addition on leaching of mineral nitrogen from arable land was investigated and evaluated in the laboratory pot experiment and in the field lysimetric experiment.

Material and Methods

Laboratory pot experiment

Experiment was performed in experimental containers with circular floor plan (Figure 1).
Containers were filled with 550 g of soil with added fertilizers according to the designed variants. Six seed of *Lactuca sativa* L. (salad) were planted in each container. After one week, we left one germinated seed in each container. During whole experiment, plants were kept in a climate chamber at 22 °C with a day length of 16 h and a light intensity of 300 $\mu mol \cdot m^{-1} \cdot s^{-1}$. Every day, salad was irrigated with 20 ml of distilled water.

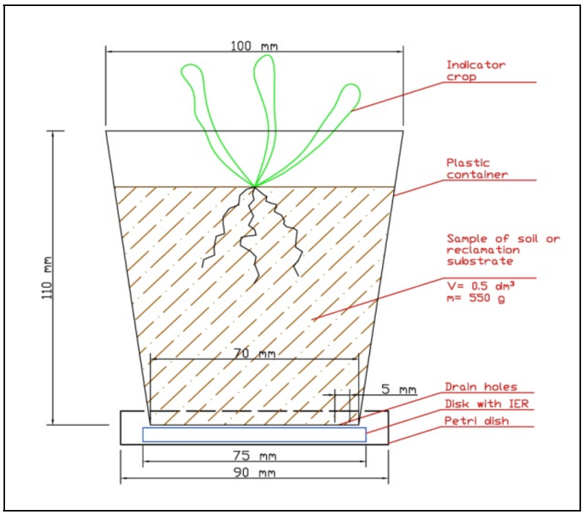
Variants of the experiment:

- C - soil as a control variant without addition of compost or mineral fertilizer;
- ČD 50 - variant with addition of compost Černý drak (28 g) from Central composting plant in Brno. In conversion, this dose represents 50 $Mg \cdot ha^{-1}$;
- CMC 50 - variant with addition of compost CMC (28 g) from composting plant in Náměšť nad

Oslavou. In conversion, this dose represents 50 Mg·ha^{-1};

- ČD 100 - variant with addition of compost Černý drak (56 g) from Central composting plant in Brno. In conversion, this dose represents 100 Mg·ha^{-1};
- CMC 100 - variant with addition of compost CMC (56 g) from composting plant in Náměšť nad Oslavou. In conversion, this dose represents 100 Mg·ha^{-1};
- NPK - variant with addition of inorganic fertilizer NPK (0,6 g) from Lovochemie a.s. In conversion, this dose represents 60 kg N·ha^{-1}. NPK is common mineral fertilizers containing N, P, K and S in the ratio 10:10:10:13. The NPK fertilizers were dissolved in 200 ml of distilled water (for each variant with NPK). NPK fertilizers irrigation was applied twice a week;
- ČD 50 + NPK - variant with combination of compost addition and inorganic fertilization.
- CMC 50 + NPK - variant with combination of compost addition and inorganic fertilization.

Fig. 1 Design of the laboratory pot experiment [6]



Measurement of the leakage of mineral nitrogen

For measurement leakage of mineral forms of nitrogen (NH_4^+-N and NO_3^--N) was used modified methods of [2, 8]

Mineral nitrogen (NH_4^+-N and NO_3^--N) leached from the soil was captured by special discs with mixed IER (Ion Exchange Resin), which were located under each experimental container (see Figure 1). 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 [8].

For the quantification of N_{min} trapped by the resin (CER and AER), the IER were allowed to dry at room temperature. Captured N_{min} was extracted from resin using 100 ml of 1.7 M NaCl. Released N_{min} was determined by distillation and titration method [9]. The results obtained from the Ion Exchange Discs were expressed in mg/dm^3 of N_{min}, NH_4^+-N and NO_3^--N of soil.

Lysimetric experiment

Twenty one lysimeters have been used as experimental containers and located in the area. The experiment was conducted in the protection zone of underground source of drinking water Březová nad Svitavou, where annual climatic averages (1962-2012) are 588.47 mm of precipitation and 7.9 °C mean of annual air temperature [6]. The lysimeters were made from PVC (polyvinyl chloride). Each lysimeter was the same size and was filled with 25 kg of subsoil and 25 kg of topsoil (arable soil). See Figure 2.

Topsoil and subsoil were collected from a field in the area. Soil samples were sieved through a sieve (grid size of 10 mm) and homogenized. Topsoil and subsoil were prepared separately. Each lysimeter had one drain hole and PVC hose for collecting soil solution. Hose leads into the plastic bottle. All lysimeters were buried into the ground. Collection of soil solution and monitoring of the lysimeters was carried out in the control shaft. Lysimeters were completed and filled in October 2012. Winter wheat (*Triticum aestivum*) was used as a model plant to determine the effect of fertilizers and on plant production. The model crop was planted into each lysimeter in October 2012.

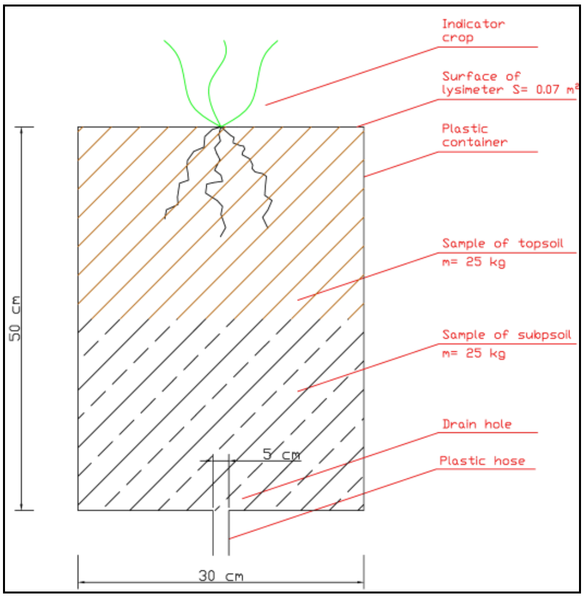
Seven variants (C1, C2 and K1 - K5) were prepared: C1 (control - without fertilization), C2 (control - with 100 % of recommended doses of N), K1 (100 % of recommended doses of compost), K2 (100 % of compost, 25 % of N), K3 (100 % compost, 50 % of N), K4 (100 % of compost, 100 % of N), K5 (200 % of compost).

Information on the applied fertilizers: Compost was applied in recommended doses of 50 Mg ha^{-1} from Central composting plant in Brno (Compost Černý drak). Nitrogen was applied as a liquid fertilizer DAM 390 converted in dose of 140 kg ha^{-1} of N.

Determination of mineral nitrogen

Soil solution was collected into plastic bottles, which were placed in the control shaft. The amount of the solution was monitored three times per week. If a solution was found in a bottle, it was taken for the determination. Samples were stored at 4°C before the determination.

Fig. 2 Detail of the lysimetric experiment [10]



Concentration of mineral nitrogen (N_{min}) was measured using distillation-titration method by [9]. Ammonium nitrogen was determined by distillation-titration method in an alkaline solution after the addition of MgO. Nitrate nitrogen was determined in the same manner using Devard´s alloy. Concentration of NH_4^+-N and NO_3^--N was calculated:

$$mg\,NH_4^+ \text{ or } NO_3^- - N = \left(\frac{\text{normality of standard HCl}}{0{,}00571}\right) x\,0{,}5\,x\,\text{titration} \quad [3]$$

The value of N_{min} was calculated as the sum of the detected ammonium and nitrate forms.
Determination of N_{min} was performed after each sampling of the soil solution and in each sample. The results obtained from the analyses of soil solution were expressed in mg of N_{min} per m^2 (mg/m^2).

Results and Discussion

Mineral nitrogen leaching in laboratory pot experiment

Leaching of mineral nitrogen was determined as the capture of ammonium and nitrate forms on the Ion Exchange Resin (mg N_{min} $dm^{-3}$of soil). Expression of results was explained in the preceding section.
Table 1 presents differences between variants with different fertilization. The highest leakage of mineral nitrogen was detected in variant NPK - only mineral fertilization (489,60 mg N_{min} m^{-2}). On the other hand the lowest with higher dose of compost - ČD 100 (15,18 mg N_{min} m^{-2}).

Table 1 Leaching of mineral nitrogen - pot experiment. Different letters indicate significant differences (ANOVA, $P < 0.05$)

	mg N-NH4 m^{-2}	± SE	mg N-NO3 m^{-2}	± SE	mg N_{min} m^{-2}	± SE
C	18,06^{a}	5,05	143,99^{a}	51,01	162,05^{a}	56,06
ČD 50	6,16^{b}	1,15	33,04^{bd}	12,10	39,20^{b}	13,25
CMC 50	4,48^{b}	1,55	38,33^{bd}	19,79	42,81^{b}	21,34
ČD 100	2,34^{c}	0,42	12,84^{c}	2,17	15,18^{c}	2,59
CMC 100	3,26^{bc}	0,73	20,72^{b}	2,52	23,98^{b}	3,25
NPK	441,97^{d}	47,16	47,63^{d}	19,91	489,60^{d}	67,08
ČD+NPK	64,67^{e}	34,19	14,69^{bce}	15,39	79,36^{ab}	49,58
CMC+NPK	109,28^{e}	51,25	7,23^{e}	1,34	116,51^{ab}	52,59

These results indicate positive influence of C_{org} (organic carbon) addition on leaching of N_{min} from arable soils. All variants with addition of C_{org} showed lower detection of nitrogen than variants without.

Mineral nitrogen leaching in Lysimetric experiment

Table 2 present distribution of leakage of N_{min} to the part ammonium nitrogen and nitrate nitrogen. Leaching of ammonium nitrogen was not significant among treatments.

On the other hand high addition of compost (variant K5) had a positive effect on concentration of nitrate nitrogen in soil solution. 200 % dose of compost in variant K5 significantly decreased leaching of N_{min} compared with all variants (Table 2).

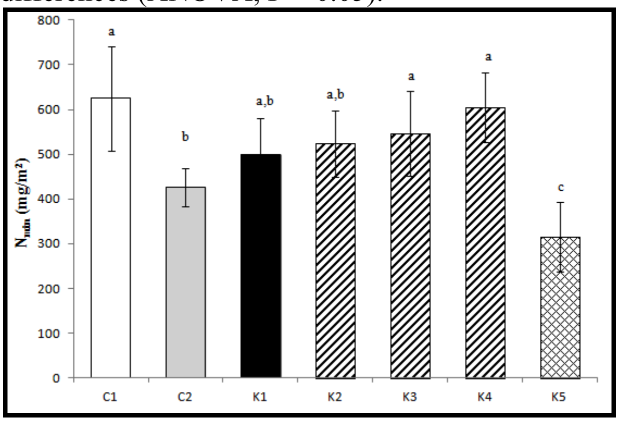
Figure 3 shows leaching of N_{min} from soil. The highest concentration of N_{min} was detected in variant

C1 - with addition 100 % of recommended dose of nitrogen (964.58 mg m^{-2}) and the lowest concentration of N_{min} was detected in variant K5 - with addition of 200% of recommended dose of compost (315.51 mg m^{-2}).

Table 2 Concentration of ammonium and nitrate nitrogen in soil solution

	mg NH_4^+-N m^{-2}	±SD	mg NO_3^--N m^{-2}	±SD
C1	56,13	31,92	568,46	85,78
C2	21,10	8,31	405,90	34,11
K1	17,68	2,34	482,10	78,05
K2	14,69	2,86	508,89	72,03
K3	35,18	18,70	510,47	75,93
K4	28,75	12,60	576,09	65,23
K5	27,63	6,64	287,88	70,69

Fig. 3 Detection of mineral nitrogen in soil solution. Different letters indicate significant differences (ANOVA, $P < 0.05$).



Positive effect of compost addition on leaching of N_{min} was confirmed by various scientific studies [6, 7, 10, 12], which confirm that C_{org} is a source of energy for soil microorganisms and its application in form of compost has a positive effect on microbial activities in soil.

Conclusion

Based on these results, we can conclude that the addition of compost have a positive effect on microbial activity and decrease in leaching of mineral nitrogen from the soil. For these comparisons, we may draw the following conclusions. There are large 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. This positive effect is manifested in all variants of fertilization.

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