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Corresponding Author:
Elke Meinken
Weihenstephan-Triesdorf University of Applied Sciences
Institute of Horticulture
Am Staudengarten 14
85354 Freising
Germany
Email: elke.meinken@hswt.de

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Nitrogen mineralization and subsequent nitrification of horn as affected by particle size and compost amendment to the growing medium

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Weihenstephan-Triesdorf University of Applied Sciences, Germany.

1. Introduction, Knowledge, Objectives

During the last years the demand for organically grown potted herbs has increased continuously. Due to a high nitrogen demand and short cultivation period, an adequate nitrogen (N) supply is one major issue for growers. Quite often the total quantity of nitrogen is applied to the growing medium before sowing using solid organic fertilizer (Burnett et al., 2016). However, then time-course of N release is crucial for successful crop cultivation: If nitrogen release is too fast, germination might be impaired due to osmotic stress. If it is too slow, plants will suffer temporally from N deficiency. Beside N release, subsequent nitrification plays an important role too, as high amounts of ammonium in the growing medium could cause growth problems (Burnett et al., 2016). Particle size of fertilizer and microbial activity of the growing medium are considered as two of the most important factors for N mineralization. Thereby, increasing fineness is usually equated with enhanced N mineralization, but particularly for N rich residues, contrary results were reported sometimes (Angers and Recous, 1997). As mineralization of organic N and subsequent nitrification is a microbial process, an increasing activity of microorganisms will accelerate N turnover (Geisseler et al., 2010, Burnett et al., 2016). Whereas microbial flora of freshly harvested peat is considered to be low (Carlile and Wilson, 1991), composts show a high microbial activity and thus can increase nutrient availability (Chaoui et al., 2003). It is the aim of this study to examine the effect of particle size of horn in combination with an increasing amendment of green waste compost (GWC) to the growing medium on the N release. For this purpose, an incubation experiment and a pot trial with parsley were carried out.

2. Material and Methods

<u>Compost amendment of growing media and preparing of horn fractions</u>

The growing media consisted of pure peat (sod peat 0-8 mm, H3-H8) or of this peat with addition of 2 and 30 percent by volume (vol.-%) of green waste compost (GWC), respectively. The GWC was purchased from a local compost facility. Salt and nutrient contents of the GWC were well below thresholds for substrate compost type 2 according to guidelines of German Quality Association for Compost (BGK, 2017). All growing media were limed to a pH of 5.5 and fertilized (P, K, Mg, trace elements) to meet plant demand according to good horticultural practice (method A 13.1.1 Annex 1; VDLUFA, 2016).

For preparing horn fractions with different fineness first coarse horn shavings (HS) were sieved by hand (mesh size 4 mm). The oversized material was grinded in a cutting mill with bottom sieves of 4, 2 and 1 mm mesh size, respectively. The milled horn shavings were partly further sieved by hand with sieves of 1 and 2 mm mesh size. The entire grinding and sieving procedure and the resulting horn fractions are shown in fig. 1.

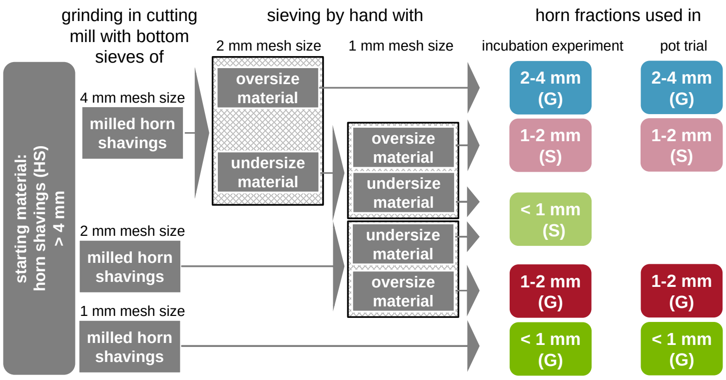

Fig. 1: Grinding and sieving procedure of horn shavings and resulting fractions (letter in brackets behind fractions indicates if upper particle size of the fraction corresponds to the mesh size of grinding (G) or sieving (S) procedure)

<u>Incubation experiment</u>

The incubation experiment was done according to method A13.5.1 (VDLUFA, 2016), whereby horn was added to the three growing media at 1000 mg total N (analyzed by Dumas method) per liter. Additionally, growing media without N fertilization and with 500 mg N/l as NH_4NO_4 were incubated. Directly after mixing as well as after 7, 14, 28 and 42 days of incubation, two vessels per treatment were taken and analyzed for NH_4- and NO_3-N (method A13.1.1; VDLUFA, 2016). Net mineralization was calculated as difference between fertilized and non-fertilized growing media.

<u>Pot trial with parsley</u>

For the pot trial the three growing media were also fertilized on basis of 1000 mg total N per liter with fractionated horn fertilizers. In addition to the treatments fertilized with horn, growing media were fertilized with 500 mg N/l, either as $Ca(NO_3)_2$ or $(NH_4)_2SO_4$ (200 mg N/l basal dressing plus 300 mg N/l top dressing (weekly portions of 50 mg/l, starting three weeks after sowing). To ensure an adequate supply with all other nutrients, treatments without and with 2 vol.-% GWC, respectively, were additionally fertilized with a N free fertilizer according to horticultural practice (A13.1.1 appendix 1; VDLUFA, 2016). Parsley 'Starlett' was sown with 50 seeds per pot (volume 510 ml) in calendar week (cw) 21/2016. 60 pots per treatment were placed in a randomized block design with four replications in a greenhouse and irrigated on demand (water quality: electrical conductivity 35 mS/m, acid capacity 2.9 mmol/l). After two and four weeks one pot per replicate was taken for analysis of pH, soluble salts, N, P and K (methods A5.1.1, A 0.1.1, A13.1.1; VDLUFA, 2016). In cw 23/2016 germinated seeds were counted, and in cw 26/2016 roots and shoots were visually rated and shoot fresh mass was measured. For germination rate and fresh mass, a two-way ANOVA combined with a Tukey test was calculated ($p \leq 0.05$). Scores of visual ratings were compared by Kruskal-Wallis and Nemenyi test ($p \leq 0.05$). Data analysis was performed using Minitab® software (Minitab Inc., State College/PA).

3. Results

Incubation experiment

Absolute height of N mineralization at day 42 was not clearly influenced, neither by the particle size of the horn fractions, nor by the percentage of GWC. However, for velocity of N mineralization, at least a small effect was found: For each growing medium, mineralization within the first 14 days was slightly accelerated with increasing fineness of horn fractions. Similarly, addition of 30 vol.-% GWC speeded up N mineralization compared to the two other growing media for each horn fraction. Furthermore, high percentage of compost increased subsequent nitrification significantly. While nearly no nitrification was found in growing media without and with only 2 vol.-% GWC, in growing medium with 30 vol.-% GWC, nitrification already started within the first 14 days and nearly no NH_4^+-N was found at day 42. Hence, similarly to mineralization, nitrification tends to be slightly faster in treatments with finer horn fractions. This positive effect of high compost amendments on nitrification was also found in NH_4NO_3 fertilized controls.

Pot trial with parsley

Germination was not adversely affected by compost amendment or by fertilizer. Germination rate ranged between 75 and 90 %, only in the treatment with 30 vol.-% GWC and $Ca(NO_3)_2$ fertilization, germination rate was remarkably low with 56 %. At the end of the trial, growth was rather weak irrespective of treatment. However, the highest parsley biomass was obtained in nitrate-fertilized growing media without compost as well as with 2 vol.-% GWC (fig. 2). Two-way ANOVA revealed that interactions between fertilizer and compost amendment were highly significant. Whereas no differences between fertilizers – neither within horn fractions nor between treatments with organic and mineral fertilization – exists for growing medium with 30 vol.-% GWC, differences in fresh mass between the $Ca(NO_3)_2$ fertilized control and all other treatments (horn fractions and $(NH_4)_2SO_4$ control) were significant for growing medium without GWC. For growing medium with 2 vol.-% GWC, this is also true with exception of coarsest horn fraction (2-4 mm (G)). Furthermore, for the growing media without and with 2 vol.-% GWC, fresh mass tends to decrease with increasing fineness of horn fractions. Similar results were found for visual rating of shoots. $Ca(NO_3)_2$ fertilized treatments without and with 2 vol.-% GWC were rated best, between all other treatments differences were not significant (data not shown).

As described for shoot growth, also root growth was quite weak and unevenly within pots. Therefore, root balls were divided in the bottom surface and three equal sections of the lateral surface and each section was rated separately from 0 = without roots to 9 = intensive rooting. For statistical testing the sum of scores was used. Thus, a plant with an excellent root ball would reach a score of 36; however, the maximum score reached by a single pot was only 28. As shown in tab. 1, in the growing medium with 30 vol.-% GWC, root growth was not significantly affected by fertilization. In growing media without and with 2 vol.-% GWC, controls with mineral fertilizers had higher rooting scores than treatments with horn. Furthermore, for both growing media, the rooting scores decreased significantly with increasing fineness of horn fractions.

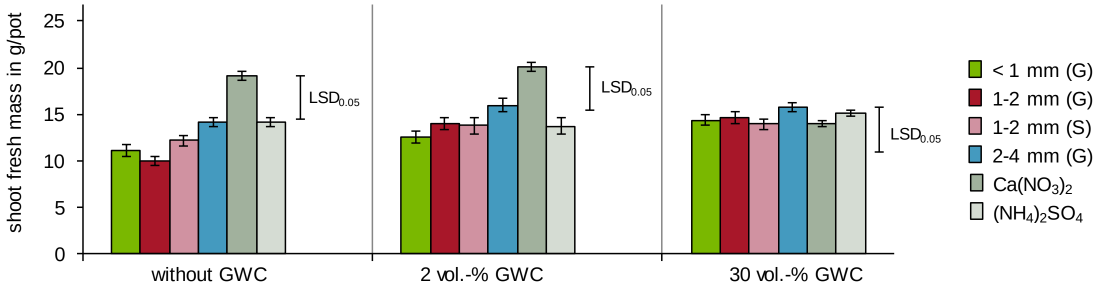

Fig. 2: Shoot fresh mass of parsley (error bars indicate standard errors; $LSD_{0.05}$ indicates least significance differences within growing media, $p \leq 0.05$, n = 4)

Tab. 1: Rating of root growth (median and inter quartile range of sum of scores[1])

fertilizer / compost	< 1mm (G)	1-2 mm (G)	1-2 mm (S)	2-4 mm (G)	$Ca(NO_3)_2$	$(NH_4)_2SO_4$
without GWC	7 $\begin{bmatrix}5\\9\end{bmatrix}$ F	7 $\begin{bmatrix}5\\8\end{bmatrix}$ F	9 $\begin{bmatrix}7\\12\end{bmatrix}$ EF	12 $\begin{bmatrix}9\\15\end{bmatrix}$ DE	17 $\begin{bmatrix}13\\18\end{bmatrix}$ A	15 $\begin{bmatrix}11\\18\end{bmatrix}$ AB
2 vol.% GWC	6 $\begin{bmatrix}5\\10\end{bmatrix}$ F	10 $\begin{bmatrix}6\\11\end{bmatrix}$ F	9 $\begin{bmatrix}7\\11\end{bmatrix}$ EF	13 $\begin{bmatrix}10\\17\end{bmatrix}$ CD	15 $\begin{bmatrix}14\\17\end{bmatrix}$ A	14 $\begin{bmatrix}12\\16\end{bmatrix}$ BCD
30 vol.% GWC	15 $\begin{bmatrix}10\\17\end{bmatrix}$ ABC	16 $\begin{bmatrix}10\\18\end{bmatrix}$ AB	14 $\begin{bmatrix}10\\17\end{bmatrix}$ ABC	14 $\begin{bmatrix}11\\19\end{bmatrix}$ ABC	15 $\begin{bmatrix}13\\18\end{bmatrix}$ AB	17 $\begin{bmatrix}12\\19\end{bmatrix}$ A

[1]Lateral surface divided in three equal sections as well as bottom surface rated separately (1 = no roots, 9 = intensive rooting); Kruskal Wallis and Nemenyi test ($p \leq 0.05$, n = 4) with sum of scores; same characters indicate no significant differences between treatments

The analysis of mineral nitrogen in the growing media (data not shown) supports the results of the incubation experiment. After 14 days, when parsley seeds had just germinated and thus their N uptake was still negligibly small, high amounts of soluble N were found in all treatments, whereby N mineralization was slightly higher in growing media with 30 vol.-% GWC than in those without and with 2 vol.-% GWC. Additionally, in the growing medium with 30 vol-% GWC, an increase of N mineralization was found with increasing fineness. While nitrification already has started after 14 days and was nearly completed at the end of the experiment (day 37) in growing medium with 30 vol.-% GWC, almost no nitrification was seen in the two other growing media until the end of the experiment. Due to the above mentioned rather poor growth of parsley in all treatments, quite high amounts of soluble N – between 150 and 250 mg/l – were found at day 37.

4. Discussion

The rather small effect of particle size on N mineralization is in line with results which were reported for plant residues with low C:N ratio (Jenssen, 1994; Angers and Recous, 1997; Bending and Turner, 1999). While all these authors only found a small increase of mineralization for finer particles compared to coarser ones at the beginning, a more pronounced effect of particle size was found for residues with high C:N ratio. Thus, the authors suggest that the particle size effect is closely correlated to N limitation of microbial decomposition which is not of importance in case of organic N fertilizers. The rather small effect of compost amendment – especially in case of 2 vol.-% GWC, which should act as inoculum – supports the suggestion of Carlile and Wilson (1991) that, due to liming and fertilization, microbial activity of peat is rapidly increasing, even if initial microbial community might be poor. This is confirmed by results of Rangeley and Knowles (1988) who reported a rapid increase of microbial activity in peat soils after liming. However, nitrification was significantly enhanced by high amendments of GWC. This may have prevented NH_4^+ toxicity, which was probably responsible for poorer growth of plants in growing media without compost and with 2 vol.-% GWC fertilized with horn and $(NH_4)_2SO_4$, respectively, compared to $Ca(NO_3)_2$ fertilized plants. Indeed, there is no apparent reason for the missing nitrification, but in recent years we found this phenomenon regularly in several incubation experiments as well as in pot trials (unpublished data). This knowledge gap in characterization and management of biological properties was already identified by Schmilewski (2000) nearly 20 years ago as major issue in current growing media research.

5. Conclusions

Neither particle size of horn nor compost amendment to the growing medium had a significant effect on the total N release of horn, only the velocity of N release was slightly increased. However, nitrification was greatly accelerated by high compost amendment which probably prevented NH_4^+ toxicity. Overall, the results highlight the gap between the importance of microbial activity in organic production and the lack of knowledge herein.

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