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Waste sheep wool – an alternative nitrogen source for organically grown potted herbs?

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Waste sheep wool – an alternative nitrogen source for organically grown potted herbs?

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1. Introduction, Knowledge, Objectives

During the last decade organically grown potted herbs are increasingly popular. Because of rapid growth adequate nitrogen supply is one of the key challenges for growers. Due to a lack of soluble nitrogen fertilizers most often nitrogen is added as complete preplant application. Currently most important nitrogen sources are horn products and nitrogen rich residues of sugar and starch processing industries (Möller and Schultheiß, 2014). But due to long distance transport and health concerns - catchword BSE - horn products are poorly accepted by consumers (Heuberger et al., 2005). Residues of sugar and starch processing industries are not available in sufficient quantities (Möller and Schultheiß, 2014).
Unprocessed wool as waste product of sheep husbandry could be a possible alternative. Some research was done with different horticultural crops as tomato, sweet pepper, eggplant, iceberg lettuce, kohlrabi or poinsettia (Górecki and Górecki, 2010, Böhme et al., 2012). Thereby increasing amounts of sheep wool increased plant growth, but especially when used for crops with short cultivation periods the material was only partially decomposed and yield was reduced. This is in line with results of a soil incubation experiment of Laber (2013) and results reported for similar materials as feathers (Choi and Nelson, 1996) or human hair (Zheljazkov et al., 2008). Additionally to kind of nitrogen source mode of application is important for effective use of organic fertilizers. To prevent growth inhibitions in early growth stages due to high salt contents or inhibitory substances (Heuberger et al., 2005, Zheljazkov et al., 2009) organic fertilizers are often not mixed evenly into the growing medium, but applied by deep-point placement method (DPP) whereby the fertilizer is placed as closely spaced depot in the lower part of the pot (Beck et al., 2005, Degen and Koch, 2014). Aim of the current research was the use of waste sheep wool as fertilizer for organically grown potted Parsley.

2. Material and Methods

Cultivation test with Parsley

Sheep wool was used pelletized and after defibring in a cutting mill. Defibred sheep wool was mixed evenly into the growing medium (70 % volume peat + 30 % volume green waste compost, limed to pH 5.5 to 6.0) giving 400, 800 and 1200 mg total N/l respectively and furthermore it was applied at the 800 mg total N/l rate by DPP. Pelletized sheep wool was used at the 800 mg total N/l level both mixed evenly in the growing medium and applied by DPP. Phytogrieß – a residue of production of maize starch adhesives which is commonly used – was used in same amounts and modes of application as defibred sheep wool (Tab. 1). Additionally a control was treated with ammonium nitrate (400 mg N/l).

Tab. 1: Fertilizer, kind of application and nitrogen level of the cultivation test

Fertilizer	Kind of application	nitrogen level (mg N_t/l)	code
Sheep wool (defibred)	evenly mixed	400	SdM 400
		800	SdM 800
		1200	SdM 1200
	deep-point placement	800	SdP 800
Sheep wool (pelletized)	evenly mixed	800	SpM 800
	deep-point placement	800	SpP 800
Phytogrieß (fine grained)	evenly mixed	400	PfM 400
		800	PfM 800
		1200	PfM 1200
	deep-point placement	800	PfP 800

Common plastic pots (volume app. 700 ml) were used. For treatments with DPP application first one-third of the pot was filled with growing medium, then the fertilizer was placed as compacted heap in the middle of the pot and the pot was completely filled with growing medium which finally was gently pressed by a 1.6 kg weight. For all other treatments the fertilizers were mixed evenly into the growing medium, pots were filled completely and the growing medium was compressed in the same way. Per pot 55 seeds of Parsley 'Grüne Perle' were put uniformly on the pressed surface and covered gently with sieved growing medium. Pots were placed in a greenhouse (block design with four replicates and 15 pots per replicate) and cultivated according to good horticultural practice. Irrigation was done by hand on top of the pots using deionized water.
Each two weeks one pot per replicate was taken for analysing pH ($CaCl_2$), water soluble salts and CAT soluble N, P, K according to VDLUFA-methods (VDLUFA, 2012). Plant growth was visually rated and documented photographically continuously during the cultivation period. At the end yield per pot (fresh and dry mass) was determinated, leaf colour was visually rated and pooled samples per treatment were analysed for total N by combustion method. For fresh and dry mass an ANOVA was done using a glm-procedure combined with Tukey test ($p \leq 0.05$). Leaf colour rating was examined using Kruskal-Wallis and Nemenyi test ($p \leq 0.05$). All statistical calculations were carried out with Minitab V16 (Minitab Inc., State College PA).

Incubation experiment

The incubation experiment was done according to VDLUFA method A 13.5.1 (VDLUFA, 2012) with two replicates using the same peat-compost-mixture as in the cultivation test. Defibred sheep wool and Phytogrieß were added at a level of 1000 mg total N/l. Incubation vessels were placed in an incubator at 25 °C and growing medium was rewetted with deionized water to a moisture level appropriate for microbiological activity three times a week. NH_4-N and NO_3-N was analyzed at day 0 and after 3, 7, 10, 14, 21, 28, 35, 49 and 63 days of incubation respectively. As control the growing medium fertilized with mineral nitrogen (ammonium nitrate, 500 mg N/l) was treated in the same way.

3. Results

Cultivation test with Parsley

Irrespective of treatment germination rate ranged between 83 and 89 %. But already after four weeks of cultivation plants in treatment PfM 1200 were obviously smaller than in all other treatments. Concurrently highest soluble salt and nitrogen content were found in this treatment with 2.32 g KCl/l and 391 mg N/l compared to 1.05 g KCl/l and 79 mg N/l when using defibred sheep wool at the same N level. Between the other treatments no differences in plant growth exist at this date.

Two weeks later at the end of the experiment plant fresh mass in treatment PfM 1200 still was reduced compared to control plants and to treatment SdM 1200. Furthermore growth of plants fertilized with 400 mg N/l using defibred sheep wool (SdM 400) was significantly reduced while fresh and dry mass of plants fertilized with 400 mg N/l as Phytogrieß (PfM 400) was comparable to those of the control fertilized with ammonium nitrate (Tab. 2). The lighter leaf colour of plants in treatment SdM 400 as well as total N content of 2.2 % confirms that they suffer from N deficiency. The optimum N level for sheep wool seems to be 1200 mg N/l while for Phytogrieß 800 mg N/l are sufficient. The higher N utilization rate of Phytogrieß compared to sheep wool is evident from total N content of plants, which is similar for PfM 400 and SdM 800 as well as for PfM 800 and SdM 1200 (Tab. 2). Comparing mode of application at the 800 mg N/l level revealed no clear difference between evenly mixing and DPP. Also equal plant growth was achieved, irrespective which type of sheep wool -pelletized or defibred- was used. However, variance between pots was markedly highest if pelletized sheep wool was mixed into the growing medium.

Tab. 2: Plant fresh (FM) and dry mass (DM), leaf colour score and total N in DM (different letters indicate significant differences between treatments with $p \leq 0.05$; ANOVA/Tukey for means of FM and DM, Kruskal-Wallis/Nemenyi for median of leaf colour score, n = 4)

Treatment	FM (g/pot)	DM (g/pot)	leaf colour	total N (mg/g)
SdM 400	14,8 f	1,8 e	3,0 a	22
SdM 800	30,4 abcd	2,6 bc	7,0 b	38
SdP 800	32,7 abc	2,6 bc	7,0 bc	59
SdM 1200	33,7 ab	2,8 ab	7,5 c	55
SpM 800	28,5 cde	2,5 bc	7,0 bc	42
SpP 800	34,6 a	3,0 a	7,0 bc	54
PfM 400	27,3 de	2,4 c	6,0 a	35
PfM 800	33,2 abc	2,7 b	7,0 b	56
PfP 800	28,9 bcde	2,6 bc	7,0 b	56
PfM 1200	24,3 e	2,1 d	7,0 b	59
control	29,5 bcd	2,6 bc	5,5 a	51

Incubation experiment

In accordance with the results of the cultivation experiment the incubation test reveals a delayed nitrogen mineralization of sheep wool (Fig. 1). While already after three days about 125 mg N/l were mineralized from Phytogrieß the same level was reached not before 28 days of incubation for defibred sheep wool. Nearly no mineralization occurred from sheep wool until day 21. Also percentage of mineralized total N at the end of the incubation period was noticeably less for sheep wool (44 %) than for Phytogrieß (57 %).

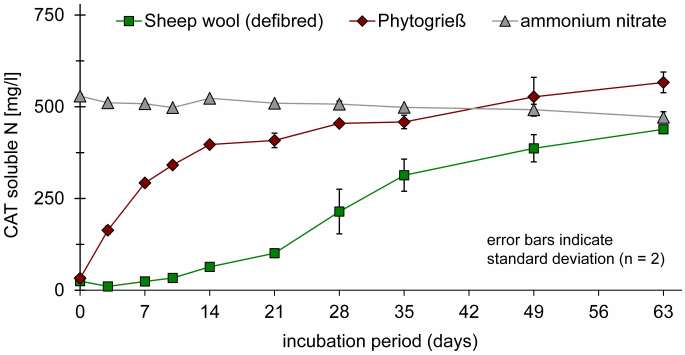

Fig. 1: Time course of nitrogen mineralization

4. Discussion

Delayed nitrogen mineralization of sheep wool is similar to results of Laber (2013) for incubation of sheep wool in mineral soils. He reported nearly no nitrogen mineralization within the first 28 days. Also total mineralization of about 40 % of total N after eleven weeks is comparable. The reason might be that cystine rich hard keratins of sheep wool as main nitrogen source are not readily degradable for microorganism (Zheljazkov 2005, Kornillowicz-Kowalska and Bohacz, 2011) and especially in case of unwashed sheep wool mineralization might be slowed down further by its hydrophobic nature due to high grease content (Górecki and Górecki, 2010, Arshad et al., 2014). Similar plant growth in treatments with defibred (and thereby cutted) and pelletized sheep wool strengthens assumption that rather chemical structure than physical properties (especially particle size) of sheep wool is the main factor of delayed mineralization. This is contrary to other organic fertilizers, e.g. horn products, where nitrogen mineralization rate is correlated to particle size (Schmitz et al., 1993). Aside from delayed nitrogen mineralization also lower percentage of mineralized nitrogen has to be considered if sheep wool is used. While 50 to 60 % of total N was released from Phytogrieß, which is within the range of other common organic fertilizers such as horn products or molasse/vinasse (Schmitz and Fischer, 2003), for sheep wool percentage was about 15 % less. Both delayed and lower mineralization explain reduced plant growth in treatments with sheep wool compared to those with Phytogrieß at the same level of N supply and coincide with findings of Zheljazkov (2005) and Böhme et al. (2012) who reported sheep wool more suitable for crops with longer cultivation periods (e.g. tomato) than for those with shorter ones as lettuce or kohlrabi.
An advantage of deep-point placement of N fertilizer instead of mixing it evenly into the growing medium as described by Beck et al. (2005) was not found in the current experiment. Similar results are reported for potted basil by Degen and Koch (2014). But as growth inhibition due to high salt content in treatment PfM 1200 show, complete preplant fertilizer application could be risky. At this N level deep-point placement might be beneficial. Regardless of reducing the risk of plant damages deep-point placement has the advantage that each pot receives the same amount of fertilizer. In contrast, by mixing pelletized fertilizers into the growing media no uniform distribution of nitrogen might be achieved, as it is indicated by increased variance of fresh mass in treatment SpM 800.

5. Conclusions

Due to slow mineralization waste sheep wool is not suitable as solely nitrogen source for organically grown potted herbs. A promising approach may be the combination of sheep wool with a rapidly mineralized fertilizer as Phytogrieß. This should result in a more uniform nitrogen mineralization rate over the entire cultivation period, which may prevent that plants temporarily suffer from nitrogen deficiency or excess.

6. Literature

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