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Home field advantage of cattle manure decomposition affects the apparent nitrogen recovery in production grasslands

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ABSTRACT

Based on evidence from forest ecosystems that litter decomposition is highest in its home habitat, the so-called home field advantage (HFA), we tested whether HFA also occurs in production grasslands, to which solid cattle manure (SCM) was applied. Two dairy farms were selected which differed in type of home-produced SCM (stacked or composted) and soil type (sand or peat). Disappearance patterns of manure dry matter (DM) and nitrogen (N) were monitored from litterbags (4 mm mesh size) during the grass growing season. At the same time, apparent herbage N recovery (ANR) of SCM, applied at two rates (200 and 400 kg N ha^{-1} yr^{-1}), was measured. On average, manure DM and N disappearances on the home farms were 20 and 14% greater, respectively, than on away farms. Differences in ANR were also very pronounced (on average 14 and 53% higher at home than away for the two respective application rates). The two SCM types were also studied on two neighbouring dairy farms (one on sand and one on peat soil) where no SCM had been applied for many years. Here, manure DM and N disappearances from the litterbags were much lower ($P < 0.01$). This experiment provides strong evidence for a home field advantage in production grasslands differing in fertilization history, showing that site-specific manure management affects the soil–plant interactions regulating plant N-availability. These findings have to be taken into account when changing fertilization regimes in production grasslands. This is the first report to quantify a HFA from an agricultural ecosystem. HFA values we report here have not been established in any ecosystem thus far.

1. Introduction

Plant nitrogen (N) availability from solid cattle manure (SCM) when applied to the surface of cultivated grasslands varies widely. In a number of recent Dutch experiments the apparent herbage N recovery from SCM ranged between 20 and 50% in the first year (Schröder et al., 2007; Shah et al., 2012a, 2012b; Sonneveld and Lantinga, 2011; Van Dijk et al., 2004). Since the major part of the N present in SCM is organically bound, its net availability for plant uptake largely depends on the balance between decomposition, mineralization and immobilization. These processes are influenced by environmental conditions (i.e. temperature and moisture), abiotic factors like soil pH and clay content, chemical composition of the applied organic matter and the composition of the soil decomposer community (i.e. bacteria, fungi and invertebrates) (Ayres et al., 2009b; Myers et al., 1982; Verhoef and Brussaard, 1990; Wang et al., 2009; Wardle, 2002).

Globally, the observed variation in decomposition of organic matter in terrestrial ecosystems is explained for about 70% by environmental conditions together with the chemical composition of organic matter (Ayres et al., 2009b). The remaining 30% is influenced by other factors like the soil decomposer community and their interaction with specific characteristics of the added organic matter together with the local soil chemical and physical properties (Ayres et al., 2009b; Bardgett, 2005; Tian et al., 1995). However, the strength of these factors and their interactions vary among ecosystems and biomes (Wall et al., 2008). In case of significant interactions, the chemical composition (lignin:N or carbon:N ratio) of the organic inputs was found to determine the composition of the associated decomposer communities and the routes and rates of the decomposition process at local scale (Ayres et al., 2009a; Negrete-Yankelevich et al., 2008). Such an association has been reported to explain why decomposition commonly occurs more rapidly when organic matter is applied to its home habitat than when it is applied elsewhere ("away"), an effect called home

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field advantage (HFA) (Ayres et al., 2009b; Gholz et al., 2000; Hunt et al., 1988; Milcu and Manning, 2011; Strickland et al., 2009a; Vivanco and Austin, 2008).

The HFA is generally stronger in cases where the organic matter quality is lower. However, despite large differences in the chemical composition of the litter from natural grasslands and forests, St. John et al. (2011) did not observe a HFA in a reciprocal grassland–forest litter transplantation experiment. They explained that lack of a HFA from a shift from bacterial- to fungal-based decomposition of grass litter when it was incubated in forest, whereas tree litter decomposition was not shifted from fungal- to bacterial-based during incubation in grassland.

SCM varies greatly in its composition and quality (lignin:N and C:N ratio) because of differences in animal origin, feed ration, bedding materials and manure handling as well as processing systems (Rotz, 2004; Tunney and Molloy, 1975). Forge et al. (2005) observed that repeated additions of cattle manure to grassland increased the soil faunal biomass as well as its activity and according to Stark et al. (2008) organic matter amendments boosted the activity of enzymes important in the decomposition process. In contrast, long-term application of mineral fertilizers to grasslands generally decreases earthworm populations (De Goede et al., 2003; Ma et al., 1990) and microbial biomass (Hopkins et al., 2011), resulting mainly from a decrease in soil pH. Hence, also in agro-ecosystems historical factors can shape structural differences in soil biota communities and may be expected to affect organic matter decomposition and mineralization. Some indication for the effect of manure management history on N mineralization from recently added SCM was obtained in a 10-week pot experiment (Nett et al., 2010). They found that organic fertilization increases the N mineralization of and N uptake from recently added SCM but this effect was not always dominant. Therefore, it remains of great interest (i) if HFA exists in production grasslands, and (ii) what its impact can be on soil N transformations and plant N uptake. Accordingly, the aim of the present study was to investigate the effects of differences in the prevailing fertilization management of production grassland and type of SCM (composted vs. stacked) on the DM and N disappearance rate of SCM and herbage N recovery. We hypothesized that (i) the DM and N disappearance rate from SCM will be higher in grasslands with a history of SCM application than in grasslands with a history of non-SCM inputs, and (ii) the N mineralization rate and herbage N uptake from home-produced SCM will be higher on the home farm than when applied on an away farm.

2. Materials and methods

2.1. Site description

Two dairy farms (A and B) were selected which differed in the type of home-produced and applied SCM. In addition, two neighbouring farms (C and D) were selected where only cattle slurry manure was produced. Farms A and C were located on peat soil in the western peat district of the province of Utrecht, whereas farms B and D were both located on a sandy soil near Veenendaal in the province of Gelderland. The distance between farms A and C was 1 km and farms B and D were located 15 km from each other. Farms A and B used cereal straw as bedding material applied at a rate of approximately 5 kg per livestock unit (=500 kg live weight) per day in a litter barn. The manure from the litter barn on farm A (AM) was extensively composted by adding regularly organic-N rich slurry and turning the manure heap 2–3 times during a storage period of 6–8 months. Within this manure handling system, the straw particles were reduced in size to approximately 2 cm length by the turning operations. This resulted in a partly composted SCM (Table 1). On farm B, the manure from the litter barn was stacked (BM) during a storage period of several months and contained longer pieces of straw of up to about 10 cm. Farm C was characterized by the application of artificial fertilizer and mineral N-rich slurry manure, and on farm D only slurry manure was used. No SCM had been used on the grasslands of farms C and D for at least 30 years (non-SCM farms). Grassland management information of the four farms is given in Table 2.

2.2. Litterbag experiment (Expt. 1)

This experiment was conducted to estimate the dry matter disappearance (DMD) and nitrogen disappearance (ND) of the two SCM types from litterbags on the four farms during the growing season of 2010.

On each farm, one permanent grassland field of about 3 ha was selected (Table 2). Soil fertility parameters from each grassland field at the start of the experiment are presented in Table 3. Each field was divided into four blocks and in each block a grass cage of 4.5 m × 1.25 m was placed at random (Lantinga et al., 2004). Inside each cage, 18 litterbags (2 manure types, 3 sampling dates and 3 mesh sizes) were randomly placed on the grassland soil surface in the last week of March 2010. The distance between the centres of two adjacent litterbags (100 mm × 100 mm × 15 mm, $l \times b \times h$) was 50 cm. For the purpose of this paper, we used only the data obtained with the largest mesh size (4 mm) which allowed the entrance of all size classes of detritivorous soil fauna. One day before placement in the field, the litterbags were filled with approximately 150 g fresh manure, corresponding to about 30 g DM for both manures. Before placement of the litterbags, the herbage was mown to a stubble height of 4 cm by using a motorized mower, and a 10 × 10 cm soil surface for each litterbag was gently roughened with a spade to facilitate soil–litterbag contact. In total, 96 litterbags (2 manure types × 4 replicates × 3 sampling dates × 4 farms) were used. The litterbags were collected for analysis on days 60, 120 and 240. In order to monitor material loss from litterbags during transportation, placement on grasslands and retrieval, they were put in traveller bags (Bradford et al., 2002). This material loss appeared to be negligible which confirmed that only mesh size and soil biota were responsible for the observed DM and N disappearances.

2.3. Manure analysis

SCM that remained in the litterbags after removal from the grasslands was oven-dried at 105 °C for 24 h, ground to pass 1 mm sieve and analysed for dry matter, N and ash content. N was measured by Kjeldahl digestion (MAFF, 1986). Ash content was determined by loss-on-ignition at 550 °C for 4 h. DMD and ND rates

Table 1
Mean (±1 SEM; $n = 3$) dry matter (DM), N_{total}, $N_{mineral}$, $N_{organic}$, C:N ratio and lignin:N ratio of solid cattle manure (SCM) from farms A and B.

Farm	SCM processing method	DM (%)	N_{total} (g kg^{-1} DM)	$N_{mineral}$ (g kg^{-1} DM)	$N_{organic}$ (g kg^{-1} DM)	C:N ratio	Lignin:N ratio
A	Composted	19.0 ± 0.2	25.3 ± 0.3	1.1 ± 0.04	24.2 ± 0.3	20 ± 0.3	13 ± 0.5
B	Stacked	20.1 ± 0.1	21.8 ± 0.1	0.8 ± 0.02	21.0 ± 0.1	23 ± 0.1	8 ± 0.6