Organic Matter Dynamics in Coarse Sandy Calcareous Soils

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Abstract

The decomposition of organic matter in coarse sandy calcareous soils (beach sand) is thought to be much higher than in acid fine sandy soils but relatively little research is performed on these soils. Laboratory incubation experiments in which the release of soil carbon (C) is determined may overestimate the release of the soil organic C, as part of the measured C may have been released from the soil carbonates. In addition, it is not clear if the contribution of organic applications to the soil organic matter is also lower on these soils compared to acid fine sandy soils. This study focuses on 1: whether the $\delta^{13}C$ signature of organic carbon differs from that of the carbonate carbon and therefore could be used to determine C-mineralization of coarse sandy calcareous soils and 2: whether and to what extent applications of domestic compost and solid cow manure or combinations of both are able to improve organic matter content and its effects on the production of ornamentals.

INTRODUCTION

The coastal region of the Netherlands is an important production area for flower bulbs and perennials. The coarse sandy calcareous soils are characterized by a low soil organic matter (SOM) content, 5-7 g kg^{-1} and high pH values due to carbonate from seashell residues. Growers highly value the SOM content and organic fertilizers are applied regularly. For some crops e.g., hyacinths, manure is thought to be essential for a good crop quality production.

Soil health problems are commonly due to intensive and narrow crop rotations of ornamentals (bulbs, perennials or field grown cut flowers). One drastic solution is to turn over the soil profile (to about 3 m deep). The SOM content of the newly created soil is even lower (<3 g kg^{-1}) which urges growers to improve the soils by applying large amounts of organic fertilizers. However, the Dutch manure legislation limits the amount of manure applied to 170 kg nitrogen (N) ha^{-1} or 85 kg phosphate (P_2O_5) ha^{-1} in 2008 which resembles approximately 22 ton ha^{-1} of solid manure (www.minlnv.nl/loket). Compost applications are limited to 85 kg ha^{-1} although 50% of the phosphate up to 7 g kg^{-1} is levy free.

The decomposition of soil organic matter on coarse sandy calcareous soils is estimated between 2 and 10% (Van Dam et al., 2004). These estimates are mainly based on laboratory measurements and on long term ‘on farm research’ (Pronk, 2007; Pronk and Van Reuler, 2007). Laboratory incubation experiments in which the release of soil carbon (C) is measured, may overestimate the release of the soil organic C. Bertrand et al. (2007) used $\delta^{13}C$ signatures of the organic C and carbonate C of the soils to identify the source of the release C, organic C or carbonate C, and found that up to 35% of the measured C had been released from the carbonates. This may explain why such high decomposition rates are found but also stresses the need to further study decomposition rates of SOM in these soils.

Regularly, large applications of organic fertilizers, e.g., up to 100 ton of manure per ha^{-1} annually, are applied. However, SOM contents above 20 g kg^{-1} are rarely found. So it is believed that the applied organic fertilizers on these soils decompose faster than on other sandy soils. Maintaining the SOM content on coarse, calcareous sandy soils by growers is therefore very challenging as the decomposition rate of SOM may be high (but it is unclear how high), and the contribution of organic applications may be lower than usually assumed. An explanation for these high decomposition rates of SOM was hypothesized by Ten Berge et al. (2007). They suggest that the organic matter in these soils has a relatively small fraction of old, stable organic matter and a relatively large young, fresh organic matter pool compared to the stable pool, 2 or 3 times larger. As the larger but younger pool contributes the most to the decomposition, overall higher decomposition rates are found. In addition, these coarse sandy calcareous soils have only small clay or silt fractions, SOM may also not be protected from decomposition (Hassink, 1997).

The first objective of this study is to test whether the $\delta^{13}C$ signature of organic C differs from that of the carbonate C of the seashells, as both are of biogenic origin. The second objective is to determine whether and to what extent applications of domestic compost (low in heavy metals), solid cow manure or combinations of both are able to improve SOM content and the effects of the applications on the production of ornamentals.

MATERIALS AND METHODS

Laboratory Experiment

To investigate whether the $\delta^{13}C$ signature of organic C differs from that of the carbonate C as both are of biogenic origin, two soils were collected. About 15 years ago these soils were newly created as described above and one was fertilized according to grower's practices while the other was not fertilized and kept bare for most of the time. The soil samples were air dried and sieved over a 5 mm screen. Three treatments were applied: untreated, fumigated with 12 M HCL (Harris et al., 2001) which removes the carbonate C and ashed (550°C) which removes organic C from the soil samples. After the treatments the soils were analyzed for $\delta^{13}C$ fractions of remaining C-sources, total C, organic C and carbonate C, respectively. The $\delta^{13}C$ was measured with the US Davies Stable Isotope Facility using a continuous flow, isotope ratio mass spectrometer (CF-IRMS, PDZ-Europe Scientific, Crewe, UK). Results for C in the treated samples are given relative to the PDB standard in δ^{13} (‰) notation where $\delta^{13} = [R_{sample}/R_{standard} - 1] * 1000$ and R_{sample} and $R_{standard}$ refer to the $^{13}C/^{12}C$ ratio of the sample and standard, respectively.

Field Trial

A farming systems trial started in 2004 with the aim to develop a cropping system for cultivation of ornamentals on coarse sandy soils with an optimal soil quality, more specifically soil health. This system should have minimal emissions to the environment. The study site is located in Lisse in the Western part of the Netherlands (lat. 52°15'N; long. 4°32') (Van Reuler et al., in prep.). Fields of 4 beds of one crop included bulbs followed by a green manure, perennials, ornamental shrubs and field grown cut flowers (Table 1). On three fields in this system (A, B and E), a study on organic matter decomposition was initiated during the fall of 2007 and will continue to 2011. The following treatments (3 m of 4 beds) of compost and solid cow manure were established (Table 2) prior to planting of the bulbs in the fall and of the perennial in the spring of 2008. Phosphate (P_2O_5) and potassium oxide (K_2O) were applied in comparable amounts in all treatments assuming a P_2O_5 and K_2O release of the organic applications in the first growing season following applications of 60 and 100% respectively. Nitrogen (N) applications were applied according the fertilizer guidelines for flower bulbs (Van Dam et al., 2004) as split applications and compensated for estimated N release from the organic applications (Table 2).

Soil samples were collected in the field trial prior to organic matter applications and stored at 4°C until further processing. A visual weekly evaluation of crop performance was made to determine if and when differences between treatments occur. Yields are determined at the end of each growing season.

RESULTS AND DISCUSSION

Laboratory Experiment

The total C content in the soil samples was low, between 10.6 and 16.5 g kg^{-1} (Table 3). The organic C content varied between 6 and 11.6 g kg^{-1} indicating organic matter contents of approximately 1.0 and 2.0%. The well fertilized soil had twice as much organic C as the unfertilized soil. The carbonate C content of the soil samples was 4.9 g kg^{-1} and did not differ between the soils.

The measured $\delta^{13}C$ values of the untreated soil samples were -15.5 and -20.0‰ (Table 3). The measured $\delta^{13}C$ values of the organic C did not differ between the soils and was -28.5‰. This value is in agreement with commonly found $\delta^{13}C$ signatures of organic C (Bertrand et al., 2007). The measured $\delta^{13}C$ signature of carbonate C was also in line with previously found values (Cerling, 1984) and although from biogenetic sources its value is distinctively different from the $\delta^{13}C$ signature of the organic C.

Field Trial

No differences between treatments in crop performance are found for *Phlox* so far. Differences were found mid May 2008 in daffodil: treatments 1 and 4 show smaller plants and less vigorous growth. In hyacinth yellow/brownish leaf tips were noticed mid May in treatments 1, 4, 6 and 8. Hyacinths are traditionally fertilized with a minimum of 60 ton ha^{-1} solid manure and our preliminary results on the yellow/brownish leaf tips suggest that treatments with lower applications performed suboptimal. The bulbs will be harvested in the summer and the perennial will be harvested in the fall. All crops are evaluated for quality production and for nutrient composition.

CONCLUSIONS

The $\delta^{13}C$ signature of organic C differs from that of the carbonate C. Therefore, laboratory incubation experiments in which $\delta^{13}C$ is measured, can be performed and used to estimate organic C release of the soils of the field trial. So far, differences in performance of bulbs (daffodil and hyacinth) between the treatments were found. Treatment 1 (no organic application) performed badly. Growth of hyacinth was hampered in more treatments than daffodil, although measurements on yield and quality need to confirm this.

The treatments applied in the trial are not all within the Dutch manure legislation. However, this research is primarily initiated to investigate organic matter dynamics. Treatments with only compost comply with the phosphate standard (due to the exemption) and so far show promising crop growth. These treatments are also expected to contribute the most to the organic matter content although this study needs to confirm that.

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Tables

Table 1. Crop rotation of the farming systems trial during 2008-2011.

Year of	Field number		
harvest	A	B	E
2008	Hyacinth - Marigold	Daffodil - Forage rape	*Phlox*
2009	Ornamental shrubs	Hyacinth - Marigold	Field grown cut flowers
2010	Perennials	Ornamental shrubs	Tulips - Fodder radish
2011	Field grown cut flowers	Perennials	Daffodil - Forage rape

Table 2. Treatments of compost and solid cow manure (SCM), the available phosphate and potassium oxide and the applied available N.

Treat-ment:	Compost (tons ha^{-1})	SCM	P_2O_5 [1] (kg ha^{-1})	K_2O [2]	N (kg ha^{-1}) [3] A	B	E
1	0	0	0+173	0+250	0+210	0+140	0+175
2	21	0	55+118	192+250	11+199	11+129	11+164
3	43	0	113+60	393+219	23+187	23+117	23+152
4	0	12	31+142	114+250	13+197	13+127	13+162
5	0	23	60+113	219+250	25+185	25+115	25+150
6	21	12	87+87	306+250	24+186	24+116	24+151
7	43	12	145+29	507+105	36+174	36+104	36+139
8	21	23	115+60	411+201	36+174	36+104	36+139
9	43	23	173+0	612+0	48+162	48+92	48+127

[1] column before the "+" of each nutrient presents the available nutrient from the organic application, column following the "+" presents the mineral application.
[2] Maximum mineral potassium oxide application was 250 kg ha^{-1} as salt damage occurs with higher application rates.
[3] Mineral N is applied as split applications.

Table 3. Results on the stable isotope measurements of the two coarse sandy calcareous soils.

Soil Sample	Treatment	Type of C left	C (g kg^{-1})	$\delta^{13}C$
1	Untreated	total soil	10.6	-15.5 (0.56)[1]
	Fumigated	organic	6.0	-28.5 (0.06)
	Ashed	Carbonic	4.9	-0.8 (0.08)
2	Untreated	total soil	16.5	-20.0 (0.28)
	Fumigated	organic	11.6	-28.6 (0.03)
	Ashed	Carbonic	4.9	-1.5 (0.32)

[1] Standard deviation of three replicates is given between parentheses.