Soil Biology & Biochemistry 42 (2010) 1991–1996

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Decomposition temperature sensitivity of isolated soil organic matter fractions

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ARTICLE INFO

Article history:
Received 1 April 2010
Received in revised form
23 July 2010
Accepted 26 July 2010
Available online 10 August 2010

Keywords:
Decomposition
Temperature sensitivity
Particulate organic matter
Non-hydrolysable carbon

ABSTRACT

The general consensus is that a warming climate will result in the acceleration of soil organic matter (SOM) decomposition, thus acting as a potential positive feedback mechanism. However, the debate over the relative temperature sensitivity of labile versus recalcitrant SOM has not been fully resolved. We isolated acid hydrolysis residues to represent a recalcitrant pool of SOM and particulate organic matter (POM) to represent a labile pool of SOM, and incubated each at different temperatures to determine temperature sensitivity of decomposition. Short-term incubations of POM generated results consistent with published experiments (i.e., greater proportion of C respired and lower Q_{10} than whole soil), while incubations of acid hydrolysis residues did not. The contrasting results illustrate the difficulty in assessing temperature sensitivity of labile versus stable SOM decomposition, partly because of the inability to quantitatively isolate labile versus stable SOM pools and to be sufficiently certain that respiration responses to temperature are not masked by processes such as enhanced stabilization or microbial inhibition/adaptation. Further study on the temperature sensitivity of decomposition of isolated SOM fractions is necessary to better explain and predict temperature responses of bulk SOM decomposition.

1. Introduction

The general consensus found in the literature is that a warming climate will result in the acceleration of soil organic matter (SOM) decomposition (Bond-Lamberty and Thomson, 2010), thus acting as a potential positive feedback mechanism (Field et al., 2007). However, the biochemical complexity of SOM and range of stabilization mechanisms have generated a great deal of debate about the relative temperature sensitivity of the decomposition of labile versus stable SOM pools (Kirschbaum, 2006; Powlson, 2005). von Lützow and Kögel-Knabner (2009) summarized the large range of contradictory results concerning temperature sensitivity of decomposition rates, and provided published evidence for each of the following four statements: 1) stable SOM pools are not temperature sensitive, 2) stable SOM pools are more temperature sensitive than labile pools, 3) labile and stable SOM pools are equally temperature sensitive, and 4) labile SOM pools are more temperature sensitive than stable SOM pools. The labile SOM is generally small (<10% of total SOC; Haynes, 2005), and by definition short-lived. Thus, if temperature sensitivity of a given soil is attributable largely to the labile SOM pool, one could expect the response in CO_2 evolution to be relatively small in magnitude and short-lived (Davidson and Janssens, 2006). Conversely, if temperature sensitivity is attributable largely to the stable SOM pool, one could expect the response to be much larger and longer-lived (Davidson and Janssens, 2006). The importance of this debate is highlighted by the fact that even modest temperature increases could cause large releases of CO_2 to the atmosphere. Global estimates of increased respired soil C released to the atmosphere are on the order of 11.1–33.8 Pg C for every 1 °C temperature increase, equivalent to as much as five times the annual CO_2 release from all fossil fuel burning (Houghton et al., 2001; Jenkinson et al., 1991; Schimel et al., 1994; Townsend et al., 1992).

The range of conflicting results can partially be attributed to the range of methods used to address the question of SOM decomposition temperature sensitivity (Kirschbaum, 2006; von Lützow and Kögel-Knabner, 2009), and our inability to consistently define and quantify labile versus stable SOM. Fractionation is a technique frequently used to address the latter issue. Particulate organic matter (POM) is frequently identified as a labile SOM pool (Gregorich et al., 2006), in spite of the potential presence of recalcitrant black C. The POM fraction consists of partly decomposed plant residues that are not bound to mineral particles, making it a good candidate for testing hypotheses concerning the temperature sensitivity of labile SOM

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doi:10.1016/j.soilbio.2010.07.022

decomposition. The non-hydrolysable SOM fraction is frequently used as a proxy for the most stable SOM pool in dynamic models (Falloon and Smith, 2000), thus making it a good candidate for testing hypotheses concerning the temperature sensitivity of stable SOM decomposition.

The purpose of this work was to assess how temperature sensitivity varies with soil organic C decomposability by assessing responses for soil fractions of different lability incubated in isolation. This work is comprised of two main experiments conducted on cultivated and non-cultivated soils from Akron, CO; one to test the temperature sensitivity of the decomposition of relatively recalcitrant SOM and the other of relatively labile SOM. For the first, we isolated acid hydrolysis residues of decreasing lability by conducting hydrolysis for successively longer durations on the non-cultivated grassland soil. For the second, we isolated POM fractions from cultivated and non-cultivated soils. Both experiments investigate how the temperature sensitivity of decomposition of available SOM varies with lability. These experiments complement each other because one experiment assessed the influence of temperature on the decomposition of the most active SOM fractions whereas the other experiment assessed temperature sensitivity of more recalcitrant SOM.

2. Materials and methods

2.1. Field site

Soil samples were collected from the Central Great Plains Research Station located in Akron, CO, at 40°9′N, 103°9′W. The soil is a Weld silt loam (Aridic Paleustoll). The climate is characterized by warm summers and cold winters and predominately sunny skies. The majority of precipitation occurs from April to August, with a total annual precipitation of 420 mm. The crop rotation and tillage study at Akron was started in 1957, using winter wheat in a crop-fallow rotation (Halverson et al., 1997). The two plots sampled for these experiments were in plots 307 and 106, which are each 30.5 m by 11 m. Both plots are wheat-fallow plots that are plowed. Plot 307 is in the SE quarter of the cultivated area and plot 106 is in the SW quarter. At the time of sampling, the plots were fallow. Samples were also collected from a grassland site north of the cultivation plots. The grassland area is dominated by blue grama (*Bouteloua* gracilis) and buffalo grass (*Bucloe dactyloides*), and has been undisturbed since at least 1957 (Bowman and Anderson, 2002).

2.2. Sample collection, preparation, and chemical analyses

Surface litter and aboveground vegetation were cleared away prior to sampling, and soil samples were collected from four replicate pits dug to a depth of 20 cm. Samples were sealed in plastic bags and returned to the laboratory. Field replicate samples were composited and passed through a 2-mm mesh sieve. Visible root material was removed by hand picking during sieving. Samples were stored air-dry until incubations began. To determine bulk density data, soil cores (6.5 cm diameter) were taken to a depth of 20 cm.

Soil C and N concentrations were determined for total soil and the various isolated fractions with a LECO CHN-1000 autoanalyzer (LECO Corporation, St. Joseph, MI, USA). Addition of strong acid to a subset of samples indicated that carbonates were not present; thus soil C hereafter is used for organic soil C. Respiration data for native and cultivated whole-soil samples were collected as part of the laboratory incubation experiment reported in Haddix et al. (in press), and are included for comparison to the isolated fractions.

2.3. Acid hydrolysis residues as a recalcitrant pool

2.3.1. Soil fractionation

Acid hydrolysis is among the earliest fractionation schemes used to isolate a resistant soil C fraction (Paul et al., 2006) and is known to isolate a pool of soil organic C that is much older than whole-soil C (Paul et al., 1997). Fatty acids, proteins and polysaccharides are susceptible to acid hydrolysis treatment, while long-chain alkyls, waxes, lignin and other aromatics are resistant to hydrolysis (Paul et al., 2006). We used duration of hydrolysis treatment to generate residues with SOM of differing decomposability, such that the recalcitrance of the SOM used for our experiments increased as the duration of hydrolysis increased. The hydrolysis method was based on that described in Paul et al. (1997). Briefly, 1 g aliquots of the non-cultivated native grassland soil were refluxed at 95 °C for various durations (1, 6, or 18 h) in 25 mL of 6 N HCl. After refluxing, the suspension was filtered and washed with deionized water over a glass fiber filter to remove excess HCl. The residue was then washed from the filter and collected in specimen cups. After performing acid hydrolysis of the soil, the pH was between 3 and 4, and therefore titrated with calcium hydroxide to bring the pH to 6.5. The samples were then oven dried at 60 °C for 24 h. Using this approach we collected sufficient non-hydrolysable soil residue for four 20-g replicate samples of each hydrolysis treatment to be incubated at three temperatures (20 g × 4 reps × 3 temperatures = 240 g).

2.3.2. Incubation

All residues for a given hydrolysis treatment were thoroughly mixed and twelve laboratory replicate samples (20 g) were drawn and placed in plastic specimen cups (100 mL, 6.5 cm diameter). Inoculum was created by incubating 20 g of untreated (i.e., non-hydrolyzed) soil for seven days following the addition of 6.5 g mixture consisting of 1 part cellobiose dissolved in water (1 mg g^{-1}) and 1 part Hoagland's solution. The inoculum was extracted from the soil by adding 200 mL of water and shaking the soil for 30 min. The soil was allowed to settle and the liquid portion was extracted. This solution was added to bring the samples to 60% of water holding capacity. Determination of the C concentration in the inoculum and subsequent correction calculations showed that C added in the inoculum did not contribute significantly to the CO_2 respired during incubation. The specimen cups were enclosed in 1-quart (946 mL) canning jars with lids containing rubber septa for drawing gas samples. Moisture inside the jars was maintained with a small (20 mL, 2 cm diameter) vial of water. Soils were incubated at one of three constant temperatures (15, 25, or 25 °C) for 56 days. Soil respiration was determined on all samples by sequential measurements as CO_2 concentrations increased. Jars were kept unopened during the full duration of the incubation. Headspace samples were collected daily for the first 14 days, then weekly for the remainder of the incubation. For each measurement, sample headspace was mixed with a large syringe and gas samples were taken through the rubber septa in the lid. We used a LI-6525 (LI-COR, Lincoln, NE) infrared gas analyzer (IRGA) to analyze CO_2 concentration. Gas samples were injected into an in-line port and carried to the IRGA with CO_2-free air. Maximum CO_2 concentrations for the IRGA (approximately 2000 μmol/mol) dictated sample volumes. At low CO_2 concentrations 2 mL samples were used, and sample volume was as low as 100 μL at high CO_2 concentrations.

2.4. Particulate organic matter as a labile pool

2.4.1. Soil fractionation

Coarse POM was isolated by size in a manner similar to that described by Cambardella and Elliott (1992). Fifty grams of air-dried soil from the cultivated and grassland treatments were slaked in deionized water for 30 min, then poured onto a 250-μm mesh screen

inside a cylinder and reciprocally shaken (120 rev min^{-1}) with 50 glass beads (diam. 6 mm) until the complete disruption of all macroaggregates. The POM fraction (including coarse sand) retained on the 250-μm mesh screen was subsequently oven dried overnight at 60 °C.

2.4.2. Incubation

While the native and cultivated soils yielded similar mass proportions of POM (~4% of whole-soil mass), the organic C concentrations of the fractions differed significantly between the two soils. Carbon-free quartz sand was added to the isolated POM fractions from both the native (7 g sand per g POM) and cultivated (0.75 g sand per g POM) soils to roughly equilibrate the C content of the samples prior to incubation. Inoculum was created for each soil (i.e., native and cultivated) in the same manner as that used for the acid hydrolysis experiment. A 6.5 g aliquot of this solution was then added to 20 g of the POM + sand mixture in specimen cups and Hoagland's solution was added to bring soil moisture to 60% water-filled pore space. Samples were then placed in sealed 0.473 L canning jars and incubated at one of four constant temperatures (4, 15, 25 or 35 °C) for 126 days. Headspace CO_2 concentrations were measured as described above. As the jars were occasionally opened to refresh the headspace and prevent excessive CO_2 accumulation, cumulative CO_2 respiration was calculated by summing accumulations over the unopened durations.

2.5. Statistical analyses

Temperature sensitivities were evaluated as Q_{10}, the proportional increase in respiration given a 10 °C change in temperature, which was calculated using the slope of a regression line between the log of total CO_2 respired during the incubation (in μg C g^{-1} sample) and incubation temperature, using SigmaPlot 11.0 (Systat Software Inc., San Jose CA) to model regression lines and associated parameter estimates. All incubations were carried out using four laboratory replicates. Data in all figures and tables represent means and standard errors. Comparisons of mean CO_2 respired during incubation as a proportion of initial sample C were performed using two-way ANOVA procedures in JMP (SAS Institute Inc., Cary NC). Incubation temperature and acid hydrolysis duration were the main effects of the ANOVA in the acid hydrolysis experiment, while incubation temperature and land use were the main effects in the POM experiment. Interactions were included in the ANOVA, and differences between means were considered statistically significant if $P < 0.05$.

3. Results

3.1. Carbon content and decomposability of isolated soil C fractions

Carbon associated with acid hydrolysis residues represented a significant proportion of total soil C (40–60%), and this proportion decreased as the duration of acid hydrolysis treatment increased (Table 1). The amount of CO_2 respired during incubation of acid hydrolysis residues increased with incubation temperature and generally decreased with longer durations of acid treatment (Fig. 1; Table 2). Overall, the proportion of initial C respired during the 56-day incubation was low (<6% of initial sample C), which can be attributed to the short duration of the incubation as well as the recalcitrant nature of the non-hydrolysable C.

Table 1
Organic C concentration of whole soil and isolated fractions used for laboratory incubations.

Fraction	Field management	Organic C concentration (g C kg $fraction^{-1}$)	Proportion of initial soil C (%)
Whole soil	Native	12.0 ± 0.1	–
	Cultivated	6.8 ± 0.02	–
1-h hydrolysis residue	Native	7.3 ± 0.07	60.8
6-h hydrolysis residue	Native	6.6 ± 0.01	55.0
18-h hydrolysis residue	Native	5.0 ± 0.02	41.7
Particulate organic matter (POM)	Native	28.6 ± 0.09	9.6
	Cultivated	5.6 ± 0.01	3.4

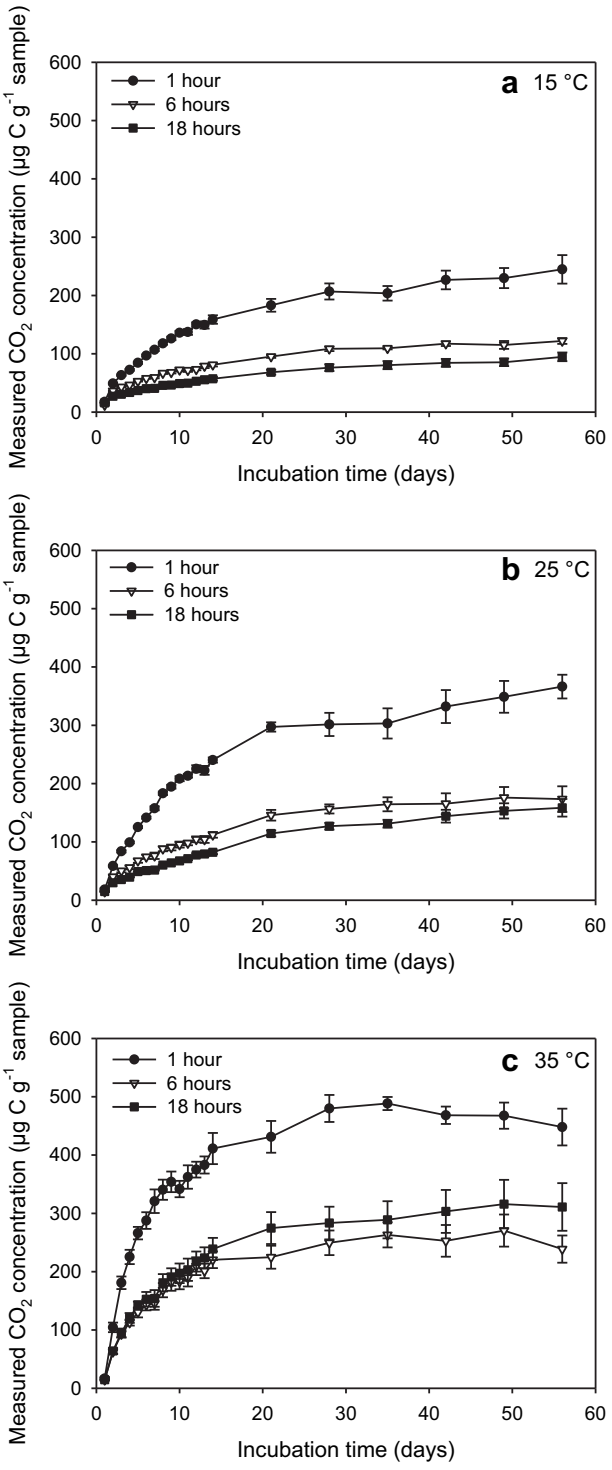

Fig. 1. Measured CO_2 concentrations (μg CO_2–C g^{-1} sample) during the 56-day incubation of acid hydrolysis residues at three temperatures. Error bars represent standard error of the mean ($n = 4$).

Table 2
Carbon dioxide (CO_2) respired during a 56-day incubation of whole soil and acid hydrolysis residues (mean ± standard error, $n = 4$).

Fraction	Land use	15 °C		25 °C		35 °C	
		(μg C g^{-1} sample)	(% initial SOC)	(μg C g^{-1} sample)	(% initial SOC)	(μg C g^{-1} sample)	(% initial SOC)
Whole soil	Native	192.0 ± 20.0	1.6 ± 0.2	448.3 ± 31.2	3.7 ± 0.3	971.4 ± 36.5	8.1 ± 0.3
1-h hydrolysis residue	Native	244.8 ± 24.4	3.3 ± 0.3	366.4 ± 20.3	5.0 ± 0.3	448.0 ± 31.5	6.1 ± 0.4
6-h hydrolysis residue	Native	120.0 ± 5.0	1.8 ± 0.1	173.3 ± 22.1	2.6 ± 0.3	238.7 ± 23.3	3.6 ± 0.4
18-h hydrolysis residue	Native	94.8 ± 7.4	1.9 ± 0.1	158.5 ± 15.1	3.2 ± 0.3	311.0 ± 41.0	6.2 ± 0.8

Carbon associated with POM fractions represented a relatively small proportion of total soil C (3–10%), and this proportion was significantly greater in native soils compared to cultivated soils (Table 1). Similar to the hydrolysis residue experiment, the amount of CO_2 respired during incubation of POM + sand mixtures increased with incubation temperature (Fig. 2; Table 3). Native whole-soil samples generated greater CO_2 respiration than cultivated samples, while the reverse was true for the POM + sand samples (Table 3). The proportion of initial POM + sand C respired during the 126-day incubation was greatly affected by temperature, ranging from 3 to 7% of initial sample C at 4 °C, up to 31–49% at 35 °C (Table 3).

3.2. Temperature sensitivity of isolated soil C fractions

Regression of incubation temperature and respiration during incubation of acid hydrolysis residues from the native soil generated values of Q_{10} that generally increased with increasing duration of hydrolysis treatments (Fig. 3, Table 4), though the difference between 1-h and 6-h Q_{10} values was not statistically different. Q_{10} values for the acid hydrolysis residues were relatively low, ranging from 1.36 to 1.79. Similar regression analysis of incubation of POM + sand samples generated values of Q_{10} that were slightly higher, ranging from 1.85 for the cultivated treatment and 2.01 for the native treatment (Fig. 4, Table 4). The difference in Q_{10} values between land use treatments was statistically significant.

4. Discussion

Two general approaches have been used to study temperature sensitivity of the decomposition of labile and recalcitrant SOM pools. In the first approach, whole-soil samples are incubated at different temperatures and the sensitivity of different pools is teased apart using modeling and curve fitting, isotopes or comparison of SOC losses using fractionations performed before and after incubation (e.g., Feng and Simpson, 2008; Karhu et al., 2010). The second approach is to incubate isolated fractions at different temperatures. Few studies have examined the decomposition dynamics of isolated soil fractions (Crow et al., 2007; Swanston et al., 2002), and fewer still have studied the temperature sensitivity of such fractions (Leifeld and Fuhrer, 2005). One could argue that the incubation of isolated fractions is not representative because the soil matrix environment has been destroyed, but the approach provides estimates closer to intrinsic temperature sensitivity of different fractions rather than apparent temperature sensitivity (sensu Davidson and Janssens, 2006) because physical protection mechanisms have been removed.

Acid hydrolysis residues were selected as a fraction to represent a recalcitrant pool SOM. Carbon concentrations measured after hydrolysis suggest that much of the hydrolysis reaction that removed labile SOM occurred during the first few hours (i.e., 61% of initial SOC remaining after 1 h versus 42% of initial SOC after 18 h). One would expect that a greater proportion of initial C would be respired during incubation of whole-soil samples compared to the

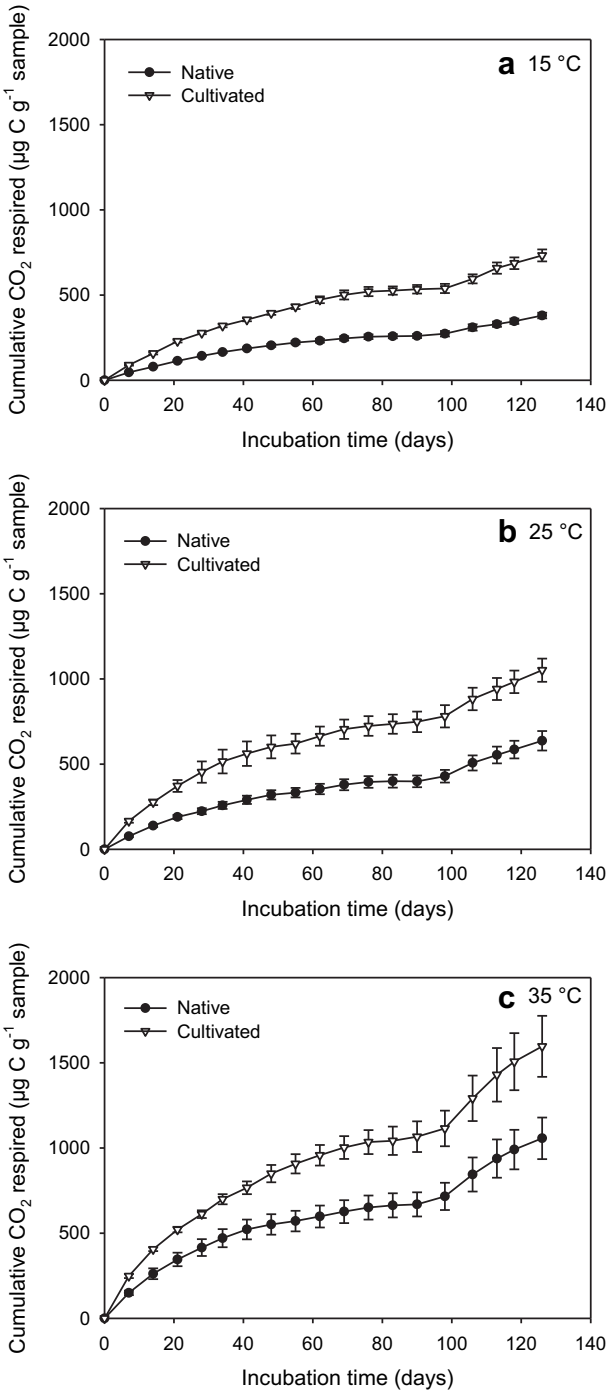

Fig. 2. Cumulative soil respiration (μg CO_2–C g^{-1} sample) during 126-day incubation at three incubation temperatures of native and cultivated POM mixed with sand. Error bars represent standard error of the mean ($n = 4$).

Table 3
Carbon dioxide (CO_2) respired during a 126-day incubation of whole soil and particulate organic matter and sand mixtures from contrasting land uses (mean ± standard error, $n = 4$).

Fraction	Land use	4 °C		15 °C		25 °C		35 °C	
		(μg C g^{-1} sample)	(% initial SOC)	(μg C g^{-1} sample)	(% initial SOC)	(μg C g^{-1} sample)	(% initial SOC)	(μg C g^{-1} sample)	(% initial SOC)
Whole soil	Native	80.8 ± 13.2	0.7 ± 0.1	416.8 ± 46.1	3.5 ± 0.4	883.7 ± 17.9	7.4 ± 0.2	1574.0 ± 61.5	13.1 ± 0.5
	Cultivated	61.2 ± 17.0	0.9 ± 0.3	219.4 ± 18.5	3.2 ± 0.3	354.0 ± 22.3	5.2 ± 0.3	690.2 ± 15.7	10.1 ± 0.2
Particulate organic matter (POM)	Native	116.9 ± 16.2	3.1 ± 0.6	379.7 ± 16.7	10.6 ± 0.5	637.0 ± 57.0	17.8 ± 1.6	1056.6 ± 122.1	30.7 ± 4.6
	Cultivated	216.5 ± 6.3	6.7 ± 0.2	732.5 ± 35.2	22.4 ± 1.5	1051.2 ± 67.9	32.6 ± 2.1	1596.6 ± 179.3	49.5 ± 5.6

acid hydrolysis residues. In addition, one might expect the dynamics of the respiration to differ among treatments because of difference in the composition of the SOM. That is, respiration from whole-soil samples would exhibit a rapid decline as labile SOM is consumed, while respiration from acid hydrolysis residues would be consistently low. The results, however, did not exhibit the expected trends. Respiration curves for the incubations at 15 and 25 °C did not show strong curvature, while the curves for the incubation at 35 °C showed a clear decrease in respiration rates after 14 days. This suggests that the hydrolysis residues were not of uniform quality, with a portion decomposing more quickly. For incubations at 15 and 25 °C, the proportions of C respired were similar between whole soil, 6-h hydrolysis and 18-h hydrolysis, while the proportion of C respired was greater in the 1-h hydrolysis samples. Similar respiration rates for hydrolysis residues and whole soils are consistent with results of Leifeld and Fuhrer (2005). It is possible that the 1-h hydrolysis removed SOM-stabilizing sesquioxides without significantly altering or removing SOM. The result was to render the residual SOM effectively more labile and thus altering its temperature sensitivity. While acid hydrolysis has no obvious real-world analog, one could speculate how a similar result could be achieved by some other mechanisms of SOM destabilization such as mineral weathering. No significant differences were observed in the proportion of C respired among samples incubated at 35 °C. The lack of differences may be due to the fact that the warmest incubation temperature provided sufficient activation energy to permit the decomposition of the hydrolysis residues. Calculated Q_{10} values for acid hydrolysis residues were also significantly less than those for the whole soil, suggesting less temperature sensitivity. These results are inconsistent with those from Leifeld and Fuhrer (2005), who found higher Q_{10} values for non-hydrolysable C. While there is still significant debate and a lack of consistent methods, our results are inconsistent with a number of other incubation studies that suggest that recalcitrant SOM is more temperature sensitive (see Table 3 in von Lützow and Kögel-Knabner, 2009). While direct comparison with whole soil may not be valid because whole-soil data were generated in a separate study (Haddix et al., in press), Q_{10} values did increase as the duration of acid hydrolysis increased. However, Q_{10} values are also expected to be greater at cooler temperatures (e.g., as seen in Leifeld and Fuhrer, 2005). Among our results, this was only the case for the 1-h hydrolysis residue samples. At cooler temperatures, respiration rates comparable with whole soils suggest that acid hydrolysis liberated SOM with decomposability similar to that of whole soils, but this was not the case at the warmest incubation temperature. It is possible that the calcium additions used to neutralize hydrolysis-induced reductions in pH enhanced stabilization of SOM through cation bridging (von Lützow et al., 2007). This effect would not have been apparent in the results of Leifeld and Fuhrer (2005) because they used NaOH to neutralize pH. The lower Q_{10}s resulting from our analyses and a larger effect associated with greater Ca^{2+} addition (i.e., a greater reduction in apparent Q_{10}s for the 18-h residues) are consistent with this. Future studies using hydrolysis residues should minimize such experimental artifacts. Our results suggest that the use of short-term incubation of acid hydrolysis residues may not be ideal for testing the temperature sensitivity of recalcitrant SOM. While non-hydrolysable C has been shown to be significantly older than whole-soil SOM (Leifeld and Fuhrer, 2005; Paul et al., 1997; Trumbore and Zheng, 1996), with a chemical composition consisting of more recalcitrant compounds (Leifeld and Fuhrer, 2005; Schnitzer and Preston, 1983), its use as a recalcitrant fraction has previously been called into question (Paul et al., 2006; von Lützow et al., 2007). There remains significant uncertainty about whether acid hydrolysis residues represent a functional pool of recalcitrant SOM, and can be used in temperature sensitivity analyses.

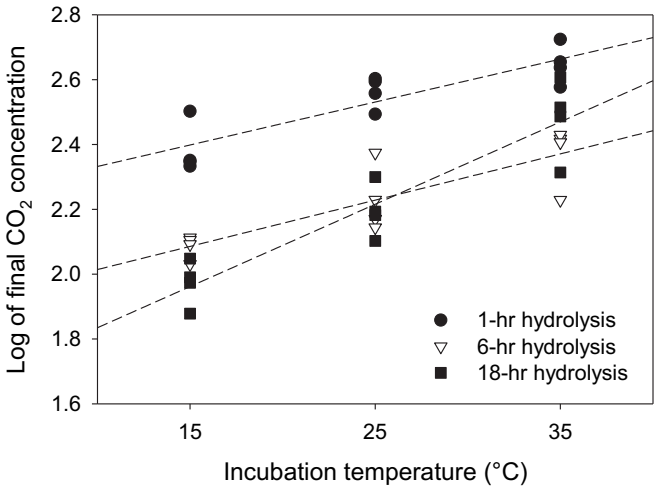

Fig. 3. Regression lines for the log of final CO_2 concentration versus temperature for acid hydrolysis residues. The slope of these lines is equivalent to the Q_{10} temperature sensitivity. Regression coefficients and Q_{10} values are given in Table 4.

Table 4
Regression coefficients and associated Q_{10} temperature sensitivity for the relationship between incubation temperature and soil respiration during incubation of native and cultivated whole soil, acid hydrolysis residues from the native soil, and POM + sand samples.

Soil	Slope	Intercept	R^2	P	Q_{10}
Cultivated whole soil	0.0294 ± 0.0036	1.52 ± 0.093	0.860	< 0.001	1.97 ± 0.10
Native whole soil	0.0356 ± 0.0024	1.75 ± 0.063	0.956	< 0.001	2.27 ± 0.19
1 h hydrolysis residue	0.0133 ± 0.0023	2.20 ± 0.061	0.764	0.0002	1.36 ± 0.12
6 h hydrolysis residue	0.0143 ± 0.0028	1.87 ± 0.074	0.721	0.0005	1.39 ± 0.13
18 h hydrolysis residue	0.0254 ± 0.0032	1.58 ± 0.084	0.862	< 0.001	1.79 ± 0.11
Cultivated POM	0.0267 ± 0.0025	2.32 ± 0.056	0.895	< 0.001	1.85 ± 0.08
Native POM	0.0303 ± 0.0027	2.01 ± 0.061	0.903	< 0.001	2.01 ± 0.09

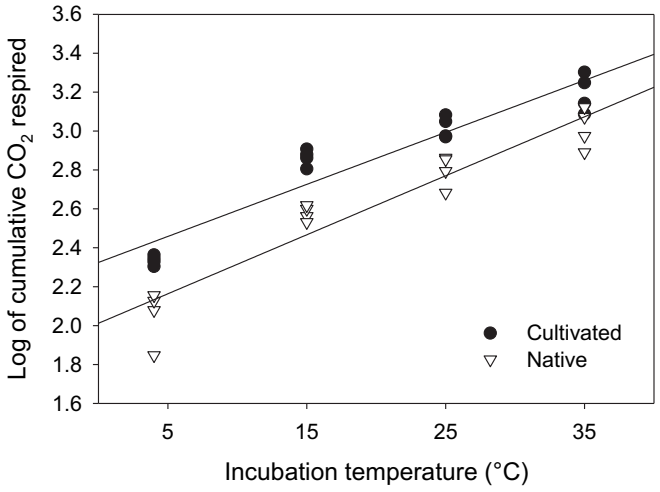

Fig. 4. Regression lines for the log of cumulative respiration versus temperature for native and cultivated POM and whole soils. The slope of these lines is equivalent to the Q_{10} temperature sensitivity. Regression coefficients and Q_{10} values are given in Table 4.

Particulate organic matter was selected as a fraction to represent a labile pool SOM. The selection of fractionation by size rather than density alleviated the potential problems associated with residual tungsten (Crow et al., 2007). Contrary to acid hydrolysis, results of the short-term incubations suggest that POM performed well for testing the temperature sensitivity of labile SOM. Sample isolated from cultivated soils respired more CO_2 than samples isolated from native soils, suggesting that recent crop-derived POM is more labile than POM derived from native vegetation. The proportion of C respired was significantly greater (typically 2× to 3×) at all incubation temperatures for POM fractions compared to whole-soil samples, and calculated Q_{10} values were significantly less for the POM + sand fractions compared to the whole-soil samples.

Conant et al. (2008) previously used long-term incubation to deplete labile SOM and determined Q_{10} values for the early and latter part of the incubation. This approach provided an integrated assessment of temperature sensitivity of decomposition of SOM subject to all stabilization mechanisms. The current study sought to test the temperature sensitivity of isolated fractions to minimize the potential dampening effect of physical protection (e.g., Gillabel et al., 2010; Plante et al., 2009), and to focus on the temperature sensitivity of what was supposed to be inherently labile versus stable SOM. Particulate organic matter generated results consistent with published experiments (i.e., greater proportion of C respired and lower Q_{10} than whole soil), but acid hydrolysis residues did not. The results illustrate the difficulty in assessing temperature sensitivity of labile versus stable SOM decomposition, which lies both in our inability to consistently define and quantify what comprises labile versus stable SOM and to be sufficiently certain that respiration responses to temperature are not masked by processes like enhanced stabilization or microbial inhibition. While long-term incubations should continue to be pursued to separate labile and stable SOM (as recommended by von Lützow and Kögel-Knabner, 2009), we suggest that further study on the temperature sensitivity of the decomposition of isolated fractions is necessary to alleviate the need for such long incubations.

Acknowledgements

This work was supported by the National Science Foundation grant DEB-0444880 and two supplements to support Research Experiences for Undergraduates.

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