

UNIVERSITY OF NAPOLI “FEDERICO II”

AGRICULTURAL FACULTY

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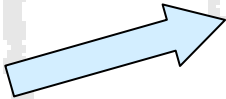
Soil chemistry department

Soil Organic Matter dynamics

- ^{13}C labelled organic material

- TMAH thermochemolysis

Dr. Riccardo Spaccini



one of the pressing problems in agro-ecosystems is represented by the continuous loss of soil organic matter content

a part the immediate effect on plant productivity the lowering of SOM level lead to a long term decrease of overall soil chemical and biochemical fertility and soil aggregate stability (soil erosion)

all these effects have as a feed back consequence, the further increase of SOC losses: agricultural activities have nowadays a significant contribute to green-house gas emissions in the earth atmosphere

in 1997 the estimation for the current loss rate from virgin soils converted to intensive agricultural exploitation was around

$$0.9 \times 10^{15} \text{ g C yr}^{-1}$$

different practices are therefore currently applied in order to reduce, in the short/medium terms, the decrease of SOC content and to produce a long term restoring or improvement of SOM level

- integration or replacement of mineral fertilizers with organic materials such as green manure, animal manure, pig slurry, recycled organic biomasses etc.

among SOM pools an important component are represented by humic materials; this colloidal organic fraction largely affect all the various aspect of long term soil fertility, moreover acting as a long term sink of soil organic matter

humic substances, such as humic acids and humin represent in fact the most persistent pool for SOC accumulation, through the selective preservation of recalcitrant material and the close interaction with finest soil fractions

humic material is believed to play a fundamental role in the stable incorporation of more labile organic compounds released from root exudates, plant litter and microbial activity, thereby increasing SOM sequestration and reducing the OC mineralization

“Organic carbon sequestration through protection by humic substances”

Objective

Study the effect of humified organic matter on the mineralization of labile organic compound in soil

a short chain alcohol (2 decanol) was labelled with ^{13}C isotope and used for soil incubation to study the OC mineralization

the ^{13}C labelled alcohol was added to soil either alone or in mixture with two humic acids extracted from lignite and from recycled organic biomass

the mineralization of labelled alcohol was followed for 6 months in all soil treatments either in bulk soils and in soil-size fractions, determining also the final incorporation of labelled compounds in soil humic substances

Why using ^{13}C labelled compound

the use of organic material labelled with ^{13}C isotope is a useful tool for the analysis of SOM dynamics and of OC mineralization

the enzymatic systems involved during photosynthesis in plant C fixation, discriminate against the ^{13}C isotope, reducing the ^{13}C content in plant tissues; the amount of ^{13}C is indicated as δ and it is determined (with IR-MS) comparing the ratio $^{13}\text{C}/^{12}\text{C}$ of the sample and that of a reference standard

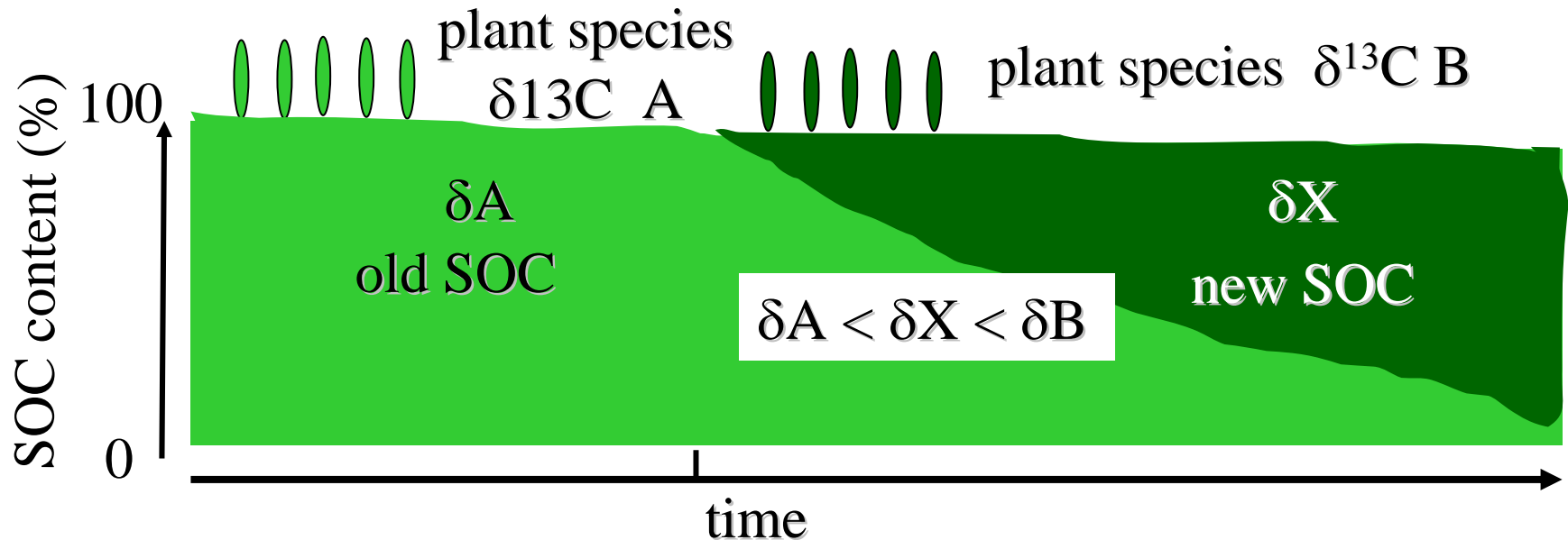
$$\delta = \left[\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}} - (^{13}\text{C}/^{12}\text{C})_{\text{reference}}}{(^{13}\text{C}/^{12}\text{C})_{\text{reference}}} \right] \times 1000$$

the ^{13}C content in the various plant species change with different photosynthetic pathway:

- C3 plants (wheat) (*Calvin cycle*) have an average ^{13}C content $\delta = -27\text{‰}$
- C4 plants (corn) (*Hatch & Slack cycle*) have average ^{13}C content $\delta = -14\text{‰}$
- CAM plants have an average ^{13}C content $\delta \cong \text{C4 plants}$
(facultative CAM have a ^{13}C content $\delta = -14\text{‰} \div -27\text{‰}$)

since there is not a net or significant microbial discrimination of ^{13}C during microbial degradation and microbial synthesis **the ^{13}C abundance of SOM reflect the composition of the plant species cultivated**

by adding to soil an organic material with different ^{13}C content it is therefore possible to **label the new entering SOC** and differentiate between old and new organic material, thereby following both processes of OC accumulation and mineralization

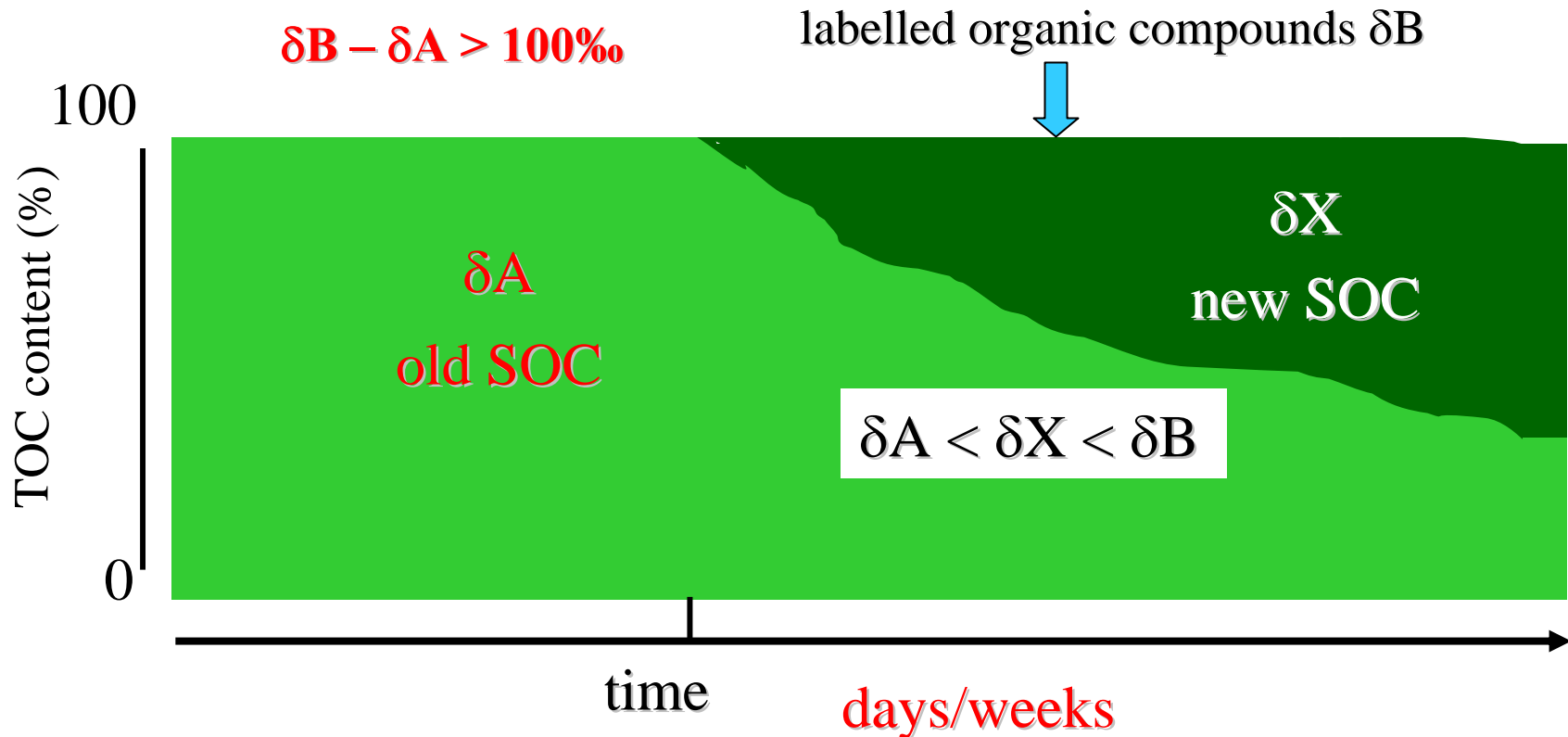


The amount of recent SOC is calculated as percentage

$$\% \text{ SOC}_{\text{recent}} = \left[\frac{(\delta X - \delta A)}{(\delta B - \delta A)} \right] \times \text{TOC}(\%)$$

in long term field experiment the shift between old and recent SOM is obtained by “**natural labelling**” replacing the previous cultivated plant species with another crop with different δ e.g. wheat (C_3 plant) replaced with corn (C_4 plant)

in short term laboratory incubation experiment, synthesized labelled organic compound, with a significant different δ , are likely used in order to have a rapid shift between old and recent SOM



“Organic carbon sequestration through protection by humic substances

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Study the effect of humified organic matter on the mineralization of labile organic compound in soil

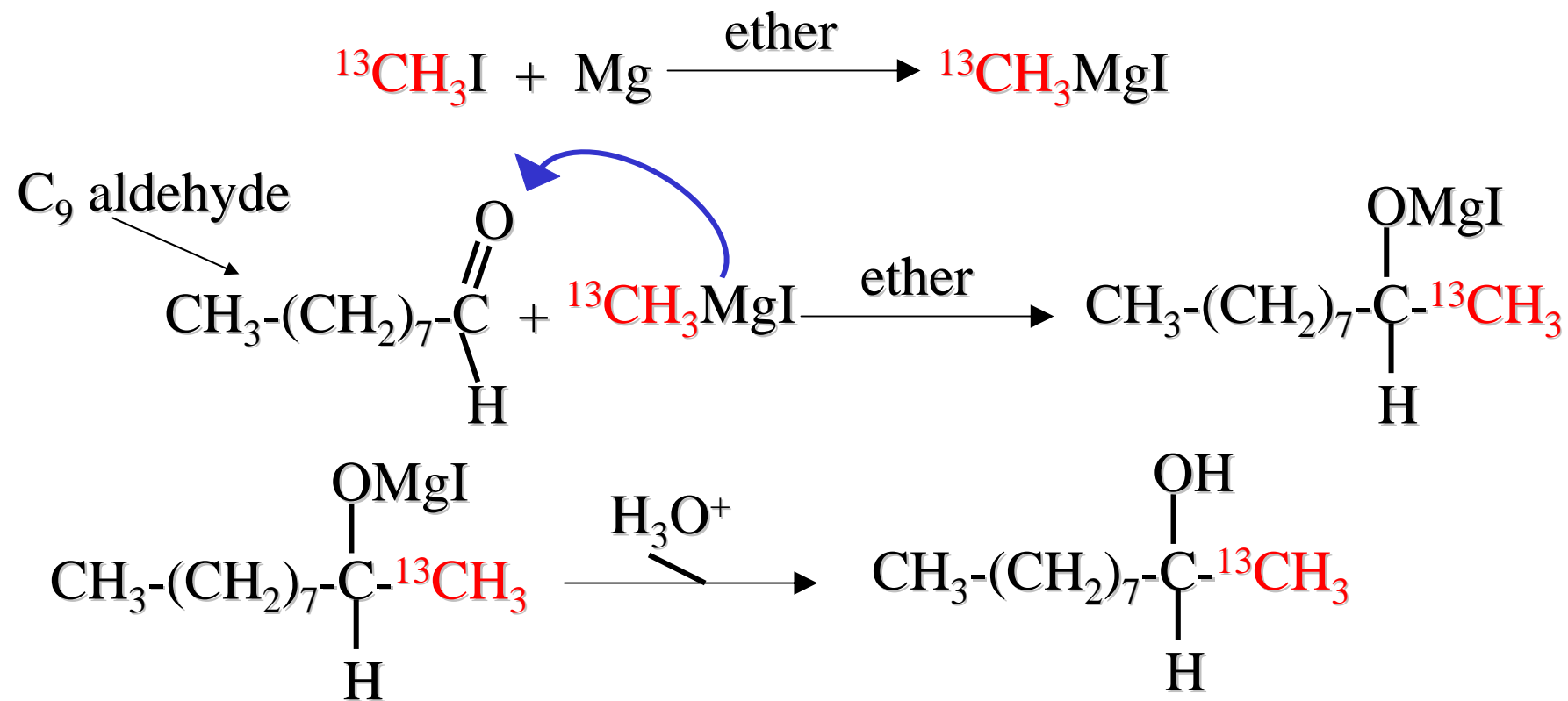
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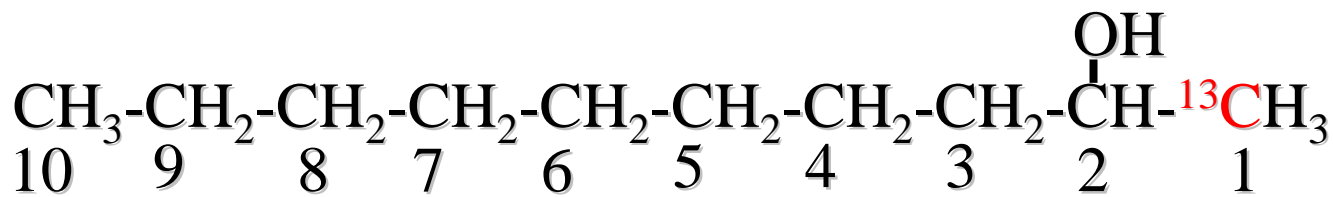
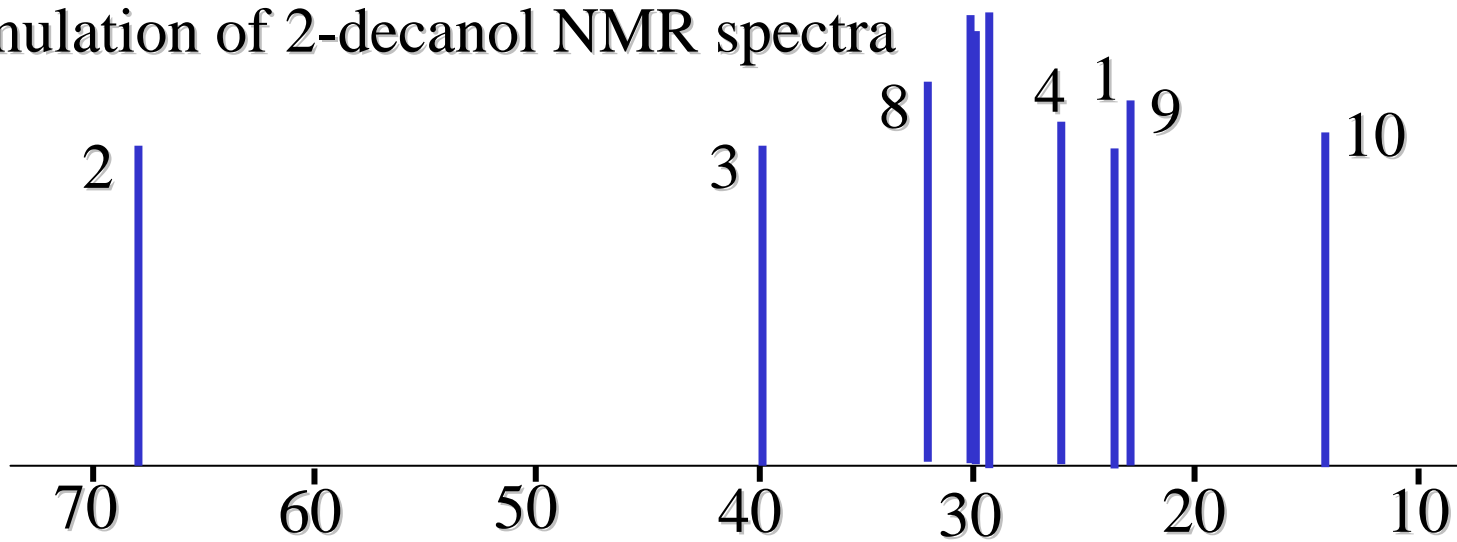
¹³C-labelling of 2-decanol

¹³C labelled 2-decanol was synthesized in our laboratory by a Grignard reaction between nonanoic aldehyde and a ¹³C-labelled methyl iodide with a yield of 76.3% as reported in the following scheme:

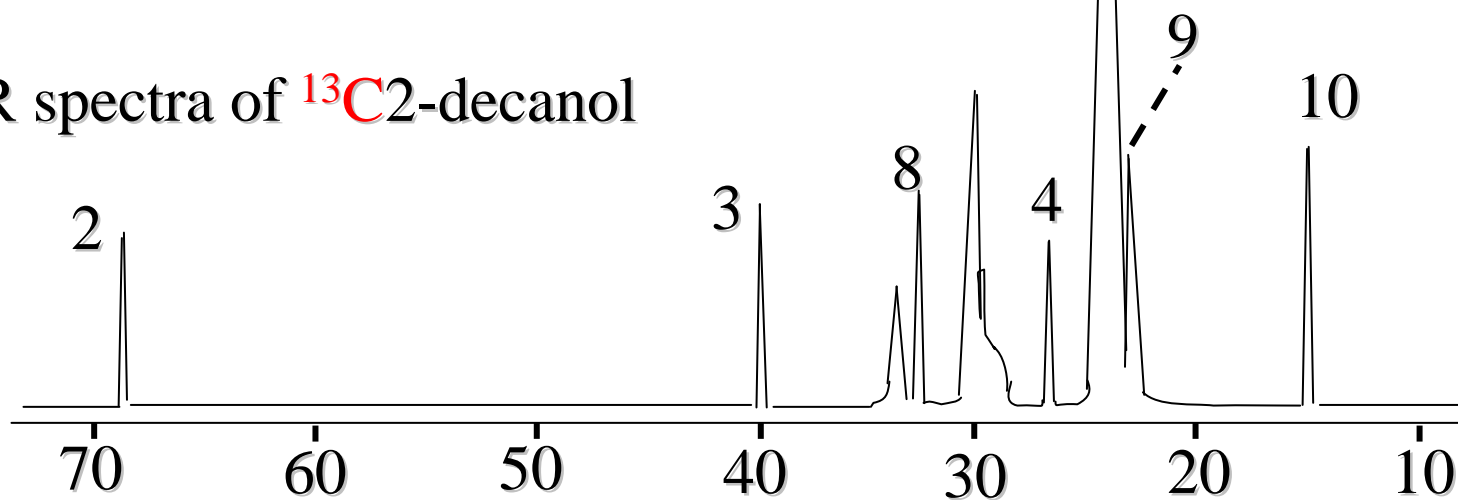


¹³C labelled 2-decanol = ¹³C2-dec.

Computer simulation of 2-decanol NMR spectra



NMR spectra of ¹³C 2-decanol



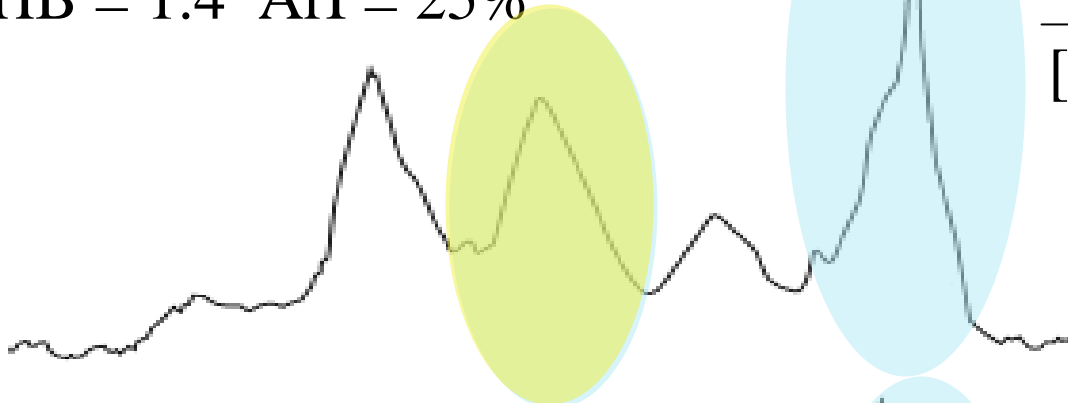
CPMAS NMR spectra of Humic acids used for soil incubation:

Lignite HAL

HB = 1.4 ArI = 25%

Hydrophobicity Index(HB)

$$\frac{[(0-40) + (110-160)]}{[(40-110) + (140-190)]}$$

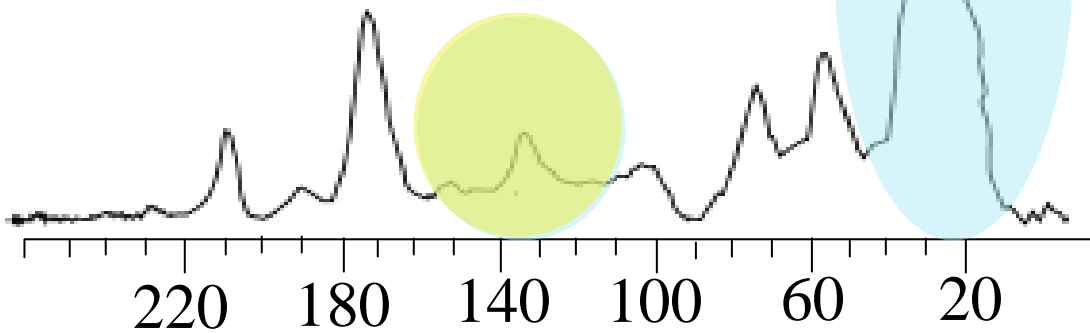


Compost HAC

HB= 1.2 ArI=5%

Aromaticity Index (ArI)

$$\frac{[(110-160)]}{[(0-190)]} \times 100$$



incubation experiment:

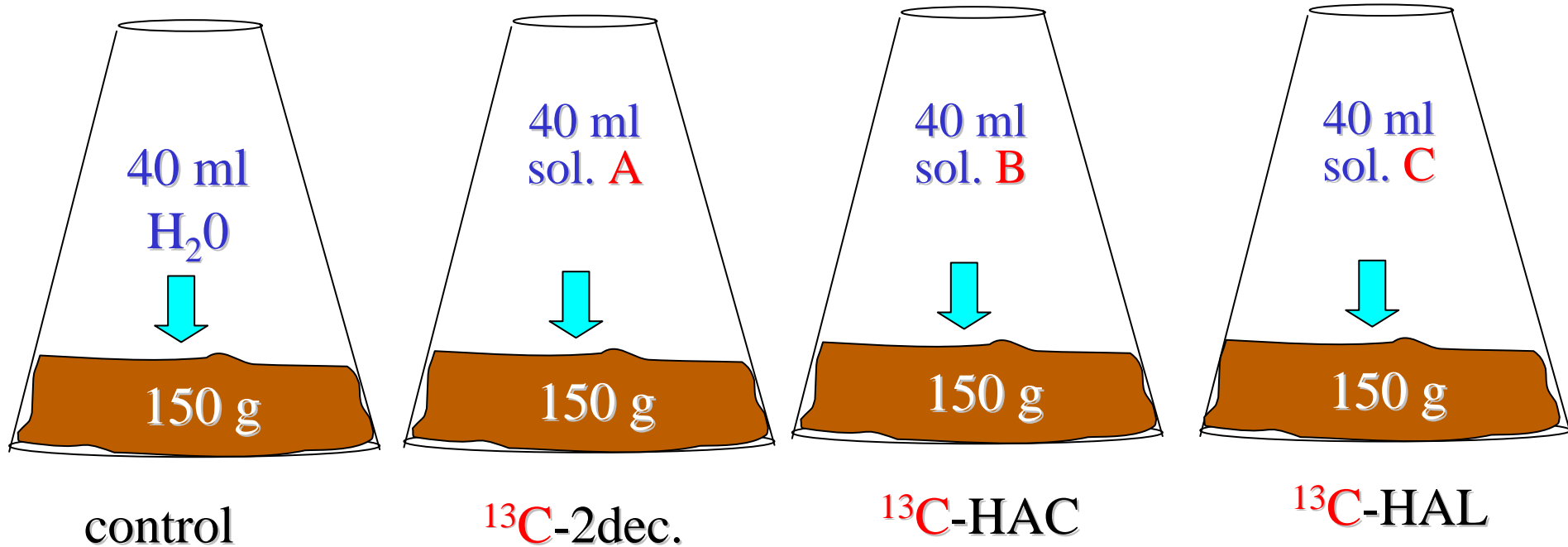
360 mg of $^{13}\text{C}2\text{-ol}$ $\xrightarrow[300 \text{ ml H}_2\text{O/Acetone}]{\text{dissolution}}$ $^{13}\text{C}2\text{-ol}$ stock solution

100 ml $^{13}\text{C}2\text{-ol}$ stock solution $\xrightarrow{400 \text{ ml H}_2\text{O}}$ 500 ml of ^{13}C labelled solution **A** $\delta^{13}\text{C} = +2600 \text{ ‰}$

600 mg **HAL** in 400 ml 0.01M NaOH solution (pH7) $\xrightarrow{100 \text{ ml } ^{13}\text{C}2\text{-ol stock solution}}$ 500 ml of ^{13}C labelled solution **B** $\delta^{13}\text{C} = +2800 \text{ ‰}$

600 mg **HAC** in 400 ml 0.01M NaOH solution (pH7) $\xrightarrow{100 \text{ ml } ^{13}\text{C}2\text{-ol stock solution}}$ 500 ml of ^{13}C labelled solution **C** $\delta^{13}\text{C} = +2800 \text{ ‰}$

soil samples from surface horizon (0-20 cm) were collected from agricultural soil (FAO cl. Dystric Cambisol) air dried and sieved through a 2 mm sieve :
pH (KCl)= 5.6; sand/silt/clay (%) =48/43/9; OM (%)= 3.1



soil samples were incubated at constant moisture for 6 months
4 replicates for each treatments

Sampling times = **t₀** 1 week; **t₁** 12 weeks; **t₂** 25 weeks

in order to follow the distribution of labelled ^{13}C -decanol also in soil fractions, the soil samples at each sampling date were physically separated in particle-size fractions through the application of low energy sonication method

low energy sonication (170 Jg^{-1}) was used in order to reproduce on incubated samples the disturbing action of agricultural practices (ploughing), raindrop and drying-wetting cycles, which cause natural breakdown of soil macro-aggregates ($> 250 \mu$)

the applied low energy thus preserve the integrity of micro-aggregates ($< 250 \mu$) thereby avoiding the artificial redistribution of organic matter among soil fractions.

Particle size fractions were obtained in the following ranges associated to classical textural classes:

2000-200 μm “*coarse sand*”, 200-63 μm “*fine sand*”, 63-2 μm “*silt*”,
< 2 μm “*clay*”, < 0.1 μm “*fine clay*” (DOM)

most soil sample (35g d.w.) in a glass beaker with 100 ml of distilled water

ultrasonication 50J s^{-1} 120 s

manual wet sieving

2000-200 μ coarse sand

2000-63 μ fine sand

< 63 μ suspension

supernatant

$\cong 1000-1300$ rpm \times 5-3 min

supernatant

pellets
(resuspension)

3 times

centrifugation at 150 g

$\cong 7000$ rpm \times 20 min

pellets
(resuspension)

63-2 μ silt

centrifugation at 3900 g

**< 0.1 μ clay
soluble fraction
DOM**

< 2 μ clay

Results

treatments	bulk soil				Sum of fractions ($2000 < \mu < 0.1$)				
	TOC		^{13}C -OC		TOC		^{13}C -OC		
	%	$\delta\text{‰}$	% TOC	mg	%	% tot	mg	% tot	
Control	t0	1.8	-26.2	/	/	1.6	88.9	/	/
	t1	1.7	-26.2	/	/	1.6	94.1	/	/
	t2	1.5	-26.3	/	/	1.4	93.3	/	/
^{13}C 2-dec	t0	1.8	-13.9	0.47	10.2	1.6	88.9	3.14	30.8
	t1	1.7	-18.5	0.29	6.0	1.6	94.1	3.60	59.5
	t2	1.4	-22.3	0.19	2.9	1.3	92.8	1.90	65
^{13}C -HAC	t0	1.9	-13.4	0.46	10.4	1.6	84.2	3.40	32.6
	t1	1.8	-14.4	0.42	9.1	1.6	88.9	3.70	40.6
	t2	1.7	-19.4	0.29	4.2	1.7	100	3.80	90.4
^{13}C -HAL	t0	1.8	-13.5	0.50	10.8	1.6	88.9	4.21	39.2
	t1	1.7	-13.9	0.49	10.2	1.7	100	5.12	50.2
	t2	1.7	-18.9	0.30	6.1	1.7	100	5.94	96.0

Coarse s.	Control			¹³ C2-dec			¹³ C-HAC			¹³ C-HAL		
	t0	t1	t2	t0	t1	t2	t0	t1	t2	t0	t1	t2
OC g kg ⁻¹	3.8	3.6	3.6	3.8	3.5	3.0	4.0	3.8	3.8	3.6	3.6	4.4
δ ¹³ C(‰)	-26.3	-26.3	-26.3	-22.3	-23.6	-24.6	-21.1	-21.6	-24.5	-19.5	-20.5	-22.5
¹³ C (μg)	/	/	/	241	150	91	270	280	110	440	380	300
¹³ C (%)	/	/	/	2.4	2.5	3.3	2.6	3.1	3.4	4.1	3.7	4.9
¹³ C E.F.	/	/	/	0.32	0.35	0.36	0.33	0.32	0.38	0.46	0.49	0.54
Fine sand												
OC g kg ⁻¹	7.9	6.5	6.0	7.4	6.1	5.0	6.7	7.5	6.9	7.7	7.4	7.0
δ ¹³ C(‰)	-26.8	-26.6	-26.7	-21.7	-23.1	-24.4	-21.1	-21.3	-22.9	-18.9	-19.9	-21.7
¹³ C (μg)	/	/	/	302	176	85	270	260	150	400	350	300
¹³ C (%)	/	/	/	3.0	3.0	3.0	2.6	2.9	3.0	3.5	4.3	4.3
¹³ C E.F.				0.35	0.37	0.39	0.44	0.46	0.52	0.52	0.63	0.67

$$^{13}\text{C E.F.} = \frac{^{13}\text{C Enrichment factor} = \frac{\text{g}^{13}\text{C} \times 100 \text{ g}^{-1} \text{ TOC size fraction}}{\text{g}^{13}\text{C} \times 100 \text{ g}^{-1} \text{ TOC bulk soil}}}$$

Results

treatments	bulk soil				Sum of fractions ($2000 < \mu < 0.1$)				
	TOC		^{13}C -OC		TOC		^{13}C -OC		
	%	$\delta\%$	% TOC	mg	%	% tot	mg	% tot	
Control	t0	1.8	-26.2	/	/	1.6	88.9	/	/
	t1	1.7	-26.2	/	/	1.6	94.1	/	/
	t2	1.5	-26.3	/	/	1.4	93.3	/	/
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	t1	1.7	-18.5	0.29	6.0	1.6	94.1	3.60	59.5
	t2	1.4	-22.3	0.19	2.9	1.3	92.8	1.90	65
^{13}C -HAC	t0	1.9	-13.4	0.46	10.4	1.6	84.2	3.40	32.6
	t1	1.8	-14.4	0.42	9.1	1.6	88.9	3.70	40.6
	t2	1.7	-19.4	0.29	4.2	1.7	100	3.80	90.4
^{13}C -HAL	t0	1.8	-13.5	0.50	10.8	1.6	88.9	4.21	39.2
	t1	1.7	-13.9	0.49	10.2	1.7	100	5.12	50.2
	t2	1.7	-18.9	0.30	6.1	1.7	100	5.94	96.0

	Control			¹³ C2-dec			¹³ C-HAC			¹³ C-HAL		
Silt	t0	t1	t2	t0	t1	t2	t0	t1	t2	t0	t1	t2
OC g kg ⁻¹	17	15.9	22	16.4	16.1	19.0	17.3	17.6	22	16.2	16.6	26
δ ¹³ C(‰)	-26.3	-26.5	-26.3	-21.6	-23.2	-24.8	-20.3	-20.7	-22.0	-19.9	-20.0	-20.7
¹³ C (mg)	/	/	/	1.45	1.00	0.89	1.8	1.76	1.64	2.0	2.1	2.8
¹³ C (%)	/	/	/	14.4	17.1	26.8	17.3	19.5	35.7	19.0	20.4	45.2
¹³ C E.F.	/	/	/	0.39	0.43	0.41	0.48	0.5	0.65	0.51	0.51	0.75
Clay												
OC g kg ⁻¹	59.3	62.2	55.0	61.0	62.6	52.0	60.5	65.8	62	60.4	63.5	62.0
δ ¹³ C(‰)	-25.8	-26.1	-26.8	-18.5	-17.9	-20.0	-18.3	-17.2	-13.7	-19.3	-17.5	-11.0
¹³ C (mg)	/	/	/	1.14	1.2	0.81	1.05	1.34	1.94	1.26	2.3	2.6
¹³ C (%)	/	/	/	11.3	37.7	32.0	10.2	14.9	42.3	11.7	22.1	42.2
¹³ C E.F.	/	/	/	0.60	1.77	1.40	0.58	0.77	2.0	0.67	1.04	2.1
DOM												
OC g kg ⁻¹	305	240	216	360	263	244	364	337	155	347	335	156
δ ¹³ C(‰)	-25.0	-25.1	-25.2	+49	+14	+9	+52	+49	-16.4	+41	+39	-18.2
¹³ C (mg)	/	/	/	6.94	2.4	0.9	7.0	5.3	0.3	6.6	5.2	0.2
¹³ C (%)	/	/	/	69	39.8	35	67	59	9.5	61	50.3	3.4
¹³ C E.F.	/	/	/	5.7	5.1	7.0	5.8	6.2	1.5	5.3	5.1	0.9

Results

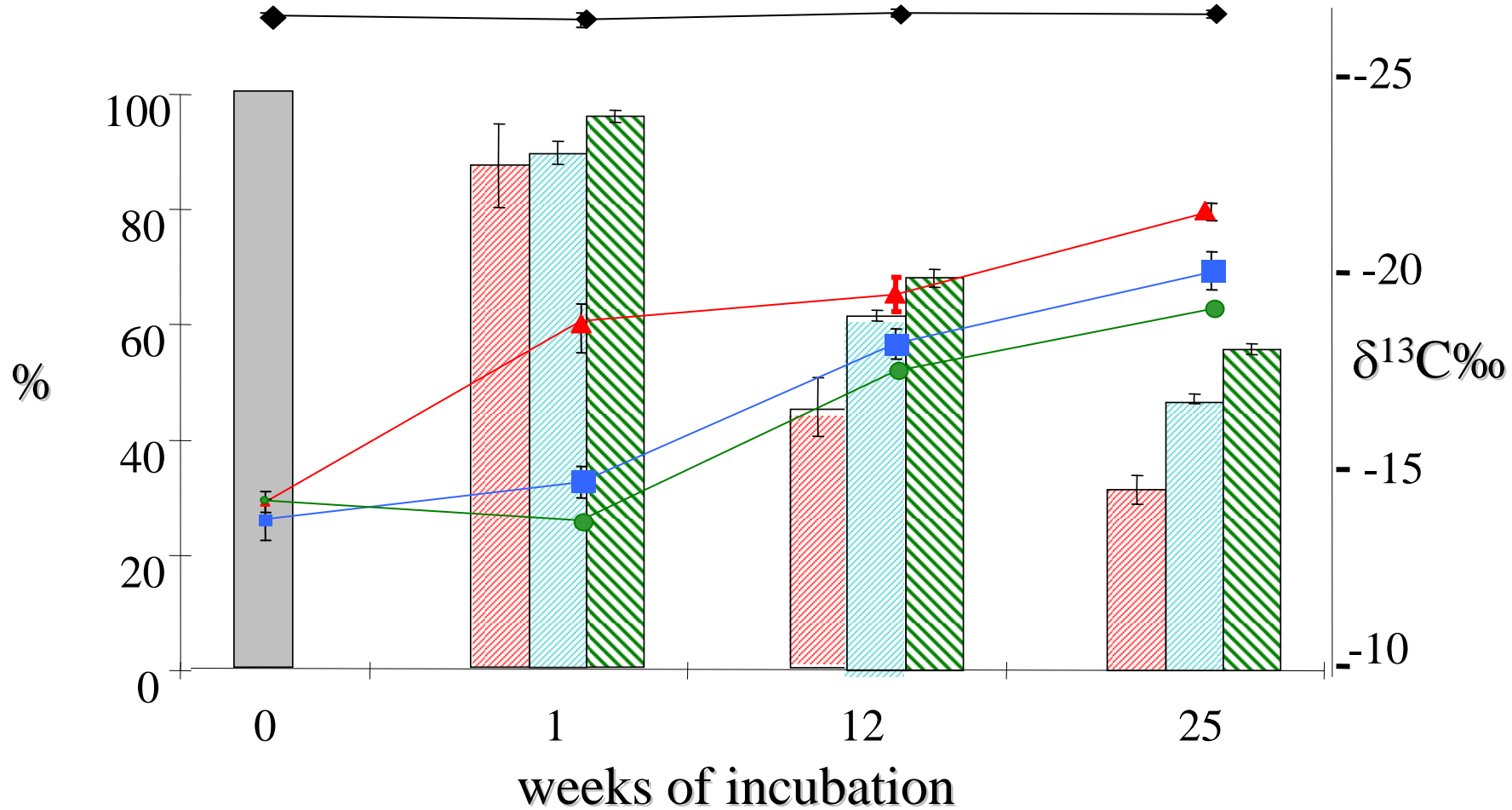
treatments	bulk soil				Sum of fractions ($2000 < \mu < 0.1$)				
	TOC		^{13}C -OC		TOC		^{13}C -OC		
	%	$\delta\%$	% TOC	mg	%	% tot	mg	% tot	
Control	t0	1.8	-26.2	/	/	1.6	88.9	/	/
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^{13}C -HAC	t0	1.9	-13.4	0.46	10.4	1.6	84.2	3.40	32.6
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	t2	1.7	-19.4	0.29	4.2	1.7	100	3.80	90.4
^{13}C -HAL	t0	1.8	-13.5	0.50	10.8	1.6	88.9	4.21	39.2
	t1	1.7	-13.9	0.49	10.2	1.7	100	5.12	50.2
	t2	1.7	-18.9	0.30	6.1	1.7	100	5.94	96.0

Residual (%) content of ^{13}C -OC respect to initial added amount

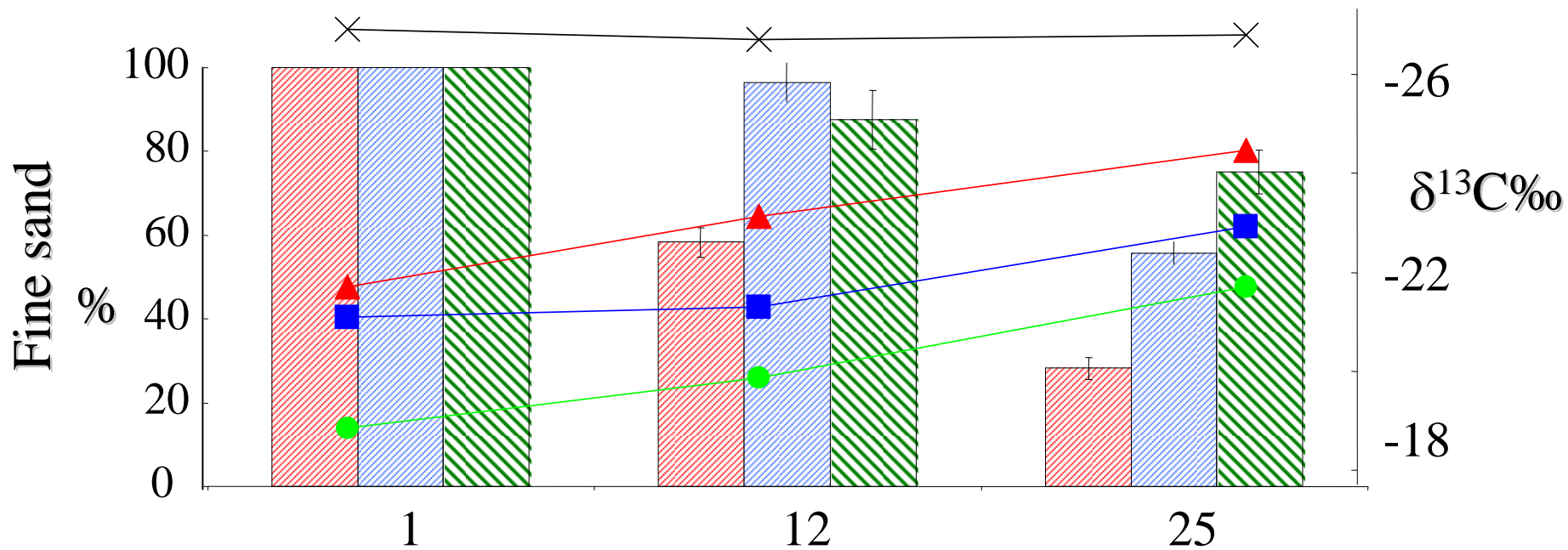
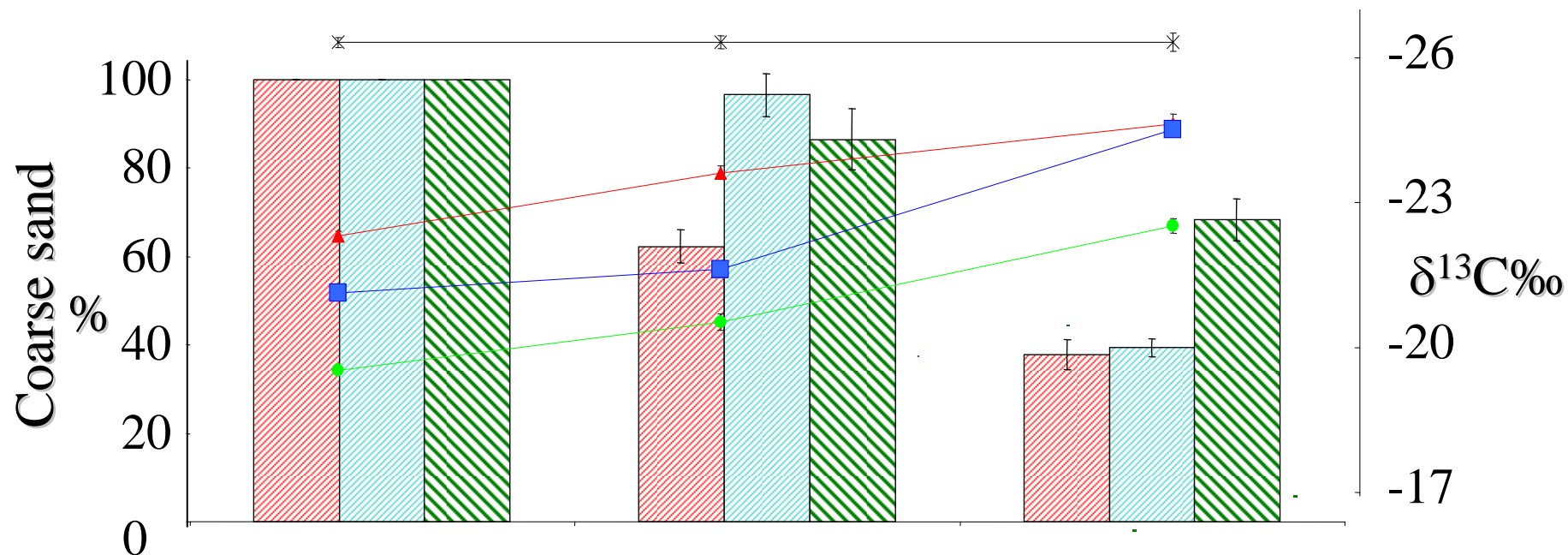
Bulk soil

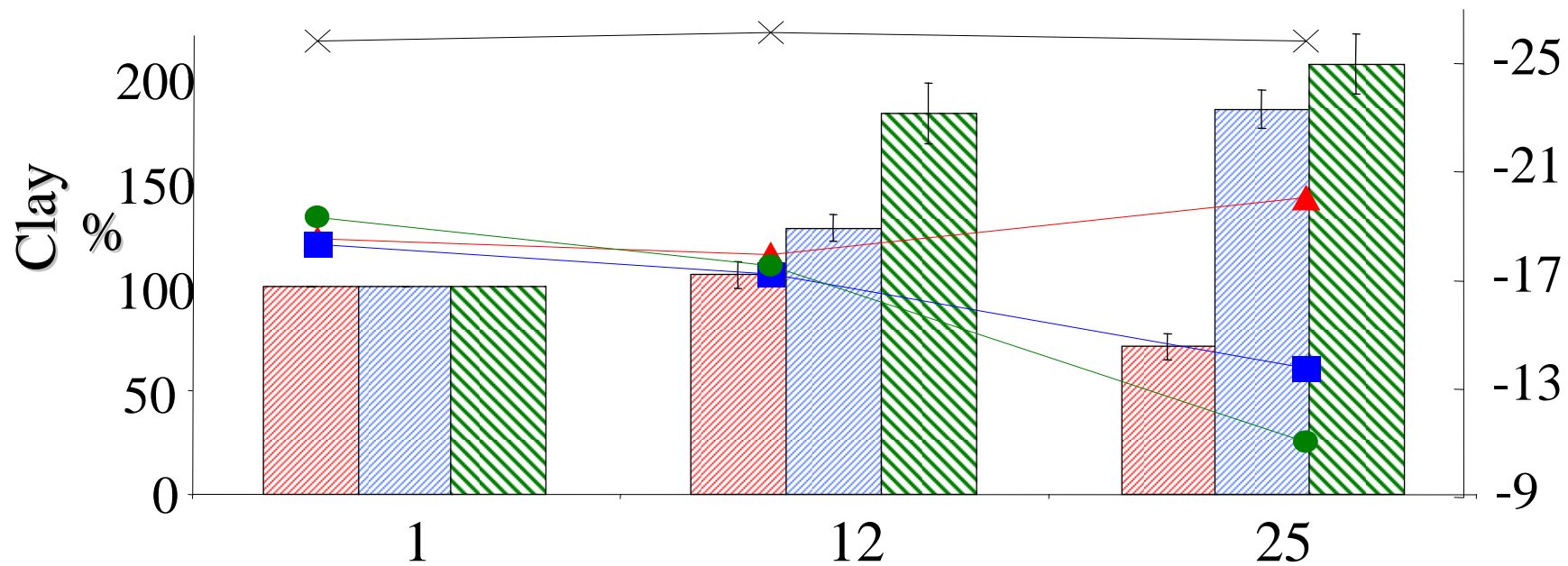
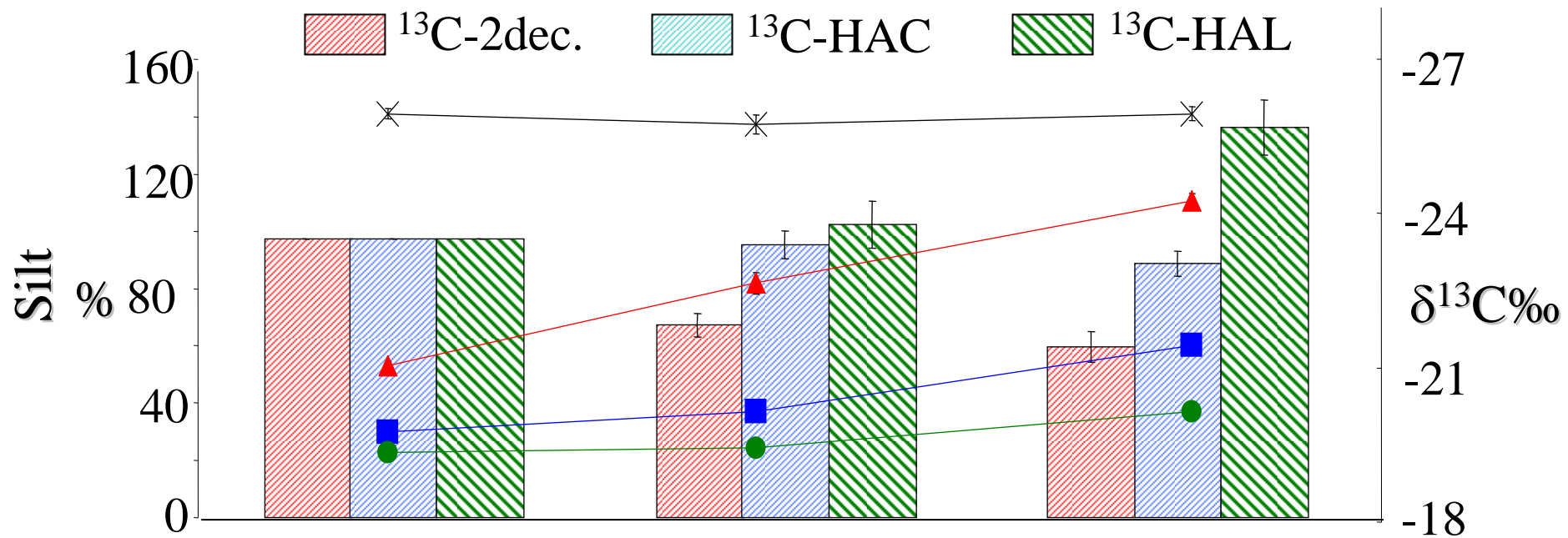
^{13}C -2dec.
 ^{13}C -HAC
 ^{13}C -HAL

control
 ^{13}C -2dec.
 ^{13}C -HAC
 ^{13}C -HAL



 ^{13}C -2dec.  ^{13}C -HAC  ^{13}C -HAL

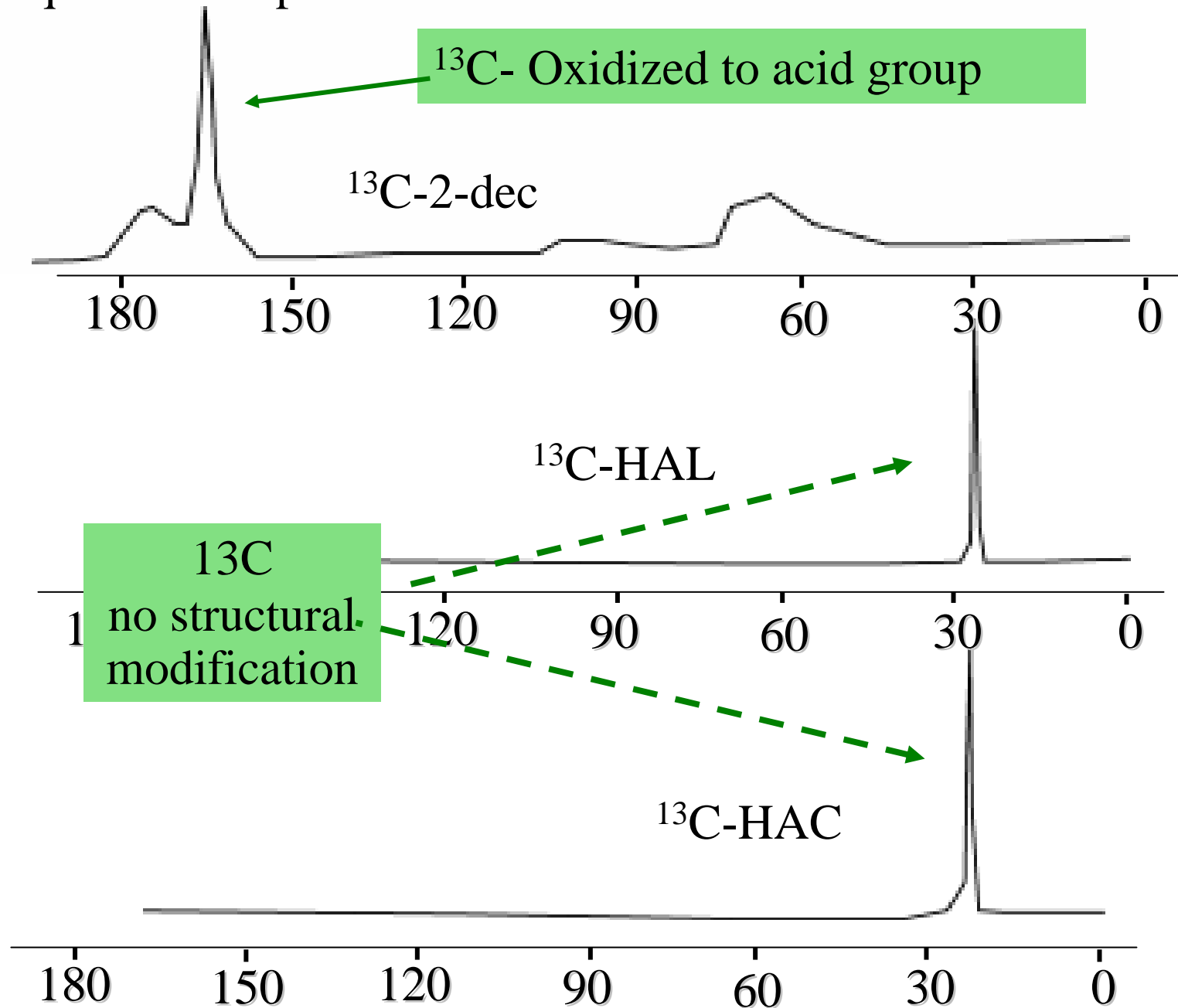




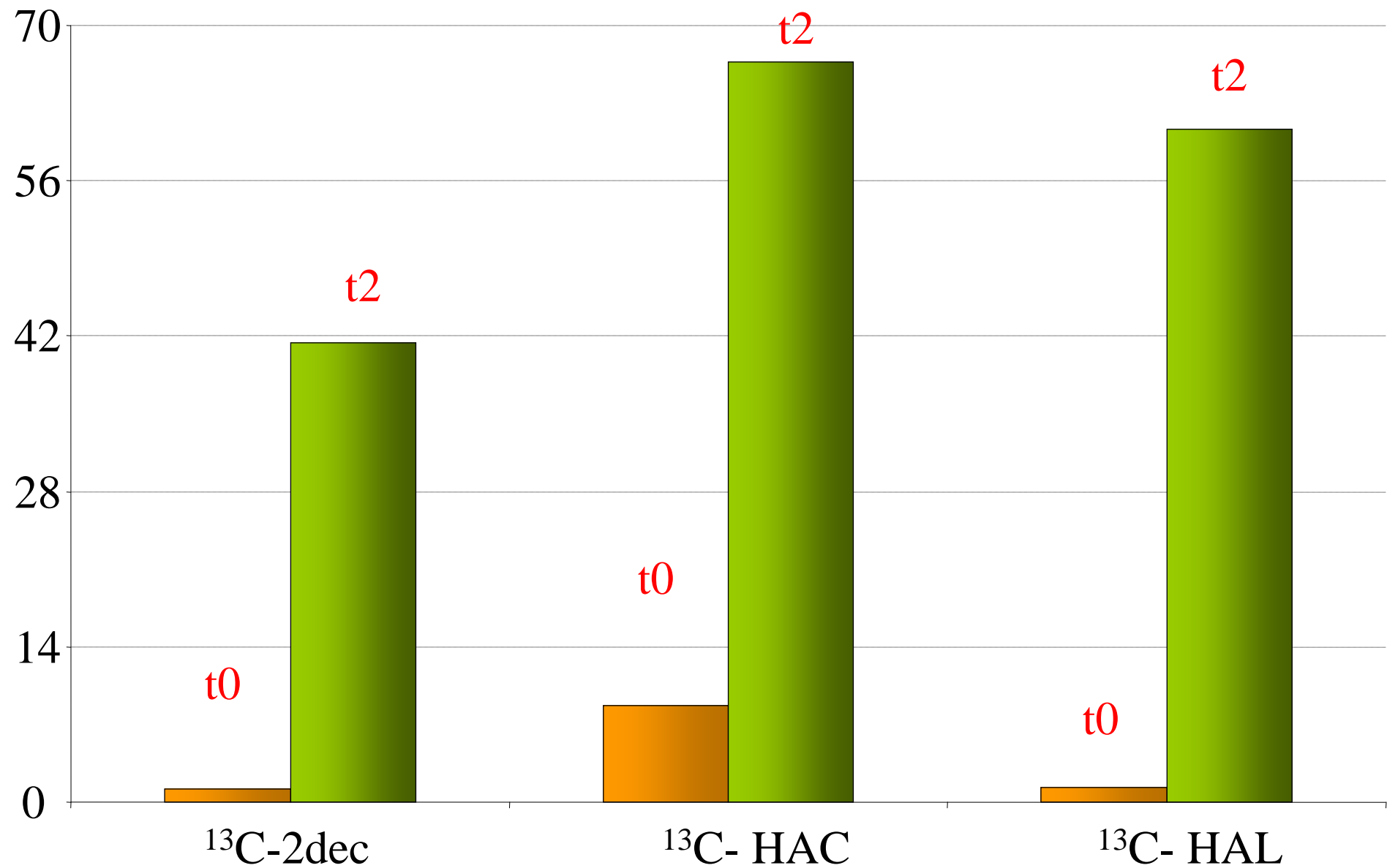
¹³C-OC content in soil humic substances extracted at the start (t0) and the end (t2) of soil incubation

treatments	Humic acids		Fulvic acids		
	$\delta^{13}\text{C}\text{‰}$	¹³ C-OC mg	$\delta^{13}\text{C}\text{‰}$	¹³ C-OC mg	
Control	t0	-26.2	/	-25.8	/
	t2	-26.0	/	-25.7	/
¹³ C2-dec	t0	-25.7	0.12	-25.1	0.1
	t2	-21.5	1.2	-23.4	0.25
¹³ C-HAC	t0	-22.0	0.9	-23.2	0.25
	t2	-15.7	2.8	-22.0	0.4
¹³ C-HAL	t0	-25.6	0.14	-23.7	0.2
	t2	-15.6	3.7	-22.4	0.4

Liquid NMR spectra of soil humic acids extracted at t2



^{13}C -OC content in soil humic acids respect to bulk soil



Conclusions

- in a short term incubation experiment the utilization of labelled ^{13}C organic compound represent a useful and effective tool to study the organic carbon behaviour and distribution in soil and soil size fractions
- in this laboratory incubation experiment, addition of humified organic materials to soil significantly increased the sequestration of organic carbon in bulk soil, soil size fractions and soil humic acids thereby reducing the mineralization of the relatively labile aliphatic alcohol such as ^{13}C -2-decanol.
- a considerable amount of ^{13}C -OC was incorporated in the stable portion of soil OM represented by HS for all treatments. This finding confirm the importance of soil humic materials for the stable incorporation of labile organic compounds.

- the distribution of residual ^{13}C -OC among soil particle-size fractions indicated in all treatments the incorporation of labile organic compound was most effective in the soil sized fractions (*silt-* and *clay-*) usually associated with stable SOM pool. This result confirms the importance of associations between fine textural fractions and recalcitrant OM
- the different protection of ^{13}C -OC shown by the two exogenous HA in the finer fractions may be related to the different chemical nature of their hydrophobic components:
 - the hydrophobicity of HAC (HI $\frac{1}{4}$ 1.20; ArI $\frac{1}{4}$ 5%) is mostly due to its large alkyl-C content that may have promoted, for chemical affinity, a preferential interaction with the predominantly aliphatic native humic matter present in the clay-sized fractions.
 - conversely, the larger hydrophobicity of HAL (HI $\frac{1}{4}$ 1.40; ArI $\frac{1}{4}$ 25%), due to a larger content of both alkyl- and aromatic-C groups, may have favored a progressively larger incorporation of ^{13}C -OC not only into the clay- but also into the silt-sized fractions that is generally associated with more aromatic humic matter

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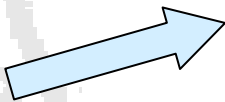
D.I.S.S.P.A.A.

Soil chemistry department

Soil Organic Matter dynamics

- ¹³C labelled organic material

- TMAH thermochemolysis



Dr. Spaccini Riccardo

application of OM to soil increase soil fertility and plant nutrition and may also reduce mineralization of biolabile compounds, thereby enhancing the role of soil organic matter (SOM) as sink of OC

these effects are achieved by improving both quantity and quality of SOM with an increased accumulation of various classes of organic compounds.

both mid- and long-term organic matter accumulation are, in fact, related to the nature and composition of OM whose effectiveness arise from the stable incorporation of exogenous organic compounds into native bulk SOM.

an increasing interest is therefore given to a deeper molecular characterization of both bulk SOM and added material, as well as to their transformed products, in order to understand the processes of effective incorporation and stabilization of specific exogenous organic molecules in soil.

Thermochemolysis of Soil Organic Matter in soil amended with recycled organic biomass (compost)

Objective

The main objective of this work was to characterize the organic matter components in cultivated soil amended with recycled organic biomass.

This objective was accomplished applying the Off-Line TMAH-thermochemolysis GC-MS technique on organic material and on soil samples in order to evaluate the incorporation of organic material in SOM and the transformation after one year of compost additions.

Soil treatments were as following:

- Control soil with inorganic fertilizer
- Soil + compost (30 and 60 t ha⁻¹)

after one year of compost addition about 1kg of soil from the ploughed horizon (25 cm⁻¹) for each treatment was randomly sampled, dried and sieved at 2mm.

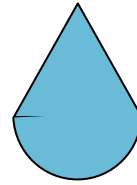
soil aggregates were destroyed with ultrasonication and soil and compost samples were powdered with electrical agate ball mill and finally sieved at 500 μm.

Soil and compost samples were analyzed by TMAH thermochemolysis GC-MS – quantitative analysis were based on calibration curves built by mixing the following standards: tridecanoic acid, octadecanol, 16-hydroxy hexadecanoic acid, docosandioic acid, beta-sitosterol, and cinnamic acid

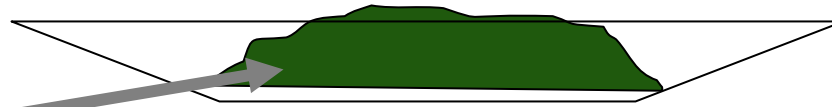
200 mg of OM
or 2 g of soil sample

+

1 ml TMAH (25% CH_3OH)



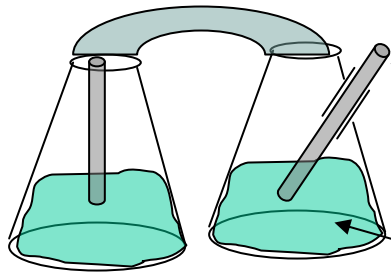
5 minutes dry with
nitrogen flow



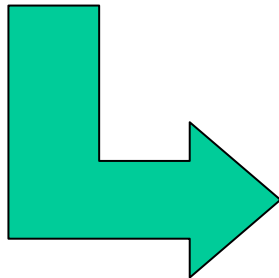
400° C

30m

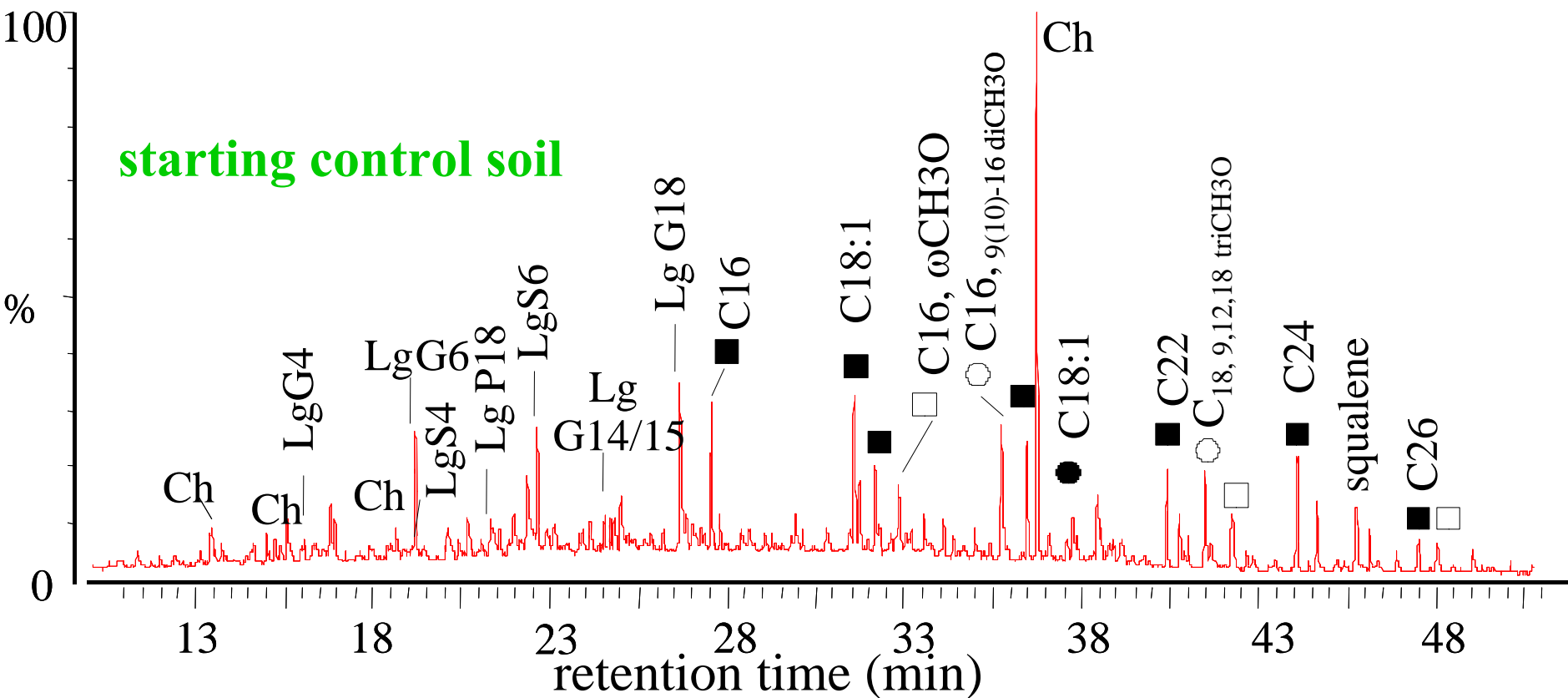
He (50-100
ml/min)



chloroform kept in ice/salt bath



GC-MS



basic lignin units

gymnosperm wood

Guaiacyl unit

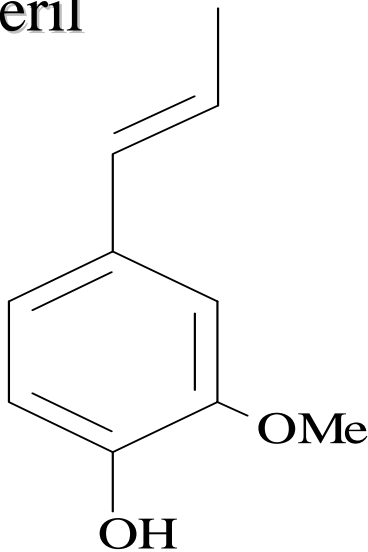
angiosperm wood

Siringyl units (prevalent)+guaiacyl

erbaceous plant

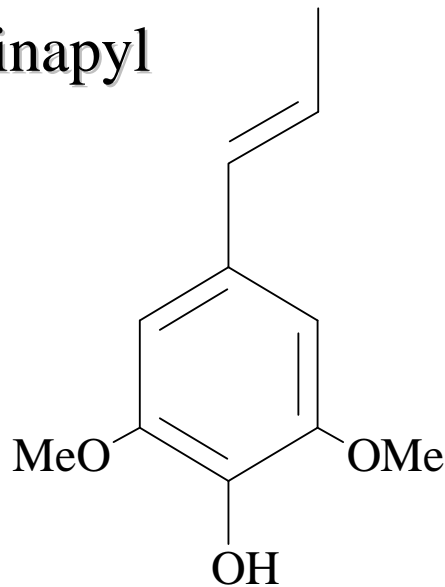
P-hydroxy phenyl propene (prevalent) +
guaiacyl and siringyl moieties

Conyferil



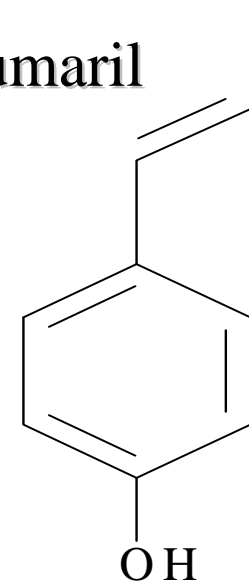
2-methoxy-4-
propenyl phenol

Sinapyl



2,6-dimethoxy-4-
propenyl phenol

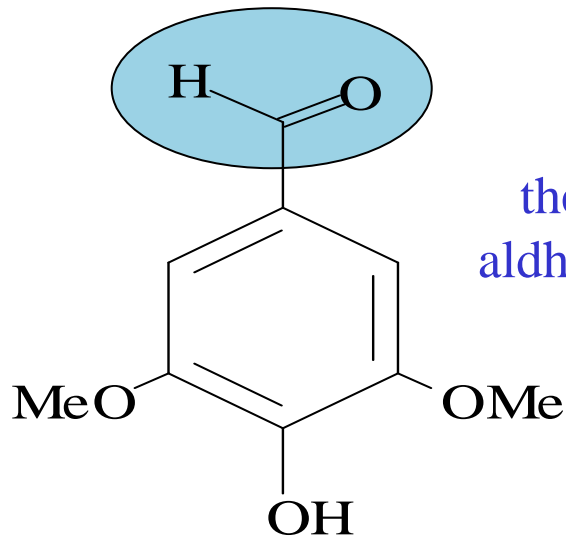
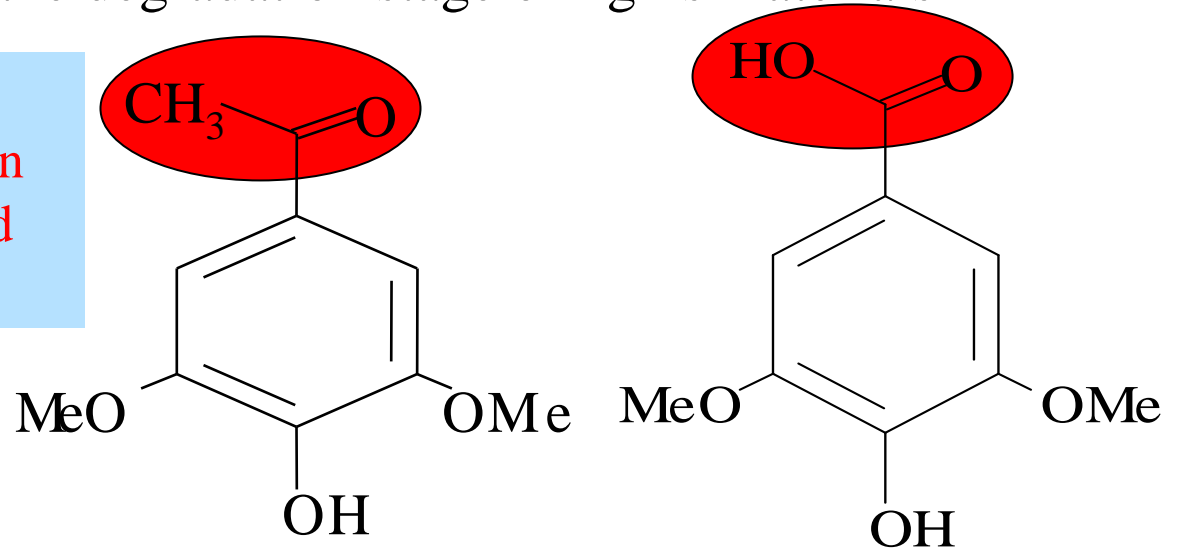
p-Coumaril



P-hydroxy
phenyl propene

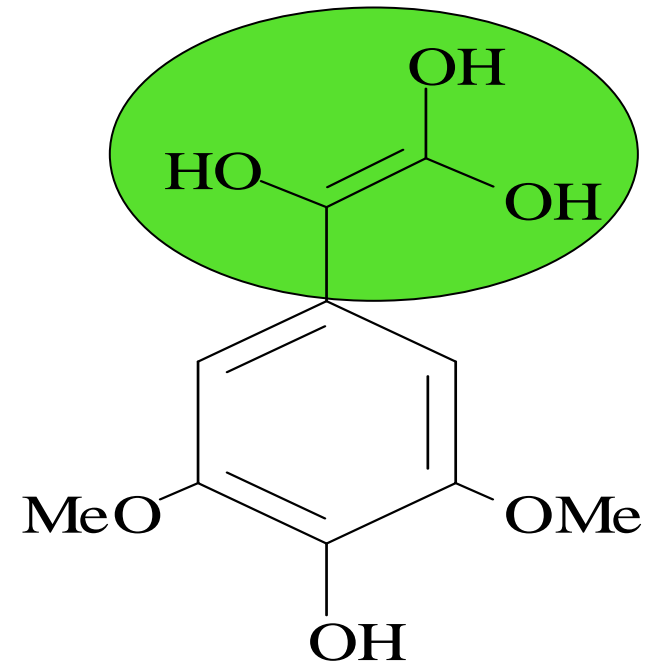
from the data of lignin derivatives it is possible to determine a structural index related to the degradation stage of lignis materials

the lignin derivatives with ketonic and acidic side chain indicate in fact an advanced degradation process



the lignin derivatives with aldehydic side chain indicate a partial degradation

whereas lignin products with intact side chain are representative of unaltered or fresh plant tissues



$\mu\text{g g}^{-1}$ soil d.w.	Initial control soil
Conyferil	120
Ad/Al_G	4.9
Γ_G	6.1
Sinapyl (S)	125
Ad/Al_s	5.3
Γ_s	5.9

Lignin

index > 2
prevalence of oxydisized structures
(high degradation)

structural
indexes

Ad=acidic form
Al=aldehydic form

$$\Gamma = \frac{\text{acidic form}}{\text{undegraded structures}}$$

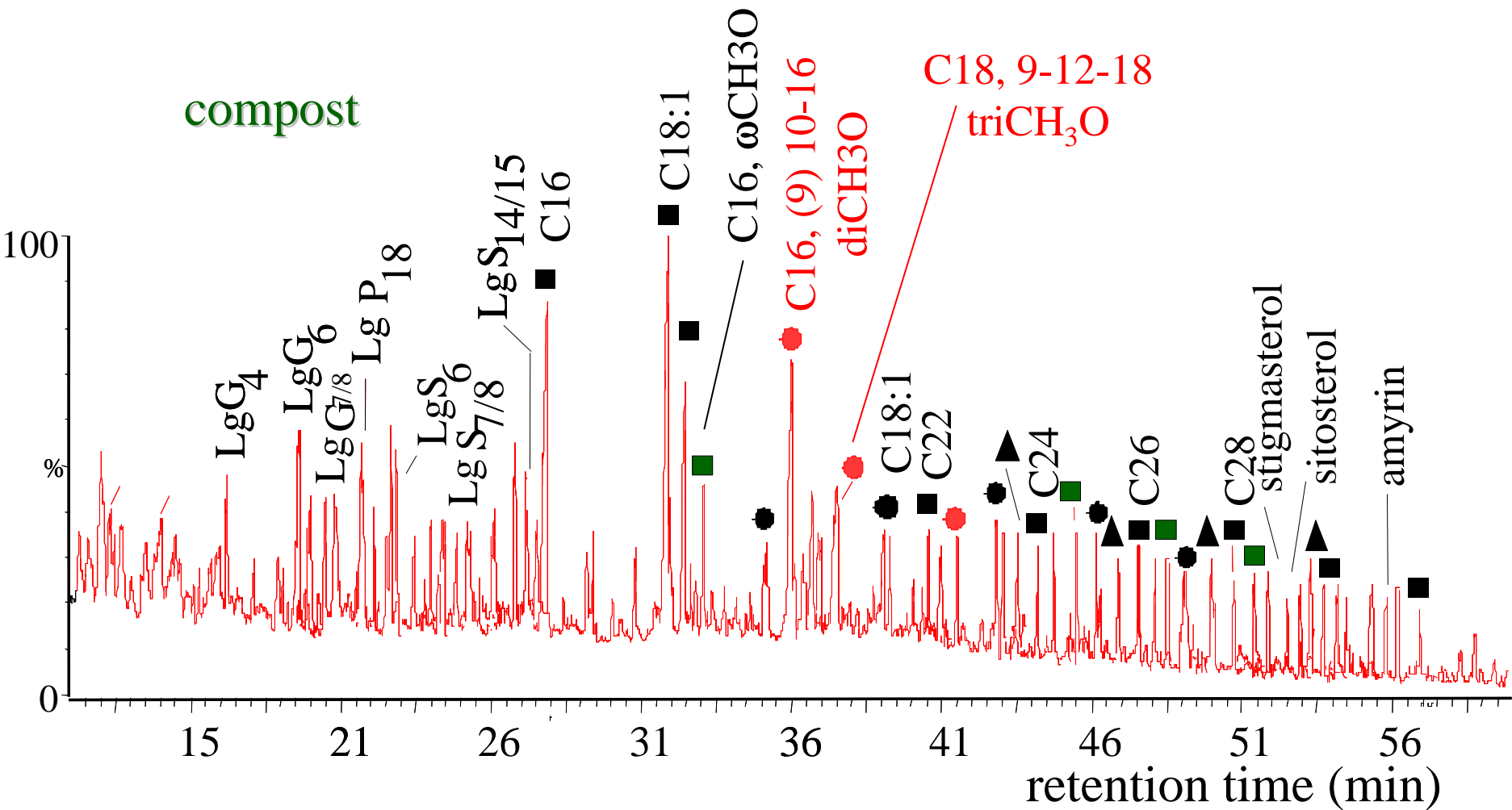
FAME	415 C₁₄-C₂₈
alkanes	37 C₁₅-C₂₇ CPI=2.3 ACL=23.5
mid chain	69 C₁₆, C₁₈
ωOH acids	87 C₁₆-C₂₂
dioic acids	59 C₁₆, C_{18:1}
sterols	/
resin acids	/

Alkyl

intermediate values indicate the
variable source origin of alkanes
(bacterial, fungi, plant)

plant markers
cutin and suberin
components

angiosperm
gimnosperm



Lg = lignin

■ Fatty acids



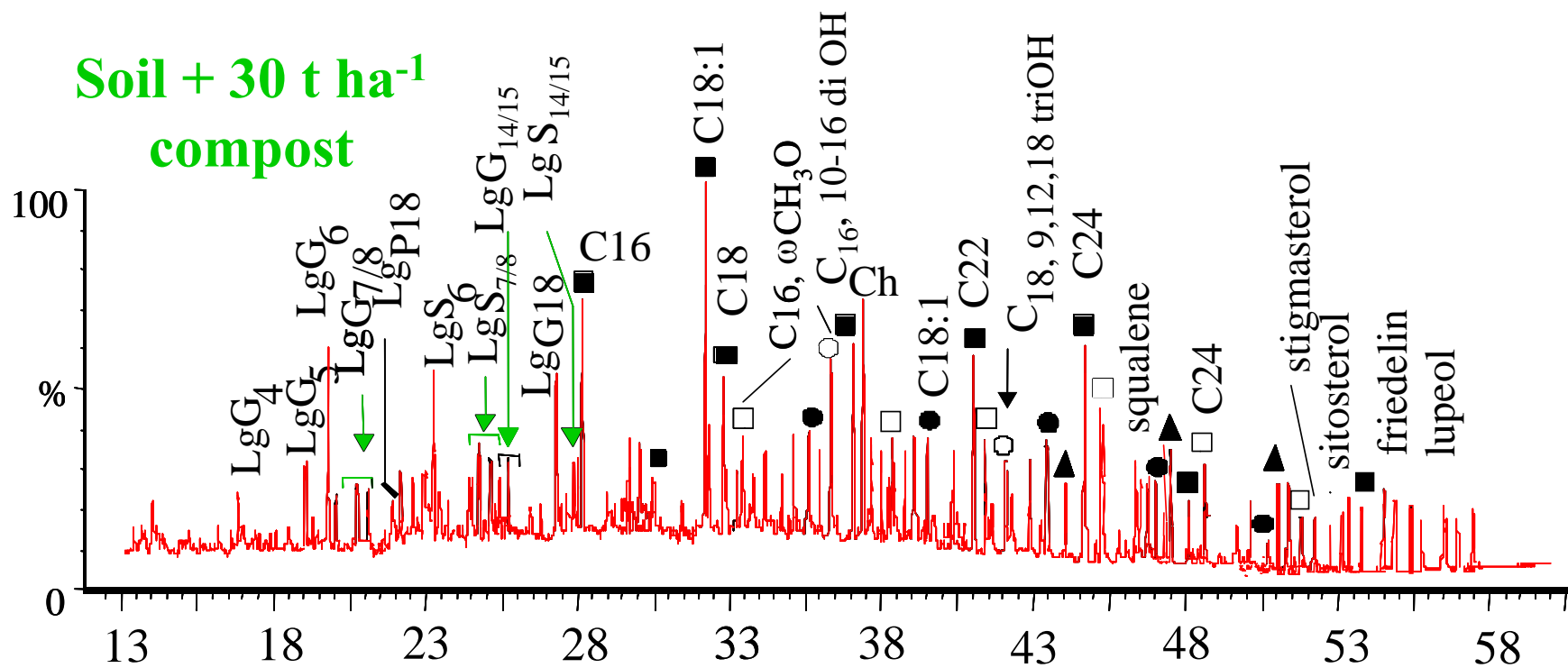
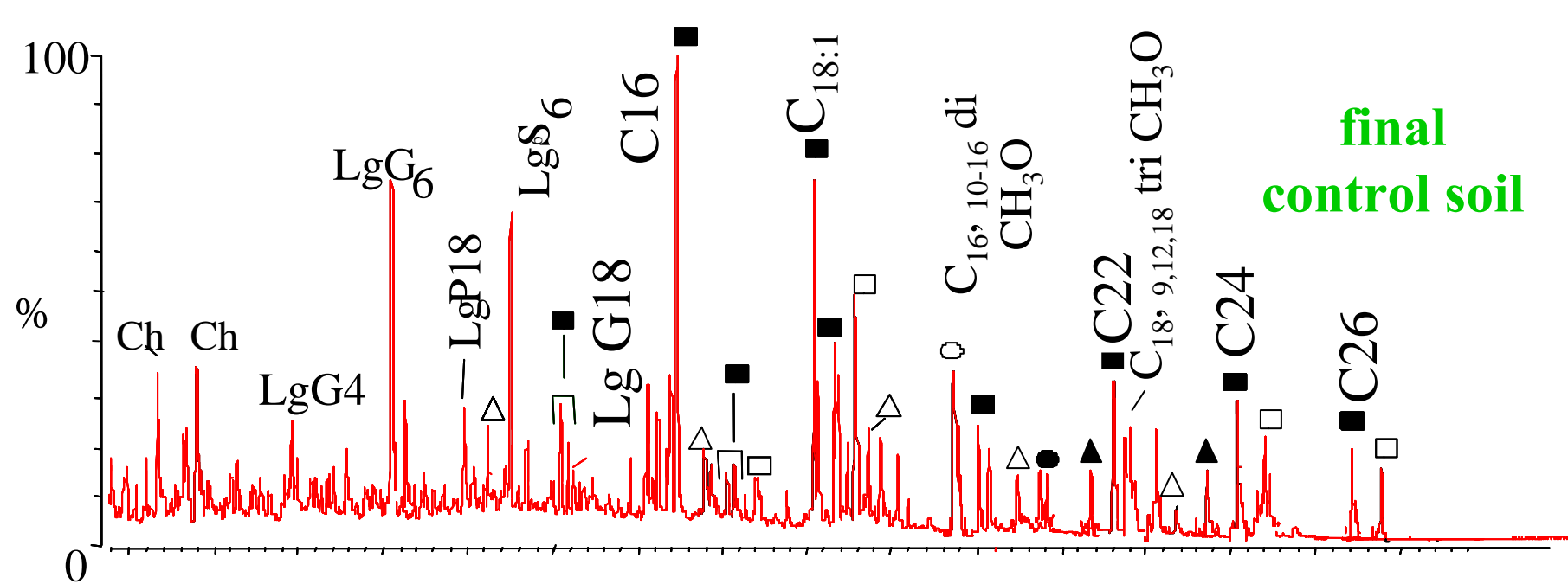
n-alkane

■ ω hydroxy acids

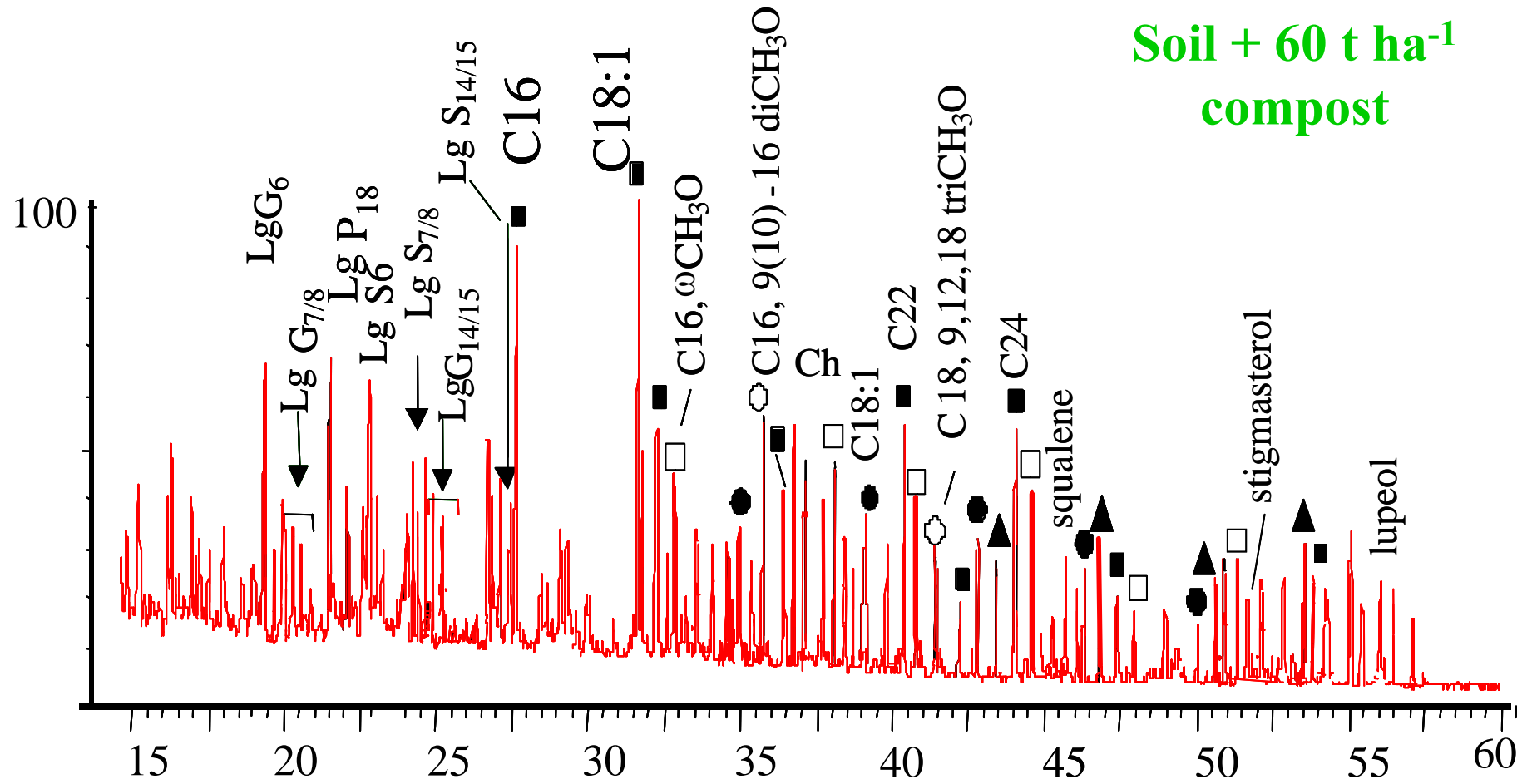
● mid-chain hydroxy acids

● alkyl-dioic acids

$\mu\text{g g}^{-1}$ soil d.w.	Initial control soil		Compost
Conyferil	120	lignin structural indexes index $\cong 2$ presence of fresh litter (low degradation)	3460
Ad/Al_G	4.9		1.7
Γ_G	6.1		2.2
Sinapyl (S)	125		3730
Ad/Al_S	5.3		2.1
Γ_s	5.9		1.6
<hr/>			
FAME	415 C₁₄-C₂₈	alkyl	10250 C ₁₂ -C ₃₂
alkanes	37 C₁₅-C₂₇ CPI=2.3 ACL=23.5	high values indicate the prevalent plant origin of alkanes	4850 CPI=4.2 ACL=29.3
mid chain OH acids	69 C₁₆, C₁₈		5500 C₁₆C₁₈
ωOH acids	87 C₁₆-C₂₂		6300 C ₁₆ -C ₂₆
dioic acids	59 C₁₆, C_{18:1}		4900 C ₁₆ -C ₂₄
sterols	/	plant markers	2780
resin acids	/		1360



Soil + 60 t ha⁻¹
compost



$\mu\text{g g}^{-1}$ soil d.w.	Initial control soil	Final control soil	Soil+ Com 30 t ha ⁻¹	Soil+ Com 60 t ha ⁻¹	Compost
Conyferil	120	110	159	186	3460
Ad/Al_G	4.9	4.7	4.0	3.8	1.7
Γ_G	6.1	6.2	4.9	5.0	2.2
Sinapyl (S)	125	120	157	225	3730
Ad/Al_s	5.3	5.5	4.3	4.1	2.1
Γ_s	5.9	6.1	4.4	3.9	1.6
FAME	415 C₁₄-C₂₈	380 C₁₄-C₂₈	492 C₁₂-C₃₀	595 C₁₂-C₃₂	10250 C₁₂-C₃₂
alkanes	37 C₁₅-C₂₇ CPI=2.3 ACL=23.5	40 C₁₅-C₂₇ CPI=2.4 ACL=24.4	123 C₁₅-C₃₃ CPI=3.8 ACL=27.7	172 C₁₅-C₃₃ CPI=3.9 ACL=28.4	4850 CPI=4.2 ACL=29.3
mid chain OH acids	69 C₁₆, C₁₈	40 C₁₆, C₁₈	98 C₁₆, C₁₈	166 C₁₆, C₁₈	5500 C₁₆, C₁₈
ωOH acids	87 C₁₆-C₂₂	62 C₁₆-C₂₂	121 C₁₆-C₂₆	200 C₁₆-C₂₆	6300 C₁₆-C₂₆
dioic acids	59 C₁₆, C_{18:1}	55 C₁₆, C_{18:1}	126 C₁₆, C₂₄	186 C₁₆, C₂₄	4900 C₁₆-C₂₄
sterols	/	/	32	66	2780
resin acids	/	/	16	32	1360

lignin

alkyl

- thermochemolysis analysis provided a detailed qualitative and quantitative characterization of SOM revealing an effective incorporation of exogenous organic compounds in soil amended with compost.
- plant biopolymers such as lignin, waxes, and aliphatic polyesters were recognized as the main sources of organic components in both soil and compost. the identified derivatives allowed the evaluation of related structural indexes associated with the overall origin and biochemical stability of SOM components.
- these results indicate that the TMAH thermochemolysis technique is a rapid and effective method for molecular characterization of SOM; such method enables the identification of a large range of lignin, alkyl and cyclic lipid biomarkers, which are useful to trace both origin and transformation of organic matter in soil .