The Importance of Root Decomposition to the Carbon Budgets of Perennial Oak Woodlands and Vineyards in California Mediterranean Climate Ecosystems

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Summary

To obtain a chronosequence of root decomposition processes, soil pits were established and fine roots collected at a number of sites to examine carbon fractions in roots from sites with different periods of fallow. Eight soil pits were established representing a six year chronosequence following vineyard removal, and analytical chemical characterization of the material was undertaken. This new approach to root decomposition allows for potential biochemical tracers of organic matter degradation to be used in a root decomposition study for the first time. It also provides information on what carbon fractions might be more recalcitrant and identifies biomolecules entering the hydrologic cycle.

(Initially this project aimed to examine age-specific decomposition rates of roots of grapevines and oak trees in the Oakville Region of the Napa Valley by using a modified root laparascopic device and collapsible minirhizotron tubes. During the course of these initial experiments, no new root births were observed in the minirhizotron tubes placed in the field. As a consequence, we outlined a new experimental approach.)

Approach and Procedures

Since the new approach to this project was undertaken in October 2005, new study sites were identified, eight soil pits were excavated and roots extracted. The root material from these eight pits was collected and sieved to separate the roots into three size classes (< 2mm, 2–5mm and > 5mm, Camire *et al.* 1991; Silver and Miya 2001). Some time was required to become proficient with and verify carbon and nitrogen analyses required in this investigation, and the procedures for extraction and measurement of lignin phenols in roots using CuO oxidation followed by pyrolysis gas chromatography mass spectrometry. Considerable time was invested in locating appropriate study sites, particularly in finding accessible vineyards representing a chronological decomposition sequence for the same rootstock, but an important result from this effort indicated that root decomposition was as nonlinear process in as much as non-decomposing roots were encountered in fallow land where vineyards were removed as many as eight years prior.

Results

Initial carbon and nitrogen data for the three size classes of roots and across the three study sites are presented in table 1 and figure 2a-h. Previously reported data has shown fine roots to be selectively enriched in nitrogen relative to carbon compared to larger root

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size classes (Silver and Miya 2001). This trend is observed in our data for the three root size classes from the undisturbed oak woodland grassland site (*table 1* and *fig. 2g & h*). The two undisturbed oak woodland grassland site samples show C:N values across the three size fractions within the range expected for a diverse range of roots (Silver and Miya 2001). The roots collected from both the vineyard fallow and row sites, however, do not show typical patterns across root size classes (*table 1* and *fig. 2a-f*). Within the three fallow sites, the C:N ratio typically decreases with declining root size fraction and the smaller size classes have lower C:N ratios than the roots > 5mm (*fig. 2b and c*). The fallow site number 1 (*fig. 2a*) may not represent typical trends as there was a very limited number of finer roots at this site, therefore, it may be atypical. Within the three current vineyard row sites, root size classes were observed to decline with respect to C:N ratio

Table 1. *Root organic matter compositional information for each study site and size class. Abbreviations: % OC – weight percent organic carbon; %N – weight percent total nitrogen; (C:N)a – atomic carbon to nitrogen ratio; $\delta^{13}C$ – stable carbon isotope deviation (per mil) relative to the PDB standard; lignin parameters are defined in the text. For the fallow soils, BV-02 represents a vineyard that was removed two years prior to excavation, ES-02 represents a vineyard excavated approximately six years prior to excavation and DF-01 approximately eight years prior to excavation.*

Type	Size mm	Map I.D.	OC %	N %	(C:N)	$\delta^{13}C$	Λ	Σ8	S:V	C:V	(Ad:Al) v	(Ad:Al) s
Fallow	> 5	BV-02	40.8	1.3	37.3	-26.4	5997.9	2.45	1.94	0.13	0.15	0.17
Fallow	2-5	BV-02	38.6	1.1	40.9	-26.1	2219.7	0.86	1.55	0.54	0.20	0.17
Fallow	< 2	BV-02	41.7	1.5	32.9	-25.8	2536.3	1.06	1.52	0.34	0.20	0.18
Fallow	> 5	ES-02	42.7	1.4	34.5	-27.5	3591.1	1.53	1.71	0.19	0.17	0.16
Fallow	2-5	ES-02	40.6	2.9	16.2	-26.9	3227.8	1.31	1.75	0.27	0.22	0.22
Fallow	< 2	ES-02	28.1	1.5	22.0	-27.4	2536.0	0.71	1.16	0.42	0.22	0.19
Fallow	> 5	DF-01	43.0	1.8	28.1	-27.8	4471.0	1.92	1.78	0.14	0.21	0.22
Fallow	2-5	DF-01	41.0	2.6	18.4	-28.5	2856.7	1.17	1.74	0.23	0.22	0.21
Fallow	< 2	DF-01	37.4	2.6	16.6	-27.8	1277.4	0.48	0.78	0.73	0.27	0.26
Row	> 5	BV-10	43.5	1.9	26.0	-26.3	4906.0	2.13	1.82	0.16	0.17	0.16
Row	2-5	BV-10	41.7	2.1	22.8	-26.1	1304.4	0.54	1.33	0.66	0.22	0.20
Row	< 2	BV-10	25.9	1.0	30.5	-26.2	1984.5	0.51	1.22	0.83	0.21	0.18
Row	> 5	ES-06	42.8	1.4	36.6	-26.9	4090.6	1.75	1.79	0.15	0.16	0.16
Row	2-5	ES-06	42.3	2.5	19.5	-27.1	1622.2	0.69	1.40	0.52	0.20	0.20
Row	< 2	ES-06	20.7	1.0	24.7	-27.2	2145.6	0.44	1.05	0.88	0.23	0.20
Row	> 5	DF-02	45.4	1.1	46.5	-28.1	7673.6	3.49	1.85	0.13	0.19	0.23
Row	2-5	DF-02	43.2	2.0	25.2	-27.5	3397.0	1.47	1.65	0.27	0.23	0.23
Row	< 2	DF-02	41.0	1.3	37.2	-26.8	1594.0	0.65	1.25	0.52	0.23	0.24
Oak	> 5	-	43.8	0.3	146.5	-26.3	11884	5.21	3.22	0.05	0.20	0.23
Oak	2-5	-	43.1	0.6	79.5	-25.8	8192.8	3.53	1.72	0.08	0.23	0.24
Oak	< 2	-	46.7	0.8	70.1	-26.0	3237.5	1.51	0.99	0.19	0.26	0.20
Oak	> 5	-	44.3	0.4	139.6	-25.9	9344.4	4.14	2.70	0.04	0.17	0.18
Oak	2-5	-	43.8	0.5	105.3	-26.0	8070.5	3.54	1.98	0.05	0.20	0.19
Oak	< 2	-	47.3	0.9	59.1	-26.8	3627.5	1.71	1.11	0.17	0.26	0.18

from roots > 5 mm to roots 2-5 mm and to subsequently increase again fine roots (< 2 mm). Grape vines are comparatively rich in nitrogen (Keller 2005) and it is possible the enrichment in the fine root fraction may be due to excessive or targeted N fertilization, although this is not highly likely. N fertilization rates have been historically low in this vineyard and *Vitis* species are known to transport large quantities of arginine, and other amino acids in the glutamine family, to roots for storage when they enter dormancy.

Root organic material compositional data is summarized in table 1. No discernable trend in $\delta^{13}C$ was observed with root decomposition or across size classes. The total yield (Λ) of eight measured lignin phenols (vanillin, acetovanillon, vanillic acid, syringaldehyde, acetosyringone, syringic acid, *p*-coumaric acid and ferulic acid) per 100 mg of sample organic carbon also showed no significant trend between fresh and decomposed roots. However, enrichment in larger size classes of roots was observed as would be expected, due to a greater proportion of woody material in the larger root materials. The total yield ($\Sigma 8$ μg) of the above eight lignin phenols per 10g of bulk sample also showed no significant trend between fresh and decomposed roots but a clear increase with increasing root size class. Acid:aldehyde ratios of vanillyl and syringyl phenols, (Ad:Al)v and (Ad:Al)s, are a measure of relative oxidation of lignin. Higher acid:aldehyde ratios indicate greater oxidation, and acid:aldehyde ratios have been shown to increase with greater microbial degradation (Hedges *et al*. 1988; Opsahl and Benner, 1998). No discernable trend was observed between fresh root material and material that had been decomposing for several years (eight) indicating little microbial degradation of lignin over the time period. Finally, the syringyl to vanillyl phenol ratios (S:V) can be used to distinguish between angiosperms and gymnosperms in fresh organic matter because of the unique angiosperm source of syringyl phenols (Hedges and Mann 1979). In conjunction with the cinnamyl to vanillyl phenol ratios (C:V), which can discriminate between woody and non-woody vascular plant materials. Since only the non-woody plants produce significant amounts of the two cinnamyl phenols (Hedges and Mann 1979), it is possible to discriminate between angiosperms and gymnopserms and determine whether or not they were woody or non-woody. The S:V vs. C:V data showed little variation between fresh and decomposed root samples; however, it shows a clear fractionation with size class (fig. 3). The use of this diagnostic biomarker has previously only been employed on whole plant material and the impacts of growth stage clearly affected the signal.

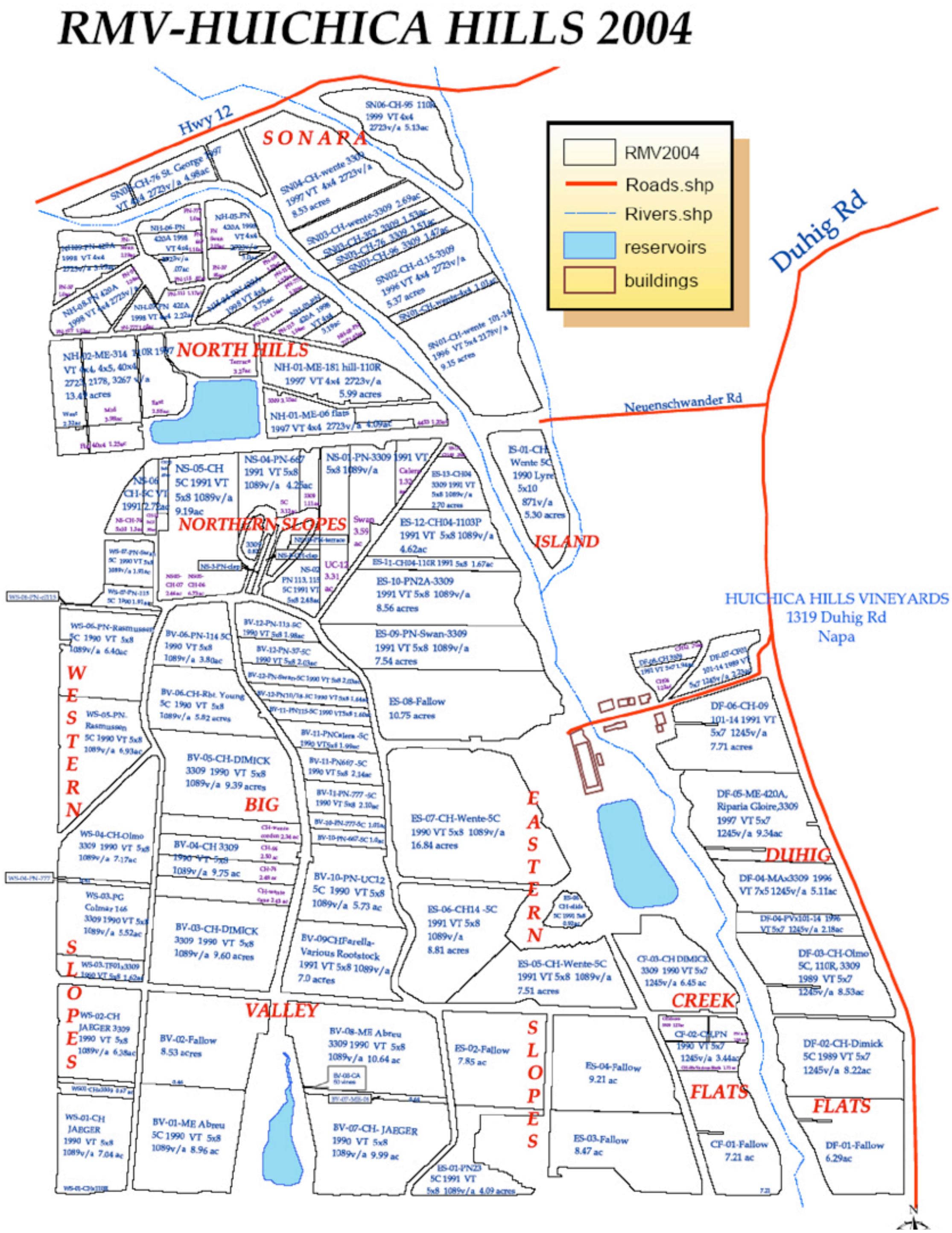
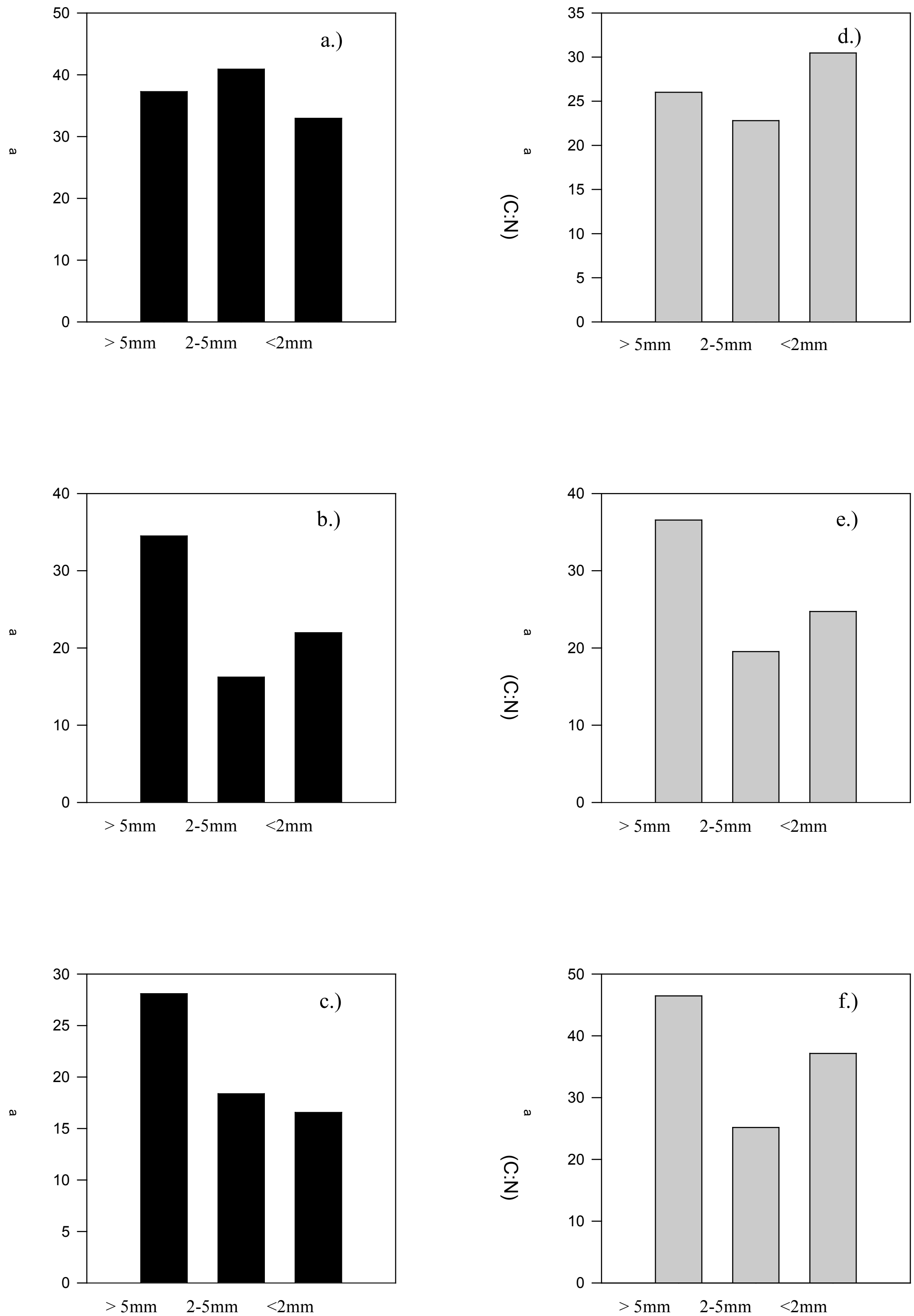


Figure 1. Carneros vineyard study site.


a.)
b.)
c.)
d.)
e.)
f.)
(C:N)
(C:N)
(C:N)
> 5mm
2-5mm
<2mm

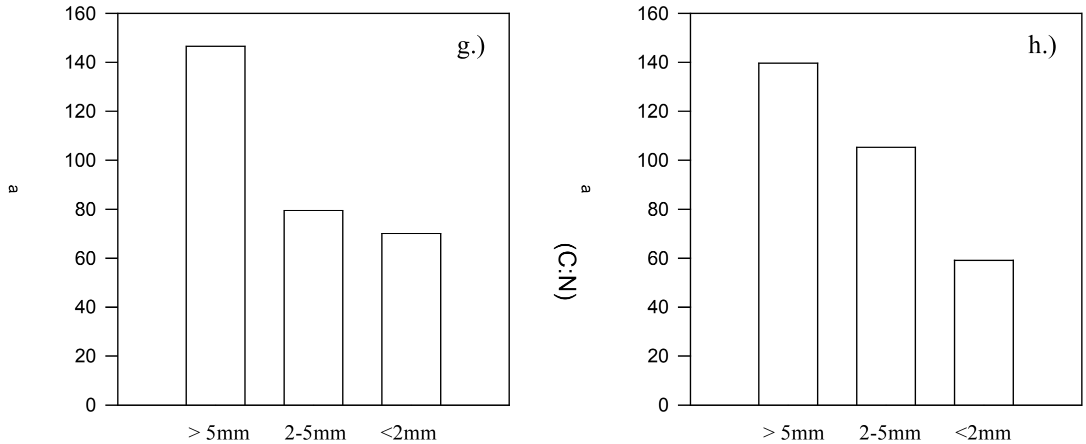


Figure 2. Summary root (C:N)a data for three different size classes. **a.)** Fallow Site 1, BV-02; **b.)** Fallow Site 2, ES-02; **c.)** Fallow Site 3, DF-01; **d.)** Row Site 1, BV-10; **e.)** Row Site 2, ES-06; **f.)** Row Site 3, DF-02. **g.)** Oak Site 1; **h.)** Oak Site 2.

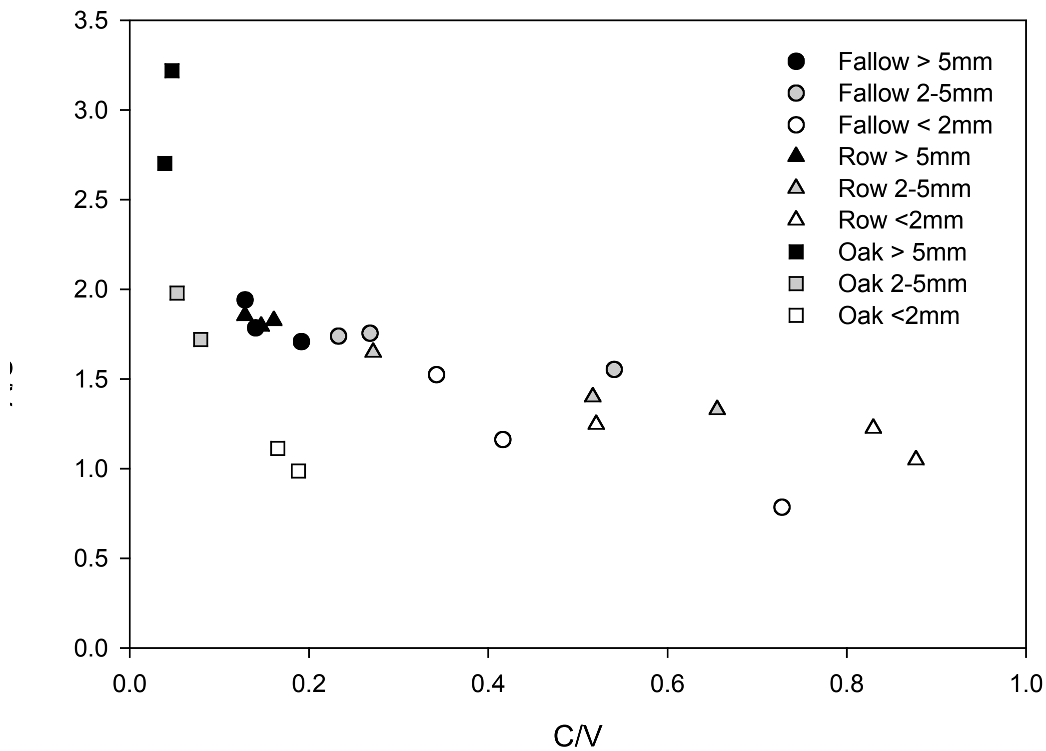


Figure 3. Lignin phenol syringyl to vanillyl phenol ratios (S/V), versus cinnamyl to vanillyl phenol ratios (C/V), for vineyards that had been fallow for up to six years and for non-fallow vineyards on the same rootstock and similar age. Shown also are S/V and C/V for roots of oaks in neighboring oaks.

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