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PREDICTING N AVAILABILITY FROM YARD DEBRIS

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ABSTRACT

Yard debris is a source of nutrients and organic matter for crop production, but variability in yard debris composition makes it difficult to predict N availability and estimate application rates. Our objectives were to 1) measure the effects of yard debris on soil N availability, and 2) develop guidelines for estimating agronomic rates for yard debris applications. We conducted field and laboratory studies that measured apparent N recovery (difference method) and decomposition (CO_2 evolution) following yard debris incorporation into a Puyallup sandy loam soil. Treatments included four commercial yard debris sources and four grass/woody mixtures prepared by combining fresh grass clippings (0, 33, 67 and 100 % by volume) with ground woody yard debris. The control was a soil-only treatment without yard debris. The laboratory incubations showed that cumulative decomposition and available N release increased with increasing grass content of the mixtures and commercial sources. Apparent N recovery was 0 to 10% for yard debris with N content < 1.6%, and 40 to 50% for yard debris with N content > 3%. Field results followed the same trends, except that apparent N recoveries were lower (ranging from 0 to 30%). Our data show that yard debris total N and C:N are useful indicators for predicting N availability, and that estimated grass content can be used as a rough surrogate for analytical data.

INTRODUCTION

Yard debris is a mixture of grass clippings, leaves, weeds, woody trimmings, other unwanted plant materials, and the soil that accompanies these materials (Kidder, 2000). Much of the yard debris from urban and suburban communities in western Washington is collected and composted at commercial facilities. In King County, for example, commercial facilities handle 185,000 wet tons of yard debris annually, which is more the 70% of the total generated in the county (Cascadia Consulting Group, 2000).

The volumes and composition of yard debris collected during peak flow periods can pose problems for composters. Peak flows occur during the spring when the yard debris is rich in grass clippings and high in moisture, and can lead to composting and odor problems. Application of these yard trimmings to cropland has potential benefits for both composters and farmers. Composters can reduce peak flows of N-rich materials, and farmers can benefit from the nutrients and organic matter in the yard trimmings. In western Washington, silage corn grown following a 45 Mg/ha (20 tons/acre dry weight) application of yard debris had equal or higher yields than silage corn grown with inorganic N fertilizer at recommended rates (Bary et al., 1999).

Characteristics of yard debris can vary among facilities and seasons, and this variability makes it difficult to predict N availability and estimate appropriate application rates. By understanding how N availability varies as yard debris composition varies, we can develop ways to predict N availability based on easily measured or observed characteristics of the yard debris. We conducted this research to 1) measure the effects of yard debris on soil N availability, and 2) develop guidelines for estimating agronomic rates for yard debris applications.

METHODS

Experimental approach. We conducted a concurrent field and laboratory study that measured apparent N recovery (difference method) and decomposition (CO_2 evolution) following yard debris incorporation into a Puyallup sandy loam soil. Our yard debris treatments were organized into two groups. The first group of treatments consisted of four commercial yard debris sources available to growers. A second group of treatments evaluated four mixtures prepared by mixing set proportions of fresh grass clippings (0, 33, 67 and 100 % by volume) with the remainder being ground woody yard debris. The control treatment in all experiments was a soil-only treatment (no yard debris added). The laboratory experiments had three replications. The field experiment had four replications in a randomized complete block design.

Sample collection. We collected yard debris samples from four commercial composting facilities (B, C, L and S) in the Puget Sound area. Fresh grass clippings and woody yard debris (no grass) were also obtained from commercial sources.

We prepared the grass/woody debris mixtures by loading a clean manure spreader with alternating layers of grass and woody debris. Each mixture was then discharged from the spreader into a pile.

Yard debris analyses. Samples of “as-is” yard debris were sieved to determine the percentage of fine material (passing a 16-mm screen), and dried at 55 ^oC to determine solids concentration. We used the fine material to represent the active fraction of the yard debris, while the coarse material (remaining on the screen) was assumed to be nearly inert during the time period of the incubations. Total C and N concentrations of the sieved, dried yard debris samples (fine fraction) were determined with a C and N combustion analyzer equipped with an infrared detector (Table 1). Ammonium-N concentrations of the fresh and dried yard debris were measured after extraction with 2M KCl, using an automated salicylate-nitroprusside method. Total N concentrations for the fresh yard debris samples were determined as:

$$\text{Total N}_{fresh} = \text{Total N}_{dried} - NH_4\text{-N}_{dried} + NH_4\text{-N}_{fresh}$$

where
Total N_{fresh} = Total N in fresh yard debris (g kg^{-1}; dry wt basis)
Total N_{dried} = Total N in dried yard debris (g kg^{-1}; dry wt basis)
$NH_4\text{-N}_{dried}$ = NH_4-N in dried yard debris (g kg^{-1}; dry wt basis)
$NH_4\text{-N}_{fresh}$ = NH_4-N in fresh yard debris (g kg^{-1}; dry wt basis)

Laboratory incubation

We added fresh yard debris (fine fraction) to 700 g of fresh Puyallup fine sandy loam soil (coarse-loamy over sandy, mixed, mesic Vitrandic Haploxerolls) collected from the site of the field experiment (0 to 15 cm depth). We incubated the fresh soil plus yard debris mixture in a

3.8 L (1 gal) plastic bag at 25 ^{o}C. The bag tops were left open to allow air exchange. We added yard debris to soil at a rate of 15 g dry matter per kg of dry soil (1.5 % w/w). Total N application rates are shown in Table 2. Soil moisture was maintained at 180 to 220 g kg^{-1} by adding moisture every 14 d. We removed a 10-g soil sample from the bags at 14 d intervals. Soil samples were extracted with 2M KCl. Ammonium and nitrate-N in soil extracts were determined by automated colorimetric methods (Gavlak et al., 1994). Apparent N recovery (ANR) was calculated by difference from measurements of inorganic N:

$$ANR = (N_{treatment} - N_{control})/N_{applied} * 100$$

where

ANR = Net difference in $NH_4 + NO_3$-N concentration in soil after yard debris application (mg kg^{-1})

$N_{treatment}$ = $NH_4 + NO_3$-N concentration in soil after yard debris application (mg kg^{-1})

$N_{control}$ = $NH_4 + NO_3$-N concentration in unamended soil (mg kg^{-1})

$N_{applied}$ = Total N applied in yard debris (mg kg^{-1}; Table 2)

Decomposition of yard debris in soil at 25 ^{o}C was measured by trapping CO_2 in 1M NaOH, and then determining the quantity of trapped C via a titration method. Fresh yard debris was added to fresh soil (50 g) at the same rate (1.5 % w/w) used in the N incubation. Yard debris decomposition was estimated by difference, using CO_2 loss from an unamended Puyallup soil as a baseline. Equations for calculating C loss (decomposition) were similar to those given previously for ANR.

Table 1. Characteristics of fresh yard debris used in field and laboratory experiments[a].

Treatment	Total Solids	NH_4-N	Total N	Total C	C:N
	%	%	%	%	
Commercial Sources					
S	20	0.45	3.32	40.1	12
C	41	0.12	1.55	28.5	18
B	34	0.23	1.78	30.6	17
L	36	0.32	1.86	29.4	16
Mixtures[b]					
0 % grass	54	0.00	0.29	40.1	138
33 % grass	38	0.14	1.17	41.0	35
66 % grass	27	0.32	2.49	39.9	16
100 % grass	20	0.48	3.57	39.8	11

[a] Total solids determined by drying fresh yard debris at 55 ^{o}C. The percent moisture in a fresh yard debris sample equals 100 minus percent total solids. Nitrogen and C analyses expressed on a dry weight basis.

[b] Mixtures (v/v) of fresh grass clippings with ground woody yard debris. The percentage of woody yard debris in the mixtures is 100 % minus the listed % grass (e.g. 0 % grass treatment contained 100 % woody yard debris).

Field experiment

We applied the yard debris and grass-woody mixtures by hand to 1.2 x 5.2 m plots on a Puyallup soil. The yard debris was the total fraction as received from each facility. The target application rate was 45 Mg dry matter/ha. Nitrogen application rates are shown in Table 2. These rates are based on the N content of the fine (Table 1) and coarse (approx. 0.3 % N) fractions, adjusted for the proportions of fine and coarse fractions in each material (Table 2).

We applied yard debris on 14 June, and incorporated it on 15 June to a depth of 15 cm, using a tractor-mounted rototiller. The plots were kept fallow throughout the experiment by hand weeding and applications of glyphosate. Plots were irrigated in late June, mid July, and early August to maintain adequate moisture for microbial activity.

Table 2. Total N application rates for yard debris treatments in field[a] and laboratory[b] experiments.

	Field		Lab
Treatment	Fine fraction	N applied	N applied
Commercial Sources	$g\ kg^{-1}$	$kg\ ha^{-1}$	$mg\ kg^{-1}$
S	960	1433	498
C	630	482	233
B	780	650	267
L	750	656	279
Mixtures			
0 % grass	NA[c]	130	44
33 % grass	NA	524	175
66 % grass	NA	1114	373
100 % grass	NA	1601	536

[a] Field experiment. Total N application rates were based on a dry matter application rate of 45 Mg ha^{-1} (20 dry ton per acre). Fine fraction yard debris passed a 16 mm screen. Fine fraction had N analyses presented in Table 1; the coarse fraction contained approximately 0.3 % N.

[b] Laboratory experiment. Total N application rates based on fine fraction yard debris incorporation rate of 15g/kg.

[c] Fine fraction not determined for mixtures treatments. The same particle size of yard debris was used in the field and laboratory for the mixtures treatments.

Soils samples for available N were collected 8, 13, 20, 33, and 54 d after incorporation. We collected and composited five cores from the 0 to 15-cm depth and three cores each from the 15 to 30 and 30 to 60 cm depths in each plot at each sampling date. Samples were extracted with 2M KCl and analyzed for nitrate-N (all samples) and ammonium N (0 to 15 and 15 to 30 cm samples only) using standard methods (Gavlak et al., 1994). We calculated ANR using the method described for the laboratory incubation.

We determined CO_2-C evolution in-situ, using Draeger™ tubes to measure CO_2-C accumulated in a closed head space above the soil surface in 30 minutes (Soil Quality Institute, 1999). We reduced the accumulation time to 10 minutes when CO_2-C evolution was rapid. Measurements were made 4, 7, 14, 28, 40 and 64 d after incorporation.

RESULTS AND DISCUSSION

Yard debris characteristics

The grass/woody debris mixtures containing 33, 67 and 100 % grass represent the range of yard debris N concentrations and C:N ratios available at commercial facilities (Table 1). The 100 % grass treatment had a similar total N concentration and C:N ratio to commercial source S. Total N concentrations for commercial samples C, B and L were greater than for the mixture containing 33 % grass and less than the mixture containing 67 % grass. The less extreme C:N ratios in the commercial samples (12 to 18) compared to the mixtures (11 to 35) is probably the result of the inclusion of other plant materials like conifer needles and shrub leaves. The NH_4-N concentrations in yard debris increased with total N concentration across the four mixtures and four commercial sources. Ammonium-N comprised 7 to 17 % of the total N present in the yard debris.

Laboratory experiment

Mixtures. Available N release was directly related to cumulative decomposition (CO_2-C loss) from the mixtures of grass plus woody debris (Fig. 1a and c). As the percentage of grass increased, so did cumulative C loss at 35 d and apparent N recovery at 70 d. The pattern of C loss over time followed first-order kinetics, suggesting that a simulation model such as DECOMPOSITION (Gilmour, 1998) may be useful in predicting available N production based

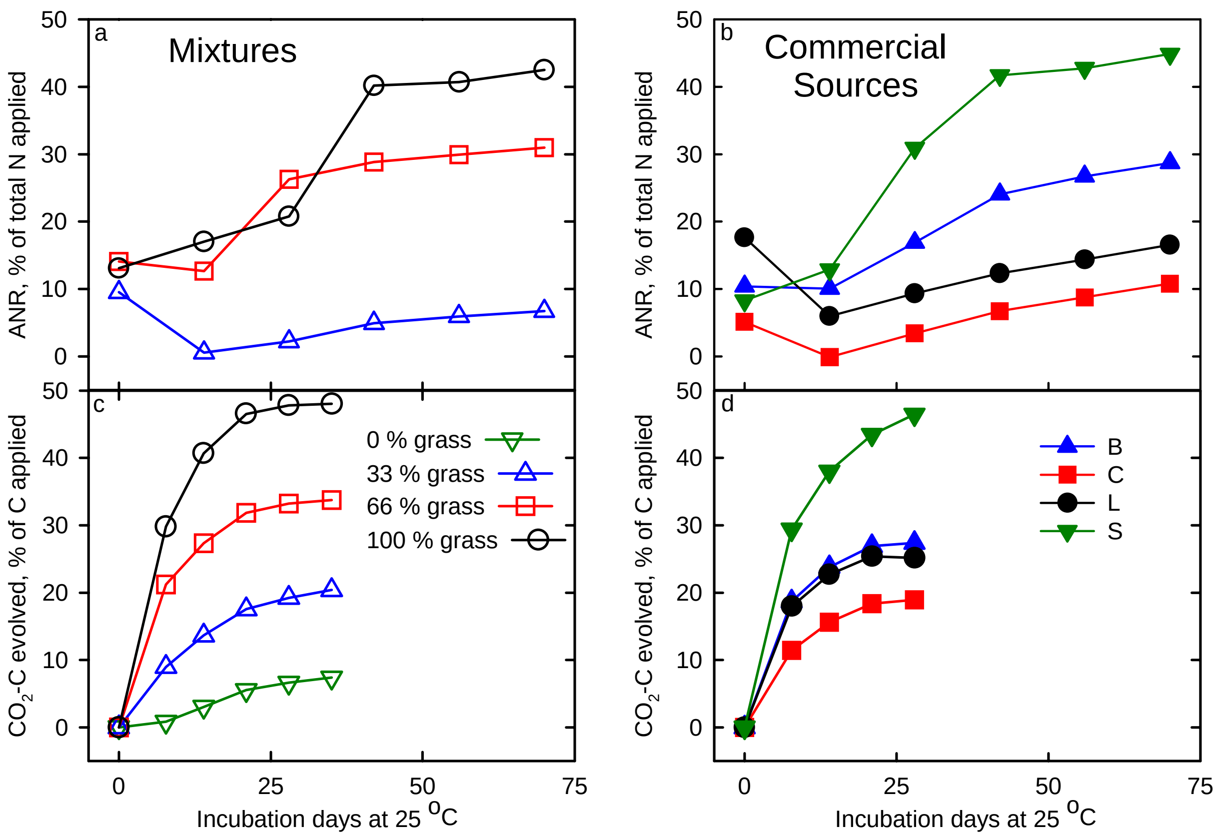

Figure 1. Apparent N recovery (a and b) and CO_2-C loss (c and d) for mixtures and commercial sources of yard debris. Laboratory incubation at 25 ^oC.

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on short term measurements of C loss. The Gilmour model uses decomposition rate constants to drive microbial activity and N dynamics. The grass contained 47 % decomposable C, while the woody debris contained only 7 % decomposable C. This reflects the higher lignin concentration found in woody debris. The amount of C loss from grass/wood mixtures was additive.

The timing of N release from yard debris mixtures was related to decomposition dynamics. During the first 14 d, grass decomposed rapidly (Fig. 1c). The inorganic N supplied by decomposition of the grass was in excess of microbial N immobilization for the 100 % grass treatment, resulting in an increase in measured apparent N recovery (Fig. 1a). In contrast, apparent N recovery decreased between 0 and 14 d for the 33 % grass treatment. All treatments exhibited increased N recovery after 14 d. A large increase in N recovery occurred between 14 and 42 d, as decomposition rates slowed. The 0 % grass mixture slowly reduced apparent N recovery throughout the experiment. By 56 d, apparent N recovery was reduced by -65 % (29 mg kg^{-1}) with the 0 % grass treatment (Table 3).

The 33 % grass mixture was near the breakeven point for immobilization/mineralization even though it had a C:N of 35. Apparent N recovery for this mixture was 0 to 10 % through 70 d. This suggests that the woody debris used in our mixtures was more resistant to decomposition, than are typical crop residues whose breakeven C:N is 15 to 20:1. Greater immobilization of available N (reduction in apparent N recovery) would typically be expected for crop residues with C:N ratios of 35:1.

Table 3. Apparent nitrogen recovery from fresh yard debris in field and laboratory experiments at 14 and 56 days after application.

	Apparent Nitrogen Recovery			
	14 d		56 d	
Treatment	Field	Lab	Field	Lab
	-----------------------------------% of total N applied---------------------------			
<u>Commercial Sources</u>				
S	17	13	29	43
C	1	0	0	9
B	10	10	14	27
L	19	6	20	14
<u>Mixtures</u>				
0 % grass	-3	-29	-97	-65
33 % grass	10	1	7	6
66 % grass	10	13	14	30
100 % grass	15	17	18	41
$LSD_{0.05}$	7	5	5	9

Commercial Sources. The same general pattern of C and N dynamics over time was apparent for the commercial sources (Fig. 1b and d) as found with the mixtures (Fig. 1a and c). Apparent

N recovery declined or remained constant for commercial sources B, C, and L between 0 and 14 d, accompanying rapid decomposition. As decomposition slowed, apparent N recovery increased between 14 and 42 d. Commercial source S, derived from source-separated grass clippings, performed similarly to the 100 % grass mixture. Cumulative C loss at 35 d and apparent N recovery at 70 d for commercial sources B, C and L were higher than measured for the 33% grass mixture and less than measured for the 67 % grass mixture.

Predicting apparent N recovery using yard debris analyses. Apparent N recovery at 56 d increased linearly with yard debris N concentrations (Fig. 2a). Yard debris from commercial facilities performed similarly to grass/woody mixtures. Apparent N recovery was 0 to 10 % for yard debris N concentrations of less than 1.6 %. The highest N recoveries, 40 to 50%, were measured with yard debris N concentrations in excess of 3 %. Apparent N recovery at 56 d decreased linearly as C:N ratios increased from 10 to 20 (Fig. 2b). Variability in apparent N recovery for the commercial yard debris sources was less (smaller sampling error) than for the mixtures, reflecting the more thorough mixing attainable at commercial facilities.

Field Experiment

The three mixtures that contained grass had positive ANR throughout the field incubation period, indicating that they were net suppliers of available N (Fig. 3a and Table 3). Apparent N recovery increased with increasing grass content, and most of increase in ANR occurred within 13 to 20 d of application. Evolution of CO_2-C was greatest during the first 20 d, and approached levels in the unamended soil thereafter (Fig. 3c). Overall, ANR after 54 d in the field experiment was lower than observed in the laboratory experiment. Lower temperatures in the field may explain part of this difference.

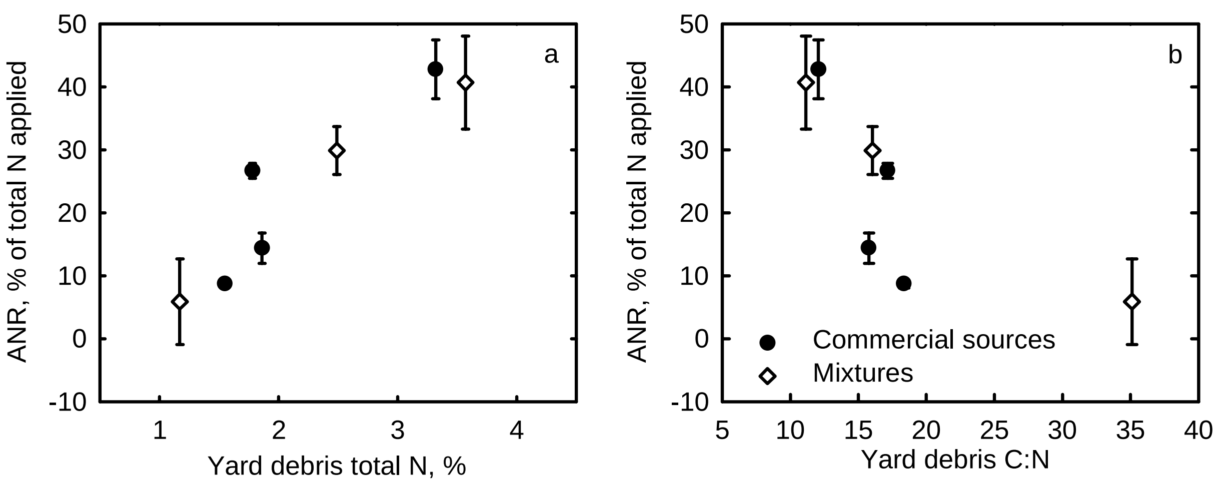

Figure 2. Relationship between N concentration (a) and C:N ratio (b) and apparent N recovery (ANR) following yard debris incorporation into soil. Laboratory incubation at 25 °C for 56 d. Mixtures containing 33, 67 and 100 % grass are shown. Error bars represent the standard deviation of the mean (n = 3).

The 0 % grass (100 % woody debris) mixture showed little difference in available N compared with the untreated soil after 14 d, but immobilization occurred thereafter (Table 3). Evolution of CO_2-C was also slow at first, but increased during the first 28 d after application. During later sampling periods, CO_2-C evolution from the 0 % grass treatment was highest of all treatments.

The field results for the commercial sources were consistent with those observed for the mixtures. The source with the highest grass content (S) had the greatest ANR, while source with the least grass (C) had ANR near zero (Fig. 3b and Table 3). Sources B and L were intermediate. None of the materials showed net N immobilization (ANR < 0) during the course of the experiment. Most of the increase in ANR occurred within the first 13 to 20 d after application, similar to the mixtures. We measured CO_2-C evolution only for source L, and it showed an initially high decomposition rate at 4 d, followed by a decline to near that of the unamended soil after 28 d (Fig. 3d).

The data suggest that decomposition and release of available N from the grass fraction of the mixtures and yard debris sources occurred rapidly in the field, and soil N measurements made two to three weeks after application could be used as an estimate of N availability during the growing season.

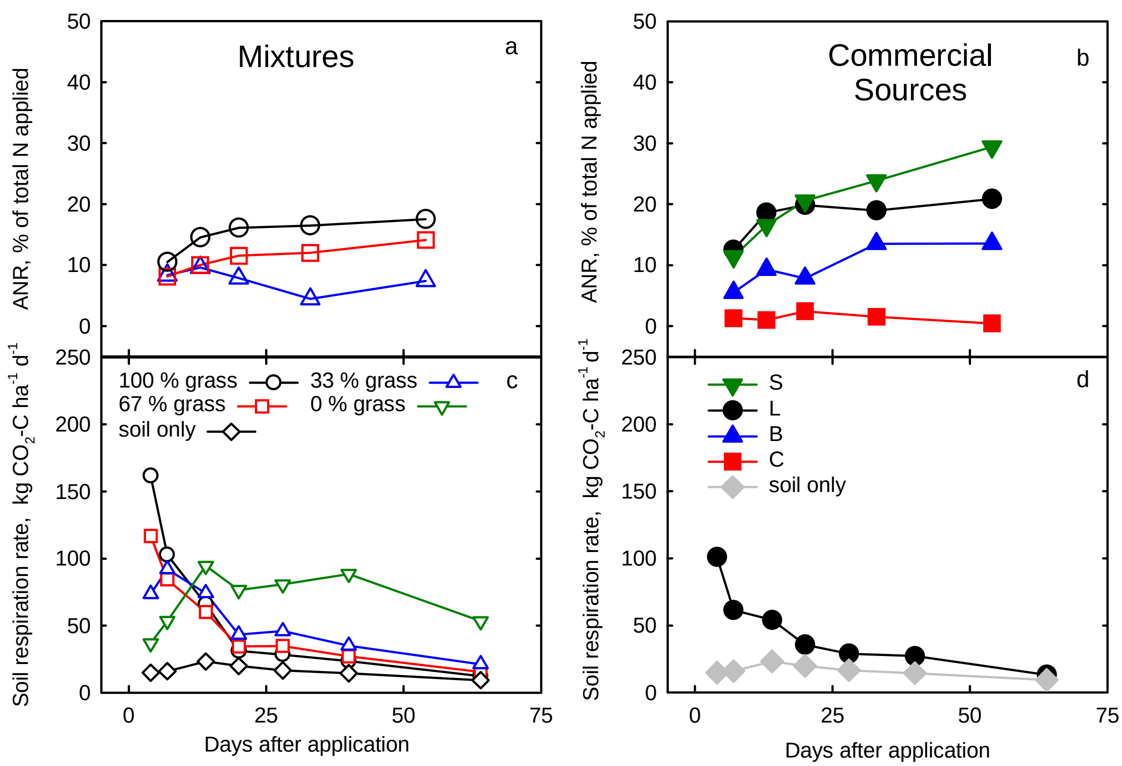

Figure 3. Apparent N recovery (a and b) and soil respiration rate (c and d) for mixtures and commercial sources of yard debris. Field experiment with yard debris incorporation on June 15 (day 0).

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Estimating agronomic rates for growers

The experimental data presented here, together with previous research by our group (Bary et al., 1999; Nartea, 2000) has provided the basis for draft guidelines for the application of fresh yard debris in western Washington and Oregon cropping systems (Table 4).

Our procedure for estimating agronomic rates (Table 4) allows users to consider analytical data (C and N concentration) and/or knowledge about the percentage of grass included in the yard debris. Our experimental data (e.g. Fig. 2) shows that yard debris total N and C:N ratio are useful general indicators, and that grass percentage (proportion of grass-like material in the yard debris) can be used a rough surrogate for analytical data.

Table 4. Draft Cooperative Extension guidance. Estimated available N supplied by a 40 ton "as-is" yard debris application. Select the row that best describes the total N or C:N analysis of the yard debris. If C and N analyses are not available, use observations about the percentage of grass-like green leafy materials in the pile. Estimates of available N are for the first 60 days after incorporation of yard debris at a soil temperature of approximately 20 ^{o}C (68 ^{o}F).

Select a row based on these columns					Estimated first-yr available N in the field		
Total N	C:N	Grass Percentage	Total Solids	Bulk Density			
%		% of pile volume	%	lb yd^{-3}	% of N applied	average lb N yd^{-3}	lb acre^{-1}
Below 1.2	Above 22	0	50	1000	-10 to 10	0	-40 to 40 [a]
1.2 to 1.8	18 to 22	30	40	1100	10 to 20	1.0	50 to 100
1.8 to 2.3	15 to 18	50	40	1200	15 to 30	2.2	100 to 200
2.3 to 2.8	13 to 15	70	30	1300	20 to 35	2.7	120 to 210 [b]
Above 2.8	11 to 13	100	30	1500	20 to 45	4.8	160 to 350 [b]

[a] These amendments are best used for mulching on the soil surface. Use of yard debris with less than 1.2 % N or a C:N above 22 is not recommended when an adequate N supply for rapidly growing crops is needed. Supplemental inorganic N fertilization may not overcome the temporary immobilization of available N that occurs with these amendments. Immobilization of available N typically occurs for 60 to 120 d after application.

[b] These amendments supply variable amounts of available N depending on the length of storage after yard debris collection and other factors not readily determined by analytical testing. Soil testing 15 to 30 d after yard debris application is recommended to fine tune available N supply for the crop. Use conservative application rates to avoid excess N supply.

We prefer using total N concentrations instead of C:N ratio for interpretive purposes for yard debris samples that contain little or no soil. When substantial amounts of soil are found in yard debris, the C:N remains a good N availability indicator, while N concentration will be artificially low. Added sand or soil dilutes the N concentration, but does not change the C:N ratio.

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