PREDICTING NITROGEN AVAILABILITY FROM ORGANIC AMENDMENTS: LABORATORY, FIELD AND COMPUTER SIMULATION

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ABSTRACT

Improved estimates of nitrogen availability from manures and composts are needed to assist land managers in supplying adequate, but not excessive amounts of plant-available N for crop production. We conducted field and laboratory studies to: (i) determine first growing season N availability for a variety of organic amendments used in small-scale vegetable farming in our region, and (ii) test the computer simulation model DECOMPOSITION as a predictor plant-available N (PAN) release from amendments. Field and laboratory estimates of PAN from amendments were similar. Plant-available N from amendments decreased as amendment C:N ratio increased from 4 to 15. For amendments with C:N < 15 (n = 25), the fitted regression equation predicting PAN (%) was 105 -7.07 (C:N); $r^2 = 0.71$. Well-composted amendments with slow decomposition rates in soil had PAN of -10 to 25%. Amendments with highest PAN had C:N < 10 and cumulative decomposition above 50 % in a 70-d incubation at 22°C. Measured and modeled PAN were linearly-related in both the laboratory ($r^2 = 0.74$) and field experiments ($r^2 = 0.78$) with slopes not significantly different than unity. Across all amendments, the model over-predicted full-season N availability in the field by 8 %. Amendments with greatest over-prediction by the model had had high initial NH_4-N concentrations (e.g. broiler litter, rabbit manure). This study demonstrated that knowledge of amendment decomposition kinetics can assist in predicting N availability from organic amendments.

Many organic amendments can be used to supplement N from inorganic fertilizers, or to replace inorganic N fertilization. Current Pacific Northwest Extension recommendations for N-based amendment application are based on limited data. Estimated first-season N availability (% of total N) is 40 to 70% for broiler litter, 0 to 20 % for separated dairy solids (Bary et al., 2000), and 10 to 30 % for uncomposted yard trimmings (Cogger et al., 2002). Extension guidance for manure application (Bary et al., 2000) also provides a general equation based on total N analysis of the amendment: first-growing season available N (% of total N) equals total N concentration in the amendment (% dry wt.) x 10. With increased interest in organic or biologically-intensive agriculture, a wider variety of amendments are available for grower use. Some amendments are expensive, so applying the amount of amendment needed to meet current season crop N requirements is an important economic consideration. We conducted this research to improve the accuracy of Extension recommendations for the utilization of organic amendments as N sources in small-scale vegetable production. The specific objectives of this study were to: (i) determine first growing season N availability for a variety of organic amendments, and (ii) test the computer simulation model DECOMPOSITION (Gilmour, 1998) as a predictor plant-available N (PAN) release from amendments.

MATERIALS AND METHODS

Plant-available nitrogen (PAN) following amendment incorporation into soil was determined in the laboratory and field. In the laboratory, cumulative decomposition (net CO_2 evolution) and cumulative apparent N recovery were determined as a treatment value minus a value for an un-amended soil control. Laboratory incubations were conducted for 70 d at 22°C with soil moisture of approximately 200 to 250 g H_2O kg^{-1}. Laboratory PAN was determined as the sum of NH_4-N + NO_3-N.

Field experiments were conducted in 2002 and 2003 on a Willamette silt loam soil (Aurora, OR), and on a Puyallup sandy loam soil (Puyallup, WA). Plots were irrigated with solid-set overhead sprinklers. Irrigation timing and amount were monitored to limit potential leaching during the summer. At field sites, organic amendments were applied 15 to 30 d before seeding sweet corn (Zea mays L.'Jubilee'), then roto-tilled into soil within 1-2 h to minimize NH_3 loss. At harvest, we measured whole plant N uptake and post-harvest soil nitrate-N (0 to 30 cm). We used a fertilizer N equivalency method to calculate PAN. We first fit a linear regression equation for each site-yr, describing N response (crop N uptake + post-harvest soil nitrate-N) to urea rates from 0 to 224 kg N ha^{-1}. We then used the observed data for organic amendment treatments and the fitted regression equations for urea response to estimate an equivalent urea-N application rate.

We evaluated a total of 42 amendment samples in field and laboratory experiments. We documented the composting, handling and storage history for the fresh amendment vs. "compost product" group (broiler litter, separated dairy solids, yard trimmings, and rabbit manure, n = 28), and included these amendments in all field and laboratory experiments. Other amendments, included in selected experiments, were obtained from third-party sources where amendment feedstock(s) and amendment processing history could not be verified.

The DECOMPOSITION model (Gilmour, 1998) was run by Gilmour without calibration. The model estimates cumulative decomposition of amendments using sequential first-order kinetics where a "rapid" fraction of amendment organic matter is entirely decomposed before decomposition of a "slow" fraction begins. Modeled PAN mineralized from an amendment driven by its decomposition rate; N mineralization occurs when amendment C:N is less than 15. For our simulations, we provided Gilmour with laboratory decomposition data, amendment moisture, total C, total N, and NH_4-N analyses. For the field PAN simulations, amendment decomposition kinetics were adjusted for actual monthly temperatures for the 2002 and 2003 growing seasons, and soil moisture was assumed not to limit amendment decomposition rate. Ammonia loss was assumed to be zero in both field and laboratory experiments.

RESULTS AND DISCUSSION

Decomposition of Raw and Composted Amendments in Soil

Composting reduced cumulative decomposition (70 d in laboratory) from 62 to 29 % of applied C for dairy solids, from 66 to 9 % for rabbit manure, and from 24 to 11 % for yard trimmings (Figure 1). Dry stacking of broiler litter (sold as "compost") did not affect decomposition rate in soil, so we averaged the decomposition rate constants across all broiler litter samples (Table 1). Amendments sold as broiler litter "compost" retained most of the characteristics of raw broiler litter: rapid decomposition during first 7 d in soil, amendment C:N of 9 to 10, and NH_4-N 5 to 9 g kg^{-1} (Table 2). For other amendments (data not shown) cumulative decomposition in soil was related to whether decomposition was allowed to occur prior to application to soil. Anaerobically-digested dairy solids had decomposition (39% in 70 d) that was intermediate between raw dairy solids and composted dairy solids. Other composts included in the study averaged 17 % decomposition in 70 d. Specialty fish byproducts, canola meal, and feather meal had very high decomposition rates (average = 76% in 70 d) as expected for raw amendments with C:N ratios of 4 to 8. Decomposition observed for peppermint hay (26% in 70 d) was similar to that of composts. Although the peppermint hay piles were unmanaged, they were likely moist enough for ongoing decomposition during 9 months of outdoor storage.

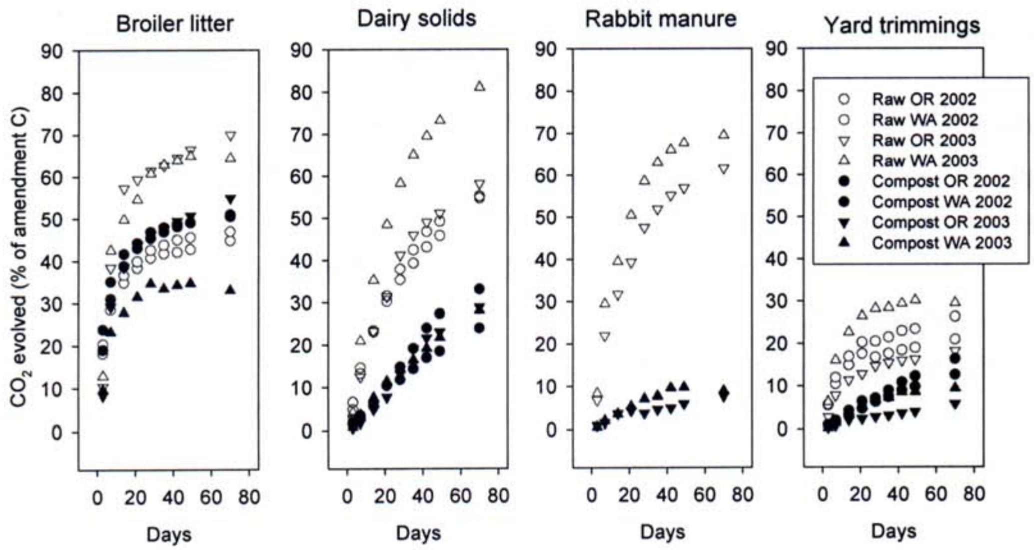

Figure 1. Cumulative decomposition from organic amendments in the laboratory at 22 °C.

Table 1. Average amendment decomposition kinetics[a] for organic amendments incubated in the laboratory at 22°C.

Material	Decomposition rate constant: Rapid	Decomposition rate constant: Slow	Rapid Fraction	Time to 25% decomposition	*n*
	d^{-1}		% of total C	d	
all broiler litter	0.043	0.003	42.6	12	13
dairy solids	0.022	0.010	44.8	14	4
composted dairy solids	0.005			65	5
yard trimmings	0.013	0.001	18.9	87	4
composted yard trimmings	0.002			206	3

[a] Two-pool first-order kinetics model. Decomposition kinetics averaged only for amendment samples with consistent number of calculated pools. Rapid fraction percentage given only for amendments with two rate constants.

Table 2. Amendment analyses and plant-available N (PAN) release in field and laboratory.[a]

Amendment	Abbreviation	C:N	NH_4-N	Field PAN	Lab PAN	n
			g kg^{-1}	(%)	(%)	
			All field and lab experiments			
dry broiler litter	BL	9	6.3	41	45	4
composted dry broiler litter	BLC	9	7.3	38	45	4
dairy solids	DS	27	1.5	9	1	4
composted dairy solids	DSC	20	0.6	5	8	4
yard-trimmings	YT	13	3.0	19	25	4
composted yard-trimmings	YTC	17	0.7	5	5	4
			Selected field and lab experiments			
anaerobically digested dairy solids	AD	20	2.4	13	14	1
BioGro pelleted fish byproduct	BG	5	1.1	77	57	2
canola meal	CAN	8	0.1	60	41	1
composted chicken litter	CCC	8	5.6	47	25	1
feather meal	FM	4	2.0	99	74	1
on-farm compost	OFC	15	0.1	6	4	2
peppermint hay	PH	10	0.4	7	3	1
rabbit manure	RM	11	7.7	27	42	2
composted rabbit manure	RMC	10	0.0	22	19	2
composted dairy solids	WC	27	0.1	-6	-7	1

[a]Plant-available N determined in the field using fertilizer N equivalency method, and in the laboratory via 70 d incubation at 22°C.

Most of the difference in cumulative decomposition between composts and raw materials occurred during the first 7 to 30 d of incubation in soil at 22°C (Table 1). Composted amendments generally had a single rate of decomposition using the rate constant fitting procedure described by Gilmour (1998). Averaged over all composts (n = 14; excluding broiler litter "compost") the average decomposition rate was 0.003 d^{-1} (0.3 % of remaining C per d). Compared to raw amendments, composts will likely be more effective in increasing soil organic matter concentrations because of their resistance to decomposition. Decomposition was rapid (> 25 % in 12 d) for broiler litter (Table 1) and for other uncomposted low C:N amendments (Biogro fish byproduct, feather meal and canola meal; decomposition data not shown).

Plant-Available Nitrogen Released from Raw and Composted Amendments in Soil

The laboratory incubation (70 d at 22°C) and the full-season PAN determination in the field (based on fertilizer N equivalency) provided similar estimates of PAN across amendments (Table 2). The linear regression equation for lab PAN vs. field PAN had a slope not different from one and a y-intercept not different than zero. Because field and laboratory estimates of PAN were similar we show only amendment C:N vs. field PAN (Figure 2). Plant-available N from amendments decreased as amendment C:N ratio increased from 4 to 15. The fitted linear regression equation for amendments with C:N < 15 (n = 25) was: PAN = 105 -7.07 x C:N ratio; r^2 = 0.71. Amendments with highest PAN had C:N ratios <10 and cumulative decomposition of > 50 % of applied C in the 70-d laboratory incubation. Amendment C:N was not linearly related to plant-available N for amendments with C:N > 15 (n = 14; r^2 = 0.02).

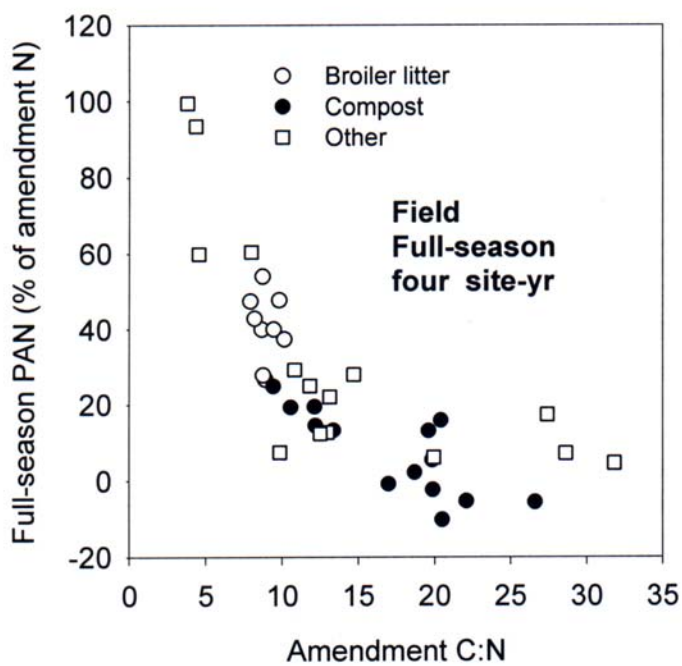

Figure 2. Amendment C:N vs. full-season PAN in the field. Field PAN was determined by fertilizer N equivalency. WA and OR field sites. 2002 and 2003.

Plant-available N was similar for all broiler litters, regardless of whether they were sold as raw or "composted" (Table 2; Figure 2). For composts (excluding broiler litter), the range of amendment CN values (12 to 22) and full-season field PAN values (-10 to 25 %) was smaller than for raw amendments (Figure 2). Rabbit manure composts and three other composts had amendment NH_4-N: NO_3-N ratios below 1 and very low decomposition rate constants in soil ($k \leq 0.003$), suggesting that these materials were very stable. Composting did not have as big an effect on the timing of PAN release and the amount of cumulative PAN (Table 1) as it did upon decomposition kinetics (Table 2). Composted yard trimmings had substantially lower PAN than raw yard trimmings, but composted dairy solids had similar PAN to raw dairy solids.

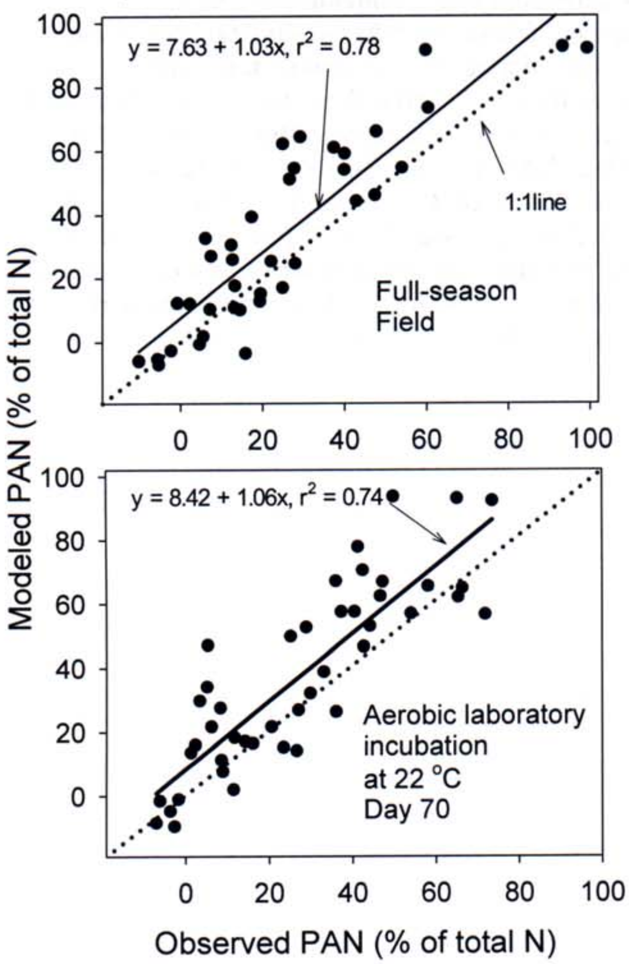

Figure 3. Observed plant-available nitrogen (PAN) from organic amendments in field and laboratory vs. DECOMPOSITION model predictions. WA and OR 2002 and 2003 data combined. Each data point represents a site-year average for an amendment. The model was run using actual site weather data.

Accuracy of DECOMPOSITION Model Simulation Predictions

Measured and modeled PAN were linearly-related in both the laboratory ($r^2 = 0.74$) and field experiment ($r^2 = 0.78$) with slopes not significantly different than unity (Figure 3). The

Modeling

Actual and modeled PAN estimates had a close linear relationship in both the lab and field studies, though the model tended to over-predict PAN, particularly for materials with high initial NH_4-N concentrations. The DECOMPOSITION model approach was most valuable for organic materials with C:N of 10 to 15. These materials had a wide range in N availability, depending upon whether the organic fraction of the amendment was readily decomposable (e.g. fresh manure) or stable (compost).

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