Scientific Papers. Series A. Agronomy, Vol. LX, 2017
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

PREDICTING PLANT-AVAILABLE NITROGEN PROVIDED BY ORGANIC FERTILIZERS AND COVER CROPS USING AN ONLINE CALCULATOR

Dan SULLIVAN, Nick ANDREWS

Oregon State University, Department Crop & Soil Science, 3017 Agriculture and Life Sciences Department, Corvallis, Oregon 97331, USA

Corresponding author email: Dan.Sullivan@oregonstate.edu

Abstract

Satisfying crop nitrogen (N) requirements efficiently in organic agriculture requires an accurate estimate of plant-available N (PAN) release from organic inputs. PAN is the sum of the mineral N present in the organic material at the time of application, plus net N mineralized (sum of NH_4-N and NO_3-N) in soil. We verified several regression equations for accuracy in predicting PAN release from organic inputs (manures, composts, and cover crop residues) for summer vegetable crop production in the Willamette Valley of Oregon, USA. An Excel spreadsheet version of the regression equations was prepared and is distributed online as the Oregon State University (OSU) Organic Fertilizer and Cover Crop Calculator.

Using the Calculator requires the user to specify the organic input application rate, its total N concentration (dry matter basis), and whether the organic input is fresh or composted. We verified the accuracy of the Calculator equations via aerobic incubation of organic inputs in moist western Oregon soils in the laboratory (sandy loam, loam, or clay loam textures; pH 5.5 to 6.5; 20 to 25°C). Fertilizer equivalency trials, where PAN from organic inputs was determined relative to PAN from mineral N fertilizers, were also used to verify Calculator predictions. Outreach publications have been developed to accompany the Calculator, in order to explain its function and to encourage farmers and farm advisors to use it.

***Key words**: nitrogen, manure, compost, cover crops.*

INTRODUCTION

Organic crop production in the USA has increased in the past decade. Farmers using organic methods in USA often have no livestock (as a source of manure), so they rely on purchased organic inputs. The *OSU Organic Fertilizer and Cover Crop Calculator* (Andrews et al., 2012) was developed to assist farmers in comparing and choosing organic inputs, based on the quantity of PAN provided.

Nutrient management guidance for fertilizer use in organic crop production is usually less precise than that provided for conventional mineral fertilizer use. Often only total nitrogen analyses for organic inputs with no estimate of PAN are provided (Kuepper, 2003), or generalized PAN predictions are provided for each category of organic material (Bary et al., 2016).

Numerous regression equations that predict PAN from total N or C:N ratio of organic materials have been reported (Vigil and Kissel, 1991; Trinsoutrot et al., 2000). This paper reports data from a number of experiments that developed or verified prediction equations for use in the OSU Calculator. We chose to base the prediction equations on the total N analyses of organic inputs, instead of C:N ratio for several reasons.

First, C analyses of most organic inputs are relatively constant, while N analyses vary widely among organic materials.

Second, organic fertilizers are marketed with guaranteed N analyses, but not C analyses.

MATERIALS AND METHODS

OSU Calculator data input requirements

The OSU Calculator requires users to specify application rate, dry matter content, and total N analysis of the organic input (organic fertilizer, compost, or above-ground cover crop biomass). The Calculator assumes that for fresh organic materials, C concentration is relatively constant (near 40%), so that total N concentration is a useful indicator of C:N ratio.

Cover crop biomass sampling is often needed to obtain an accurate estimate of cover crop biomass and its N concentration (Sullivan and Andrews, 2012).

Predicting PAN from fresh (uncomposted) organic fertilizers (e.g. manure and specialty products)

For organic fertilizers, the Calculator uses linear regression equations with two time steps (28 and 70 d; Figure 1). The time steps are equivalent to approx. 600 and 1500 degree days (0 ^{o}C base temperature) after soil incorporation: Prediction equation for PAN at 28 d after soil incorporation (Equation 1):

When fertilizer total N < 6% dry wt. basis,

% PAN = -30 + 15 (fertilizer total N%)

When fertilizer total N ≥ 6% dry wt. basis,

% PAN = 60%

Prediction equation for PAN at 70 d after soil incorporation (Equation 2):

% PAN = 28 d PAN + 15%

Prediction of PAN from Cover Crop Residues

The Calculator uses a regression equation (Vigil and Kissel, 1991) for estimating PAN after soil incorporation (Equation 3):

% PAN = -53.44 + 16.98 (cover crop %N x 10)$^{1/2}$

Prediction of PAN from compost

The Calculator does not use a regression equation to predict compost PAN (Table 1).

Table 1. Predicted PAN from compost. OSU Calculator[1]

	OSU Calculator PAN prediction	
Compost total N	28 d	70 d
% dry wt	% of total N	% of total N
Less than 1%	0	0
1-2%	0	5
2+ %	5	10

[1]PAN estimates valid only for finished composts that are biologically stable. Some organic materials marketed as "compost" do not meet this criteria (e.g. dry stacked poultry litter)

Data from field and laboratory trials did not show a strong correlation between compost total N percentage and PAN (Gale et al., 2006). We prefer to estimate first year PAN from a compost analysis that includes total C and N, and mineral N (NH_4-N and NO_3-N). Most of the first year PAN supplied by compost is present as mineral N in compost at the time of application (Gale et al., 2006). Predictions of PAN from compost are included in the OSU Calculator primarily for the purpose of demonstrating that compost is a poor choice for supplying PAN.

Determination of PAN in laboratory incubations

Laboratory incubations were used to verify the appropriateness of Calculator PAN predictions. In laboratory incubations, PAN released from the organic input was determined experimentally by difference from a soil-only control treatment:

% PAN from organic input =

(Amended - Control)/Input N x 100

where: % PAN = percentage of total input N that is recovered from soil as NO_3-N after incubation; Amended = Soil NO_3-N *with* organic input after incubation (mg/kg); Control = Soil NO_3-N *without* organic input after incubation (mg/kg); Input N = concentration of total N added to soil via organic input (organic fertilizer, compost, or cover crop; mg/kg)

Soil was analyzed for both NH_4-N and NO_3-N, but NH_4-N concentrations were always insignificant after 4 weeks of incubation. Therefore, only soil NO_3-N was used to estimate PAN for organic inputs.

RESULTS AND DISCUSSIONS

Calculator assumptions and limitations

The Calculator does not account for NH_3 that may be volatilized from organic fertilizers following field application. It also assumes that PAN is not lost via leaching or denitrification. In our field trials, PAN loss was apparently minimal, because PAN determined in lab and field were similar (Gale et al., 2006). Our field trials were conducted in summer in a Mediterranean climate under sprinkler irrigation, so leaching from the root zone was minimized. Organic fertilizers were incorporated within a few hours after application to minimize N loss via NH_3 volatilization. Our predictions are based on a soil temperature of approximately 22^{o} C. Soil temperature may not be as important in controlling the rate of N mineralization from fresh organic inputs, as it is in controlling the rate of N mineralization from soil organic matter (Hartz and Johnstone, 2006).

PAN from fresh organic materials

For fresh organic materials, we found a linear correlation between organic fertilizer total N % (dry weight basis) and PAN measured in field trials and in laboratory incubations (Figure 2;

Gale et al., 2006). We found that dry-stacked poultry litter (sold as "compost", but not actually composted) had cumulative decomposition and PAN that was similar to that of fresh organic materials (Gale et al., 2006). To evaluate PAN release from organic specialty products, we performed a 28 d laboratory incubation using fertilizers offered for sale to organic farmers in Portland, Oregon, including: seed meals, fish byproducts, and animal byproducts (Table 2). Most of the specialty products decomposed rapidly. Specialty products containing more than 6% total N released 60^{+}% PAN in 28 d. For speciality fertilizers with high N concentrations (6+% total N in DM), the amount of C lost by decomposition (% of applied C) and the amount of PAN (% of total N) was of similar magnitude.

PAN from cover crops

We verified the predictive value of the regression equation (Equation 3) published by Vigil and Kissel (1991) in cover crop incubation trials (Table 3 and Figure 3; Sullivan et al., 2011; Sullivan and Andrews, 2012) and in a field trial (Figure 4). We have the greatest amount of verification data for the Calculator prediction equation for cover crops that contain 2 to 4% N (dry weight basis).

The Calculator prediction equation for PAN worked well for single cover crop species, or for mixed cover crop species (Figure 3). The Calculator prediction equation for cover crops over-predicted PAN at 4 weeks incubation time (Table 3 and Figure 3). At 10 weeks, Calculator PAN predictions were less than or equal to the PAN measured in incubations.

Calculator PAN predictions had reasonable accuracy in a no-till field trial, where the cover crop residue decomposed on the soil surface (data not shown). PAN values for organic materials did not differ when evaluated in soils differing in texture (silt loam vs. sandy loam vs. clay loam; data not shown).

PAN from compost

Field trials and laboratory incubations showed that well-composted organic materials provided little or no PAN during the year following application (Gale et al., 2006). A few composts, derived from animal manure (no bedding) or from green, leafy crop residues, had total N percentage greater than 2%, and provided PAN. Woody composts with PAN less than 1% had negative PAN values during the first weeks after incorporation into soil. Overall, we do not recommend compost for short term supply of PAN. This recommendation is supported by other research reports (Hartz et al., 2000; Prasad, 2009). Compost should be regarded as a source of organic matter and mineral P and K for building soil reserves, not a rapidly-available N source.

Table 2. Decomposition and PAN from organic fertilizers in a 28 d aerobic incubation in Chehalis silt loam soil (fine-silty, mixed, superactive, mesic Cumulic Ultic Haploxeroll)

Fertilizer N source[1]	Fertilizer		PAN	Decomposition	
	Total N	C:N	28 d	7 d	28 d
	%		% of fertilizer N	% of fertilizer C	
seaweed extract	1	29	0	21	38
kelp meal	1	26	-6	8	14
alfalfa meal	2	17	4	32	48
ground fish bone	5	3	33	20	33
meat and bone meal	8	5	44	41	53
soybean meal	8	5	68	49	69
fish/feather/alfalfa meal	8	5	58	43	59
bone meal	9	5	58	49	59
feather meal, bone meal	9	4	63	27	54
fish meal	9	4	62	50	65
corn gluten meal	10	5	72	49	69
granulated feather meal	11	4	65	31	55
fish protein digest	12	4	64	52	61
feather meal	13	4	63	41	59
blood meal	14	4	63	39	57

[1]Organic fertilizers contained additional salts supplying other nutrients in addition to N (blended fertilizers). Fertilizers were added at rate of 300 mg total N kg^{-1} dry soil, incubated at 22° C, 250 g kg^{-1} soil moisture

Table 3. Plant-available N measured in cover crop incubations vs. PAN predicted by the OSU Calculator regression equation[1]

Cover crop N concentration	PAN measured in cover crop incubation				PAN Predicted by OSU Calculator
	2008	2009	2010	3-yr Average	
% dry wt.	.-----------------PAN (% of cover crop total N)-----------------				
		28 d at 22° C			
2.0	13	23	15	17	22
2.5	21	30	23	25	31
3.0	30	36	31	32	40
3.5	39	43	39	40	47
		70 d at 22° C			
2.0	27	37	41	35	22
2.5	33	43	48	41	31
3.0	38	49	54	47	40
3.5	44	55	61	53	47

[1]OSU Calculator regression (Equation 3). Cover crop biomass included legumes: crimson clover (*Trifolium incarnatum*), common vetch (*Vicia sativa*), and non-legumes: cereal rye (*Secale cereale*), oats *(Avena sativa*), or phacelia (*Phacelia tanacetifolia*)

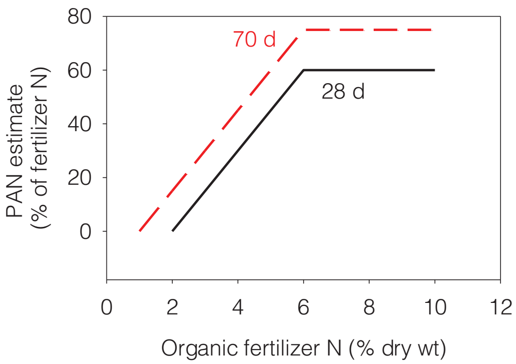

Figure 1. Regression equations implemented within the OSU Calculator for "fresh" organic materials that have not been stabilized by composting (Equations 1 and 2). The Calculator estimates PAN at approximately 28 d and 70 d following application at 22° C

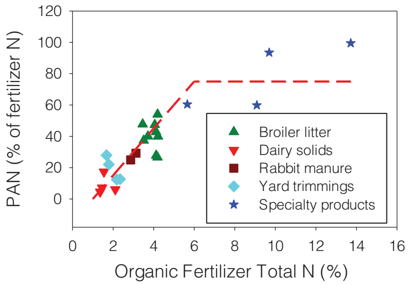

Figure 2. Plant-available N provided by fresh manures and other organic inputs in a series of four field trials. PAN determined via N fertilizer equivalency vs. urea-N (Gale et al., 2006). Dotted line is the equation chosen for implementation as 70 d predicted PAN in OSU Calculator (Equation 2)

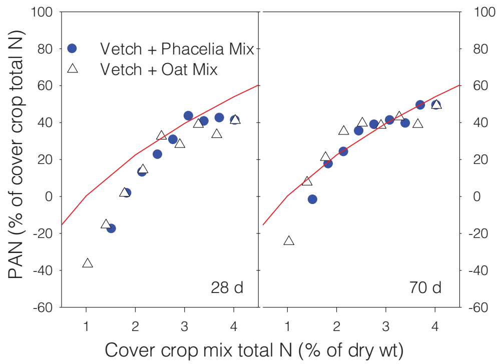

Figure 3. Plant-available N after 28 d (left) and 70 d (right) following addition of mixtures of cover crop residues to Chehalis silt loam soil (Garrett, 2009) vs. predicted PAN (solid line; Vigil and Kissel, 1991; Equation 3) in an aerobic laboratory incubation (22° C; 250 g kg^{-1} soil moisture). Cover crop total N concentrations (dry wt. basis) were 40 g kg^{-1} for vetch (*Vicia sativa*), 10 g kg^{-1} for oat (*Avena sativa*), and 15 g kg^{-1} for phacelia (*Phacelia tanacetifolia*). Cover crop mixtures were added to soil at a total dry matter rate of 5 g kg^{-1} soil, with variable proportions of vetch in the mix (0, 12, 25, 37, 50, 62, 75, 87 and 100% by weight)

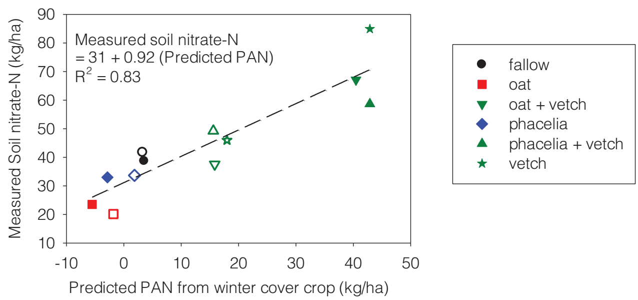

Figure 4. Predicted PAN (Vigil and Kissel, 1991; Equation 3) from cover crop residues vs. soil nitrate-N (0-30 cm depth; Garrett, 2009) measured in mid-July (approximately 65 d after cover crop incorporation). Soil samples collected between rows where crop (broccoli; *Brassica oleracea* var. *italica*) roots were absent. Filled symbols = 2007 data; open symbols = 2008 data

CONCLUSIONS

The OSU Calculator is available online for free download (Andrews et al., 2012). Calculator predictions can be verified in the field by soil sampling early in the growing season, prior to significant crop N uptake or opportunity for PAN loss. Verification studies conducted in the field require characterization of organic inputs (application rate, total N percentage and dry matter), and replicated fertilized and unfertilized treatment areas within the same field.
Verification can also be accomplished by laboratory incubation experiments as outlined in this paper. We welcome collaborations to verify the suitability of the OSU Calculator in diverse environments.

ACKNOWLEDGEMENTS

The Romanian-U.S. Fulbright Commission and Laura Paulette (USAMV Cluj-Napoca) provided support for the prinicipal investigator in 2016-17. Linda J. Brewer, OSU Dept. Horticulture, edited the manuscript.

REFERENCES

Andrews N., Sullivan D.M., Julian J., and Pool K., 2012. Oregon State University Organic Fertilizer and Cover Crop Calculator (West of the Cascades). http://smallfarms.oregonstate.edu/calculator.

Bary A.I., Cogger C.G., and Sullivan D.M., 2016. Fertilizing with manure and other organic omendments. PNW 533. Washington State University Cooperative Extension Service. Pullman, WA.

Gale E.S., Sullivan D.M., Hemphill D., Cogger C.G., Bary A.I., and Myhre E.A., 2006. Estimating plant-available nitrogen release from manures, composts, and specialty products. J. Environ. Qual. 35: p. 2321-2332.

Garrett A., 2009. Improving nitrogen management with cover crops in organic broccoli production. M.S. thesis. Oregon State University, Corvallis, OR. http://hdl.handle.net/1957/12109.

Hartz T.K., Mitchell J.P., and Giannini C., 2000. Nitrogen and carbon mineralization dynamics of manures and composts. HortScience 35: p. 209-212.

Hartz T.K. and Johnstone P.R., 2006. Nitrogen availability from high-nitrogen-containing organic fertilizers. HortTechnology 16: p. 39-42.

Kuepper G., 2003. Manures for organic crop production. Appropriate Technology Transfer for Rural Areas (ATTRA). Fayetteville, AR. http://attra.ncat.org/attra-pub/PDF/manures.pdf.

Prasad M., 2009. A literature review on the availability of nitrogen from compost in relation to the nitrate regulations SI-378 of 2006. Environmental Protection Agency, Wexford, Ireland. http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=146.

Sullivan D.M. and Andrews N.D., 2012. Estimating plant-available nitrogen release from cover crops. Pacific Northwest Extension Publication 636. Oregon State University Extension Service. Corvallis, OR. https://catalog.extension.oregonstate.edu/pnw636.

Sullivan D.M., Datta R., Andrews N., and Pool K.E., 2011. Predicting plant-available nitrogen release from cover crop residues. p. 55-60. In: Proc. Western Nutrient Management Conference, 3-4 March 2011. http://smallfarms.oregonstate.edu/sites/default/files/WNMC11_Sullivan_p55.pdf.

Trinsoutrot I., Recous R., Bentz B., Lineres M., Cheneby D. and Nicolardot B., 2000. Biochemical quality of crop residues and carbon and nitrogen mineralization kinetics under nonlimiting nitrogen conditions. Soil Sci. Soc. Am. J. 64: p. 918-926.

Vigil M.F. and Kissel D.E., 1991. Equations for estimating the amount of nitrogen mineralized from crop residues. Soil Sci. Soc. Am. J. 55: p. 757-761.

CROP SCIENCES