Optimizing Poultry Litter Application Rate to Balance Corn Grain Yield, Soil Phosphorus and Nitrous Oxide Emissions

Lucélia C.R. de Brito[1], Michel A. Cavigelli[2], Kathryn E. White[2], Nhi Tran[2], Harry H. Schomberg[2], Alondra Thompson[2], Henrique de Souza[1]
[1] Universidade Federal do Piaui, Teresina, Piaui, Brazil; [2] Sustainable Agricultural Systems Lab, USDA-ARS, Beltsville, MD, USA

Introduction

Determining optimal poultry litter (PL) application rates for long-term use is challenging due to the poorly characterized effect of antecedent applications on soil fertility, especially in organic grain systems where livestock manures—which provide multiple nutrients in ratios different than crop needs—are often a dominant nutrient input.

Evidence from the long-term Farming Systems Project (FSP) in Beltsville, Maryland, USA (established 1996) suggests that repeated applications of PL at University recommended rates—especially in shorter rotations—are greater than optimal to meet agronomic and environmental goals of sustainability (Table 1).

Table 1. Impacts of long-term organic management on soil fertility and environmental parameters at FSP. Means across two conventional systems (No-Till and Chisel Till) included for comparison.

System	Crop Rotation [a]	Frequency of PL application	PMN (kg ha^{-1}) [b]	Corn Grain Yield (Mg ha^{-1}) [b]	N_2O Emissions (kg N_2O-N kg^{-1} yr^{-1}) [c]	Mehlich-3 P (mg kg^{-1}) [d]	MD FIV [d]
Conv.	C-*r*-S-W/S	NA	235 b	6.87 b	0.86 b	44 b	93 b
Org2	C-*r*-S-*v*+*r*	3 of 6 years [e]	297 a	9.23 a	1.60 a	58 a	118 a
Org3	C-*r*-S-W/*v*+*r*	4 of 6 years	323 a	10.2 a	1.59 a	56 a	116 a
Org6	C-*r*-S-W/A-A-A	2 of 6 years	325 a	9.41 a	0.78 b	47 b	99 b

[a] C=corn, S=soybean, W=winter wheat, A=alfalfa, *r*=rye cover crop, *v*=vetch cover crop
[b] Potentially mineralizable N (PMN) and corn grain yields measured in microplots to which no N sources were added in 2009; results reflect long-term residual effects of cropping systems management, which, in organic systems, largely reflect PL inputs (Spargo et al. 2011).
[c] N_2O emissions across full rotations, 2008, 2010, 2011
[d] Mean, 2003-2014 (White et al. submitted); MD FIV=Maryland Fertility Index Value; Optimum=50-100; Excessive > 100.
[e] PL was applied in organic systems for corn to supplement N provided by preceding legumes and for wheat to meet N needs.

Long-term organic management with PL applications at agronomically appropriate rates resulted in:

- Soil PMN levels that provided sufficient N for corn grain yields of 9.6 Mg ha^{-1} (153 bu a^{-1}) in Org2, Org3, and Org6
- Excessive soil test P in Org2 and Org3
- High soil N_2O emissions in Org2 and Org3

→ Question: By how much should PL application rates be reduced?

Materials + Methods

To determine optimum PL rates, we established PL reduction (PLR) microplots in the corn phase of FSP organic systems.

PLR microplots
- Established in 2017, 2018, 2019, and 2020 in each of four FSP replicate plots during corn phase
- Dimensions: 4.6 m x 9.1 m (15' x 30')
- PL rates: 1x, 0.67x, 0.33x, and 0x
- 1x = University of Maryland NuMan program recommended rate, accounting for previous legume inputs

Table 2. 1x PL application rates (Mg ha^{-1}, dry weight basis) by year

System	2017	2018	2019	Mean
Org2	6.1	5.2	4.3	5.2
Org3	3.4	5.2	5.4	4.7
Org6	3.4	5.2	5.6	4.7

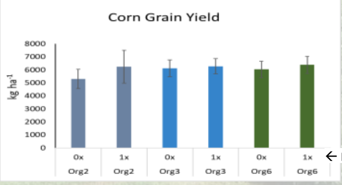
- Data reported here are from microplots hand weeded to eliminate confounding effects of weed competition (see White et al. oral presentation for impacts of weeds on corn grain yield and soil NO_3-N).

Materials + Methods (cont'd)

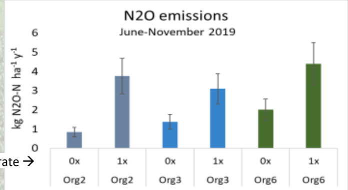
Table 3. Response variables measured.

Variable	Method	PLR microplots sampled	Years measured
Corn grain yield	Almaco small plot combine	0x, 0.33x, 0.67x, 1x	2017-2019
Soil N_2O emissions	Closed chamber method, 28 sample dates after PL application, 3 replicates, exponential decay interpolation	0x, 1x	2019
Soil NO_3-N	KCl extraction, 0-30 cm depth, periodically after PL application	0x, 0.33x, 0.67x, 1x	2017-2019
Soil moisture	Volumetric water content, TDR (CS655), 0-12 cm depth	0x, 1x	2017-2019
Soil test P	Mehlich-3 P, 0-20 cm depth	0x, 0.33x, 0.67x, 1x	2017-2019

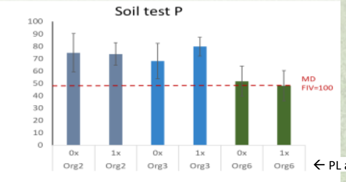
Results and Discussion: 2019



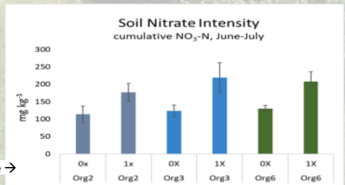
- Corn grain yields were similar in 0x and 1x PLR microplots in all systems in 2019.



- Soil N_2O emissions substantially lower in 0x than 1x PLR microplots
  - Org2: 88% decrease
  - Org3 and Org6: 54-55% decrease



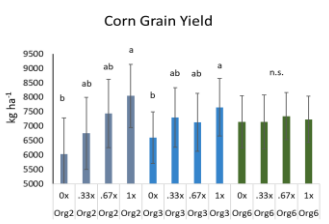
- Omitting PL for one growing season did not impact soil test P in any system (2017 results shown; 2018 similar; 2019 pending)
- MD FIV > 100 is excessive
- Soil test P lowest in Org6 due to less frequent PL application and greater crop P uptake



- Soil nitrate intensity, which has been correlated with N_2O emissions (e.g. Zebarth et al. 2008), shows same pattern as N_2O emissions.

- 2019 results suggest that eliminating PL application reduces N_2O emissions substantially without limiting corn grain yield, and without altering soil test P
- Additional years of collecting N_2O data are warranted because:
  - Mean corn grain yields, 2017-2019, differed from those in 2019 alone (see next panel)
  - N_2O emissions often show high interannual variability in response to weather patterns

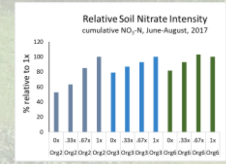
Results and Discussion: 2017-2019 (see also White et al. oral presentation)

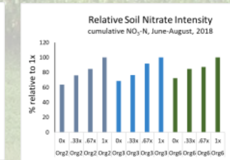


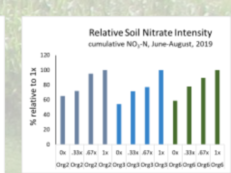
- Unlike in 2019 alone yields averaged across three years decreased with decreasing PL application rates in Org2 and Org3.
  - Org2*: 25% yield decrease between 1x and 0x PL
  - Org3: 13% yield decrease between 1x and 0x PL
  - Org6: no PLR impact

(*Results illustrate impacts of the first round of PLR in the three systems, so data for Org2 are for 2017 and 2018 only)

- Results support need for additional years of N_2O emissions measurements, including in 0.33x and 0.67x in Org2 and Org3 systems, to find optimal PL application rate that maintains crop yields and soil test P while reducing N_2O emissions
- Soil nitrate intensity data for Org2 and Org3 in 2017, 2018, and 2019 suggest that N_2O emissions will be reduced at intermediate PLR rates







Conclusions

Reducing PL application rates on soils with a long history of PL application shows promise to reduce soil N_2O emissions in organic grain cropping systems without impacting agronomic performance.

- Org2 and Org3:
  - N_2O emissions reduced by 88% and 55%, respectively, at 0x PL application rate in 2019
  - Corn grain yield reduced at the 0x rate (means, 2017-2019) but not intermediate rates
  - Further investigation of N_2O emissions at intermediate PL rates (0.33x, 0.67x) are needed to determine optimum PL rate to minimize N_2O emissions without impacting corn yield and soil test P
- Org6:
  - N_2O emissions reduced by 54% in 2019
  - No impact on corn grain yields at 0x PL application rate (means, 2017-2019 and 2019 alone)
- All systems
  - Longer term trends in soil test P and yield of other crops in rotations are being evaluated

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USDA NIFA United States Department of Agriculture National Institute of Food and Agriculture

GRACEnet USDA - ARS Greenhouse Gas Reduction through Agricultural Carbon Enhancement

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