California Department of Food and Agriculture
Fertilizer Research and Education Program
Final Report

A. Project Information:

Report type: Final

FREP grant number: 16-0670

Time covered by the grant period: 03/2017 – 12/2021

Project title: Evaluation of certified organic fertilizers for long-term nutrient planning

Project leaders:

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B. Abstract:

The use of organic amendments and fertilizers has the potential to improve agricultural sustainability widely, yet the nutrient availability profiles of these materials must be better understood. With strong growth in the sale of organically certified agricultural products, this understanding is also critical to farm-level profitability. Due to the complicated nature of nitrogen cycling, much the nitrogen is unavailable to crops initially, with the release rate being dependent on soil temperature and moisture regimes, and soil edaphic conditions. For this reason, laboratory incubations in combination with field trials and modeling were used to investigate this question. Results from the literature meta-modeling exercise showed that the commonly used single pool model may not be the most appropriate model for all organic amendments (mean sigma = 17.4). Notably, the model parameters representing turnover rates (k) did not differ by carbon to nitrogen ratio, unlike potential mineralizable nitrogen. After 60-days of aerobic incubation, only amendment type was significantly different in total net mineralized nitrogen (p= 5.54e-15). A field trial was conducted during the first year of the project that included both compost and pelletized chicken manure applied at a rate of 140 kg N/ha. Results showed higher pepper (*C. annuum*) yield under the compost amendment treatment (4087 kg/acre) when compared to the other treatments. Both compost and chicken pellets also increased fertilizer use efficiency (FUE) (p=0.002) when measured with ^{15}N labeled urea. Chicken manure pellets had the highest FUE (42% of applied N) which was an unexpected result. Results reinforce that the nitrogen availability of organic amendments is predominately controlled by carbon to nitrogen ratios. Data will now be compiled and used to constrain the DayCent model output and compare results with COMET-Farm tool reports.

C. Introduction:

Understanding the release of plant available nitrogen (N) from organic fertilizers is critically important to achieving high N use efficiency (NUE) and minimizing N loss to the environment, including from organically managed agroecosystems. With this information, growers will be empowered to manage nutrients more precisely according to seasonal and site-specific conditions. The challenge of understanding net N mineralization from organic fertilizers is directly related to complex interactions affecting the process directly such as weather, soil biology and physical properties and directly from the organic input quality and chemistry and intensive management practices (Cabrera et al., 2005; Schomberg et al., 2009). Although, in general, inorganic N can be released quickly from high-N containing chemical fertilizers (Joseph et al., 2017), there is limited information on the degree to which biotic and abiotic factors influence characteristics of nutrient release, for example the release rate, total plant availability or the significance of short-term verses long-term immobilization processes from organic nitrogen sources. In the laboratory, the nitrogen mineralization potential, i.e. the availability of plant-available nitrogen over a given time, is often assessed with laboratory incubations of soil and or mixtures of soil and amendments (Stanford and Smith, 1972). The method is accurate in predicting the nitrogen mineralization potential of different amendments and soil nitrogen. Yet, the lack of information on the nitrogen mineralization kinetics of organic fertilizers within different soil types and/or temperatures under field conditions has limited the ability to make clear application recommendations. The inclusion of mineralized nitrogen from organic sources of nitrogen into fertilizer recommendations is essential to improving NUE and optimizing agronomic planning. Underestimation of the contribution of organic soil amendments and fertilizers to plant-available nitrogen can result in excess reactive nitrogen being released into the environment. Over fertilization has been shown to result in increased nitrous oxide emissions (Stehfest and Bouwman, 2006) and the pollution of groundwater with nitrate (Harter and Lund, 2012). To avoid such serious consequences of over-fertilization, it is necessary to accurately predict nitrogen release from organic sources and sync nitrogen supply with crop nitrogen demand.

D. Objectives:

1. Conduct an extensive literature review on soil N mineralization and crop N availability as affected by organic based N fertilizers.

2. Determine seasonal N mineralization and N mineralization potential in soils repeatedly amended with organic fertilizer in CA.

3. Conduct field trials to assess and confirm lab and DayCent model results and to inform the COMET–Farm.

4. Conduct extensive engagement and outreach to inform on the value and to reassess organic fertilizer amendment rates to avoid N loss and promote healthy soils.

E. Methods:

Objective 1:
A review of relevant literature was conducted using keyword searches such as organic amendments, soil amendments, organic fertilizers, compost, waste-derived amendments, nitrogen mineralization using google scholar, Web of Science, and Scopus. Literature deemed relevant has been complied and sorted based on research questions, fertilizer or amendment type, methodology (field v. laboratory) and results. Criteria for extraction of data from individual studies will include only incubations conducted under aerobic conditions without the presence of plants, with each reporting measurements of mineral N (NH_4^+ and NO_3^-, or combined), include organic fertilizers or amendments that are under C/N ratio 30 (to avoid severe immobilization), and total organic N of the amendments. Single pool nonlinear exponential regression models will be fit to all amendment type categories. The single compartment model represents one pool of potentially mineralizable N (as % of added organic N), fit to measured cumulative mineralized N from the amendment (Nmin) over time period t, released at rate k (week 1).

Objective 2:
A randomized, full factorial designed aerobic incubation experiment was carried out during the 2019 project period 2 consisting of two soil types (clay and sandy soils) and eight organic fertilizers (seabird guano, hydrolyzed fish protein, pelletized feather meal, and powdered blood meal, soybean meal, alfalfa meal, chicken manure pellets and bone meal), each treatment was replicated three times. Organic amendments were selected based on the following criteria: used commonly in organic agriculture, available readily to the market and low C/N ratio (<10). Organic amendments were added at a rate of 250 mg N kg^{-1} soil. This rate represents a common high N application rate used in organic agriculture systems. Two soils were used in this study, Newpark silty clay loam (fine-silty, mixed, superactive, thermic Calcic Pachic Haploxerolls), referred to hereafter as clay soil, and Arnold loamy sand (mixed, thermic Typic Xeropsamments) referred to hereafter as sandy soil. Samples were incubated for a length corresponding to the day sampled, with a final sample being taken after 60 days. The incubation was carried out at two temperatures 10°C and 20°C in temperature-controlled rooms. At each sampling day, one of the five falcon tubes in a Mason jar was harvested and 8.0 grams of soil was sampled and extracted with 0.5 M K_2SO_4 and shaken for 1 hour. The supernatant was subsequently filtered through Whatman Q6 glass filters and analyzed for nitrate (NO_3^--N) and ammonium (NH_4^+-N) concentrations using the colorimetric method (Verdouw et al., 1978; Doane and Horwáth, 2003).

Objective 3:
DayCent is an ecosystem scale biogeochemical process model designed to simulate nutrient cycling of C and N through the atmosphere, soil and plant systems (Del Grosso et al., 2001). Model iterations are carried out on a daily time step, giving a high-resolution picture of changes in nutrient pools. Input data required to run the model and simulate processes of interest include daily meteorology, soil properties, plant biomass and crop C accumulation, agricultural management practices and site-specific information such as geographic location. Model validation and calibration will be carried out according to Del Grosso et al. (2011), using crop growth, soil inorganic N, trace gas emissions, and soil C data. Initially, modeled crop biomass C data will be compared to experimental observations to confirm the simulation is reasonable. Further comparisons will be made of observed data to model soil C, inorganic

N and gas emissions. Calibration will be performed on soil water, carbon, and nitrogen parameters. Evaluation of model performance will be quantified using various statistical measures including root mean square error (RMSE) and coefficient of determination (r2). Once complete, calibrated model simulations will be carried out to show long-term outcomes associated with long-term organic amendment applications. A field trial was conducted in Aromas, CA during the 2017 Summer growing season in sandy loam soil to validate the model. The crop variety of this trial was Chile Pepper (*Capsicum Annuum*), with each treatment containing ~60 plants. The experimental design consisted of a randomized complete block design with two organic amendments (compost and chicken manure pellets), one inorganic fertilizer (urea) and a control. The middle row of each treatment block was labelled with $(^{15}NH_4)_2SO_4$ to measure plant nitrogen uptake and immobilization/mineralization. The organic amendments were applied at the rates equivalent to 125 lb N/acre. The inorganic treatment was applied at the rate of 250 lbs N/acre. At harvest, total crop biomass and fruit yield was recorded for each treatment.

Objective 4:
Outreach was conducted with the aim of engaging targeted clientele such as organic growers, Certified Crop Advisors (CCAs), Pest Control Advisors (PCAs), agricultural non-profits, researchers, and other technical assistance providers. The approach taken by the project team was to host and/or attend a variety of educational events. These included grower meetings, scientific and popular conferences. When the opportunity was available, attendees were surveyed concerning management practices and intention to implement strategies discussed during presentations. All attendance data and survey responses were tracked.

F. Data/Results:

Objective 1:

Data from 37 studies that reported amendment C/N ratio (see Figure 1), with a total of 861 observations were used. The dataset was divided using C/N ratio as a grouping factor and fit to the single pool exponential kinetic model (Stanford and Smith, 1972) using Bayesian non-linear regression. Identification of unknown parameters, both representing the total percent of nitrogen be mineralized (N_0) or the turnover rate characteristic of the mineralization process (k), were carried out. After the fitting procedure, a resampling technique using Markov Chain Monte Carlo sampling, which samples over 2000 iterations of the algorithm, was implemented. The Gelman-Rubin statistic, R-hat, of approximately 1 was used to determine model convergence. Results show that materials with low C/N ratio 0-5 have a mean percent nitrogen of 38.36 (CI: 23.25-51.72), next C/N ratio 5-10 have a mean value of 9.82 (CI: 7.51-12.27), middle range C/N ratio 10-15 have the value of 8.07 (CI: 6.27-9.90) and high C/N ratio 15-30 have the value of 1.12 (CI: 0.23-2.04). The model fits for the single pool were generally poor and need further refinements as seen by high sigma values (mean sigma = 17.4). Composts and organic fertilizers differed significantly in potentially available N ($p<0.05$). Turnover rates did not significantly differ, but organic fertilizers were slightly higher than others in reported in this review ($p=0.12$)

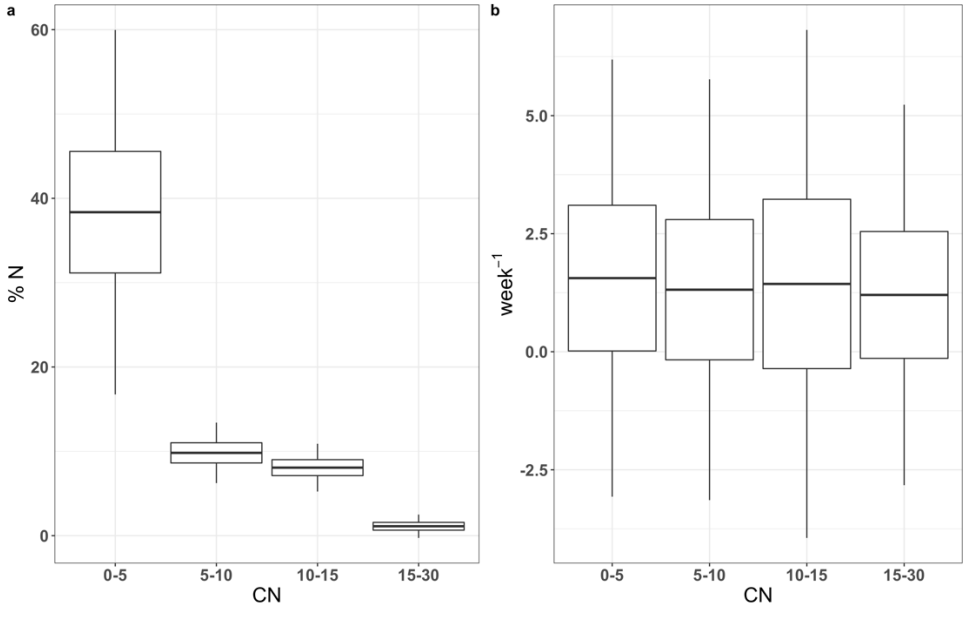

Figure 1: Model parameter boxplots, grouped by C/N ratio, fit using a single pool non-linear regression model. Mean values and confidence regions are determined using MCMC sampling of the posterior density function each unknown model parameter (N_0 and k). Figure 1a shows values for parameter representing %N and Figure 1b showing values for rate constant in weeks.

Objective 2:

Two 60-day aerobic laboratory incubations were carried in two soils with eight certified organic fertilizers. The application rates of the fertilizers were set at 250 mg N kg^{-1} soil. Incubations took place at two temperatures 10°C and 20°C. Results showed that early in the release of N from the materials, both temperature and soil type were significant influences of net N mineralized (p= 0.028 and p= 0.029, respectively). Yet, over the entire 60-day incubation period these factors appear to become less relevant. With the amendment type being the only significantly different factor (p= 5.54e-15) by the end.

Figure 2: The summation of two separate 60-day aerobic laboratory incubations measuring net N release as net mineralized N (mg/kg d.w) which occurred during project year 2018-2019 with 3 replicates of each organic amendment, in two soil textural types at 10°C and 20°C. Vertical bars depict standard error (n=3).

Objective 3:

Both organic amendments, compost and chicken pellets, showed increases in fertilizer use efficiencies and well as different N availabilities for the organic amendments. The

assessment of N availability from the different N pools available to the crop was determined using two methods. The first is an indirect method using the ratio of total N uptake to apply N fertilizer, the other a direct measure of labelled ^{15}N-urea uptake. When calculated indirectly, as a difference between applied and taken up, fertilizer N utilization was significantly higher ($p=0.002$) but when calculated directly as the difference in ^{15}N enrichment, no significant difference was detected. This difference can be attributed to the soil N cycle being augmented by the addition of N fertilizer, potentially making more N available from the soil N pool that is not accounted for in the calculation (Yan et al., 2020). Additionally, to determine the N availability from organic fertilizers, in terms of fertilizer equivalence, the A-Value approach was used. This yield independent value represents the plant available N from the pool of interest, which is the soil/organic amendment pool combined. Using this calculation, the A-Value or fertilizer equivalents was determined to be significantly different than the inorganic N treatment ($p=0.0012$). Comparing the two organic amendments, the chicken manure provided more N, shown as a lower A value. When the crop N distribution was evaluated. Total -^{15}N also showed to be evenly distributed between crop components with a max ^{15}N enrichment of 0.85 % excess. Results indicate that the high C:N ratio amendment, compost increased total pepper yield overall (mean = 32.6 kg and sd = 10.7). Initial results from running the DayCent model are presented in Figure 4. Aligning crop biomass and fruit carbon is the initial stage of model calibration. Results show that biomass C matched model outputs better (RMSE=35.96) than crop fruit did (RMSE=95.06). This is likely due to the model parameter representing harvest index and requires further attention.

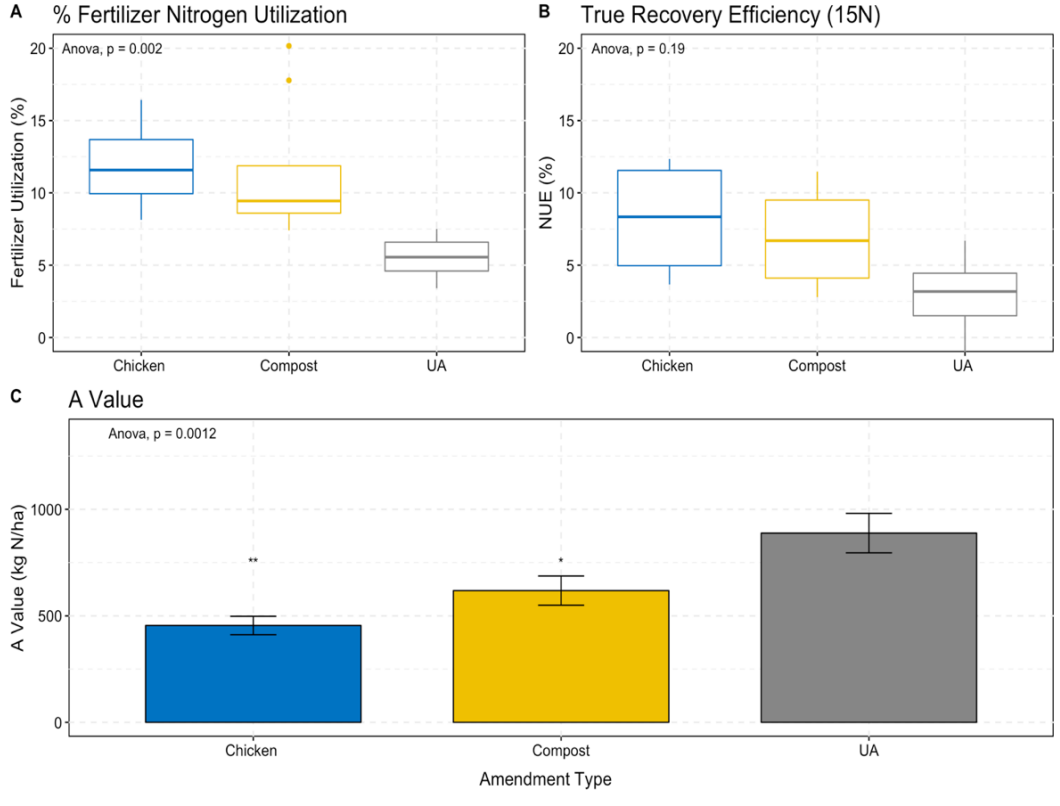

Figure 3: Nitrogen use efficiency as shown by % fertilizer nitrogen utilization by ^{15}N tracer method (A), true nitrogen recovery as % of total applied nitrogen (B) and the nitrogen supply capacities of soil under each treatment as calculated in kg/ha (C). 4 replications of each treatment.

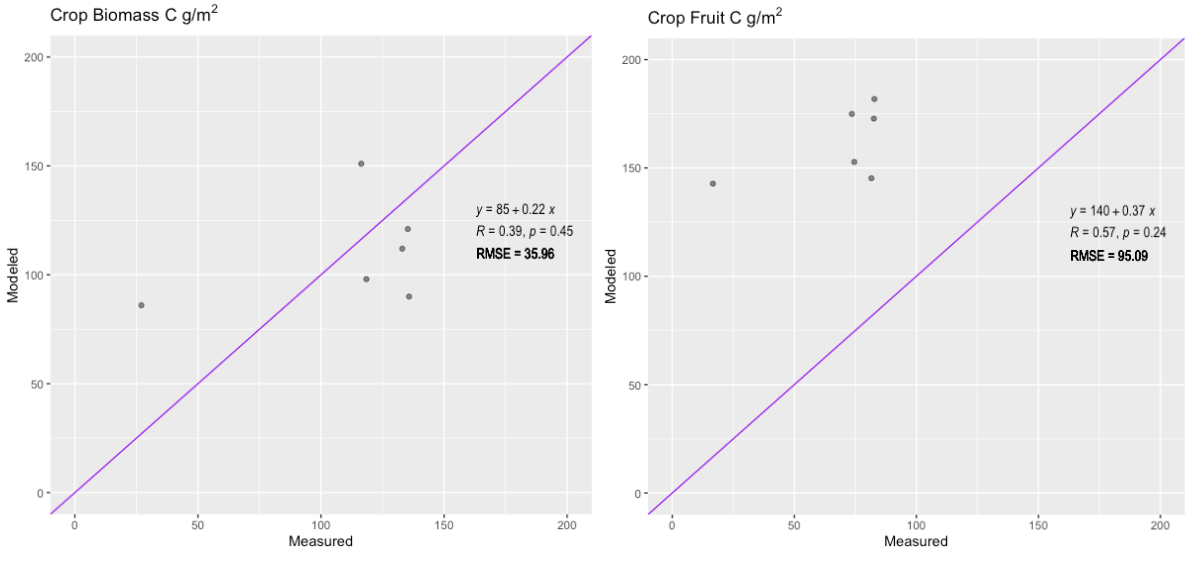

Figure 4: DayCent model results showing both crop biomass and fruit from measured field observations and model outputs. Within figure display of linear equation, R-value, p-value and root mean squared error. 1:1 line is shown in purple.

Objective 4:

Multiple outreach events were carried out over the course of the project period, each aimed at reaching different audiences. Project results were shared at each of these events listed below.

Outreach Event 1:

- Event title: 2018 Central Coast Pepper Production Workshop
- Date: March 22, 2018
- Location: Old City Hall, Gilroy, CA
- Presentation title: Soil Amendments of Biological Origin
- Number of Participants: 50
- Audience: Conventional and Organic Pepper Producers of the Central Coast.
- Evaluation: The audience responded well with ~30% of attendees raising their hands when asked if they are using organic amendments and ~15% raising their hands when asked if they are currently not using organic amendments would they consider using them in the future. Generally, most growers generated questions concerned food safety issues.

Outreach Event 2:

- Event title: 2018 Central Coast Organic Amendments Workshop
- Date: November 17th, 2018
- Location: Agriculture and Land Based Training Association, Salinas, CA
- Presentation title: The Use of Organic Soil Amendments
- Number of Participants: 50
- Audience: Organic Vegetable Producers of the Central Coast.
- Evaluation: Our project team coordinated a field day style workshop for growers within the Central Coast in collaboration with the Agriculture and Land-based Training Organization (ALBA). This day-long workshop was a combination of informational presentations and hands-on demonstration. Post workshop evaluations are attached to this report.

Outreach Event 3:
- Event title: 2019 SSSA International Soils Meeting
- Date: January 7th, 2019
- Location: San Diego, CA
- Presentation title: Exploring Nitrogen Fertilizer Transformations
- Number of Participants: 12 discussions with attendees
- Audience: CCAs, PCAs, researchers, other technical assistance providers

Outreach Event 4:
- Event title: 2019 Central Coast Organic Amendments Workshop
- Date: November 9th, 2019
- Location: Agriculture and Land Based Training Association, Salinas, CA
- Presentation title: Long-term Nutrient Management with Organic Amendments
- Number of Participants: 46
- Audience: Organic Vegetable Producers of the central coast.
- Evaluation: Our project team coordinated a field day style workshop for growers within the Central Coast in collaboration with the Agriculture and Land-based Training Organization (ALBA). This day-long workshop was a combination of informational presentations and hands-on demonstration.

Outreach Event 5:
- Event title: Science of Healthy Soils
- Date: January 28th, 2020
- Location: Moss Landing Marine Lab, Moss Landing, CA
- Presentation title: Understanding Soil Health: Managing Expectations, Experiencing Results
- Number of Participants: 56
- Audience: 50% of attendees self-identified as growers

Outreach Event 6:
- Event title: 2020 FREP/WHPA Annual Conference
- Date: January 28th, 2020
- Location: Moss Landing Marine Lab, Moss Landing, CA

- Presentation title: Evaluation of Certified Organic Fertilizers for Long-term Nutrient Planning
- Number of Participants: 142
- Audience: Growers, technical assistance providers, CCAs, researchers
- Evaluation: At the FREP/WHPA conference attendees were surveyed during presentation breaks. Survey results are presented below in the Outreach Summary section.

Outreach Event 7:

- Event title: The EcoFarm Conference: Reimagining Our Future
- Date: January 21st, 2021
- Location: Virtual
- Presentation title: Selecting Compost for Use in Agricultural Production
- Number of Participants: 42
- Audience: This event was a mix of small growers, technical assistance providers and sustainable agriculture enthusiast.

Outreach Event 8:

- Event title: Dirt First Conversation Series: The Compost Conundrum
- Date: May 4th, 2021
- Location: Virtual
- Presentation title: Selecting Compost for Use in Agricultural Production
- Number of Participants: 129
- Audience: Growers, ranchers, technical assistance providers

Outreach Event 9:

- Event title: ASA, CSSA, SSSA 2020 Virtual Annual Meeting
- Date: November 11th, 2021
- Location: Virtual
- Presentation title: Kinetic Modelling of Nitrogen Mineralization from Organic Fertilizers
- Number of Participants: 24
- Audience: CCAs, PCAs, researchers, other technical assistance providers

G. Discussion and Conclusions:

Organic fertilizers have diverse mineralization responses across different temperatures and soil textures, although our results showed that this effect is limited over the long-term. Further, the magnitude of these impacts appears to be variable depending on specific conditions. As our incubations have shown, early in the N release from these amendments, environmental conditions can impact the dynamics but over time this impact may be less important as amendment type become the comminating control over total N release. This finding has significant implications for long-term agronomic nutrient planning, potentially allowing growers to reduce applications within certain soil types as well as adjust for seasonal temperature fluctuations. For example, if applications of organic fertilizers are applied early in the season, in a sandy soil, the release rate will be faster than if applied in a clay soil at the same point in the season. This could lead to over application of fertilizers. Additionally, if growers are attempting to time crop N uptake with N release it will be challenging to predict this release. Based on our literature data collection and model fitting

exercise, C/N ratio may be an appropriate single predictor for homogenous, high-N containing fertilizers, but additional factors are necessary to understand nutrient release for more complex carbon amendments such as composts. According to our results we would caution against using compost as a sole N source for crops as well as making grower recommendations based on kinetic model fitting alone. Additional research is required to determine specifically why amendments that may have similar general characteristics turnover mineral N differently. Research related to this project will continue, including exploring additional factors within the literature derived dataset, aerobic incubations of more amendments at different temperature ranges, additional field experiments, kinetic model fitting and DayCent model validation. Information generated by this project aims to increase grower' confidence in using organic fertilizers and amendments.

H. Challenges:

Several notable challenges occurred during the project period. These include issues with grower communications and field trial coordination. Due to misunderstandings concerning the need for continued data collection, the project field trail layout was adjusted during the second year by the grower without consultation with project leadership. Solutions such as sharded digital notepads were proposed. Complications with laboratory experiments also happened. These included high variability in the data resulting from low application rates of fertilizers. Corrective action will be taken in future incubations. A significantly burdensome challenge that continues is those related to the COVID-19 pandemic. The associated restrictions continue to impact our projects at multiple levels, including personnel, supplies and facility access. University initiated regulations restricted access to laboratory facilities, temporary paid labor, and student interns. Additionally, laboratory supplies continue to be backordered. For example, pipet tips are not expected to arrive until Fall 2022. Our project team became fully operational in May 2021 and has been catching up on backlogged tasks associated with this and other projects since. We have adjusted work plans and personnel to accommodate this on-going disruption.

I. Project Impacts:

- The project generated a large dataset, combining literature laboratory and field observations related to the mineral N release characteristics of several organic fertilizers and amendments. This includes information on responses under different environmental conditions within California soils.

- Results from this project will improve future research related to modeling N mineralization in arable systems. This includes providing data for future calibration of agroecosystem biogeochemical models such as DayCent.

- Information generated by this project will serve to guide growers in making long term nutrient planning decisions, ideally improving crop N uptake efficiency, and reducing losses to the environment.

- Research-based information on best management practices when using organic fertilizers and amendments was provided to many growers and other agricultural stakeholders through direct engagement and targeted communication.

J. Outreach Activities Summary:

Extensive outreach was conducted throughout the duration of this project with a total of 9 events reaching 551 members of the agricultural community. Project staff participated in different types of events including grower meetings, field days, scientific conferences, and virtual trainings. When appropriate, outreach participants were surveyed to measure impact. Example results show that 21% of respondents (n=55) reported that they are only using only manure or liquid fertilizer products, only 3% reporting using a combination of animal byproducts, plant products and liquid products only 4 % reported using only plant products. When asked to rank decision-making priorities concerning the use of organic amendments, a majority (22%) of respondents (n=63) reported costs of amendments as the most important factor, 19% reported soil health as their primary motivation, with nutrient availability listed next (15%). When asked which factor influenced N mineralization most, in their option, respondents (n=54) stated that moisture and irrigation (30%) was the most dominant environmental control follow by soil type (24%) and fertilizer type (22%). Further, when questioned about the time scale that growers are using when deciding to use organic amendments, over 30% of respondents (n=66) reported that they are applying using an annual timeframe followed by 16% reporting per crop time scale. Notably, only 1.5 % of participants reported factoring their applications into 5+ year time frames. These results will serve to aid FREP in determining future funding goals, which could potentially include looking at long-term cost benefits of organic fertilizer use as well N outcomes from integrating organic fertilizers into other organic N management strategies such as cover cropping. Select outreach materials are attached at the end of this report.

K. References: List literature and references cited in the report. Any referencing style can be used as long as it is consistent throughout the report.

L. Appendix:


2018 Central Coast Organic Amendments Workshop
Saturday, November 17th 2018
Time: 8:30 - 3:30 pm
Where: ALBA, 1700 Old Stage Road, Salinas CA
Sign Up Here
http://ucanr.edu/omas2018
RCD MC
FREP
UC CE
ALBA

2019 Central Coast Organic Amendments Workshop

Lunch Provided

Date: Saturday, November 9th 2019
Time: 8:30 am to 3:30 pm
Location: ALBA, 1700 Old Stage Road, Salinas, CA

This training is supported by the 'California Climate Investments' and the CDFA Fertilizer Research and Education Program

M. Factsheet/Database Template

Project Title: Evaluation of certified organic fertilizers for long-term nutrient planning

Grant Agreement Number: 16-0670

Project Leaders:

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Start Year/End Year: 2016/2021

Location: Northern, California

County: Yolo, Monterey

Highlights:

- Nitrogen mineralization characteristics of many organic fertilizers and amendments were described, including under California conditions.
- Potentially available N and turnover rates were determined using commonly applied regression models and evaluated.

- Dataset was generated to be used for future research on long-term nutrient management prediction using agricultural biogeochemical models.

- Broad research-based extension to growers and agricultural stakeholders aimed at improving the use of organic fertilizers and amendments.

Introduction

To increase the use of organic amendments to improve agricultural sustainability, the nutrient release dynamics of these materials must be better understood. Due to the complicated nature of nitrogen cycling, much the nitrogen is unavailable to crops initially as well as being dependent on soil temperature and moisture regimes. This project includes a literature review and meta-modeling exercise, field trials, aerobic laboratory incubations and extensive outreach. A field trial was conducted during the first year of the project resulting in a higher crop yield under the compost amendment treatment when compared to the pelletized chicken manure and inorganic fertilizer treatments. Laboratory incubations showed that nitrogen availability from organic amendments is directly related to material carbon to nitrogen ratios with a limited influence of soil texture. Data must now be compiled and used to constrain the DayCent model output and compare results with COMET-Farm tool reports.

Methods/Management:

This project combines data gathered from the literature, aerobic lab incubations and field trials to better understand plant available nitrogen release dynamics from organic nutrient sources added to the soil. Using this empirical data, the project established projections of seasonal variability and long-term nutrient value of select organic fertilizers, including impacts on soil nitrogen reserves and multiyear soil nutrient increases will aid immensely in developing fertilizer recommendations for organic growers. Modeling nitrogen mineralization responses were modeled using common single pool non-linear regression models. Information including net nitrogen mineralization generated by our project will also assist in the broader effort to parameterize the DayCent model, so that the model can accurately predict nitrogen mineralization rates at different soil temperatures under soil conditions in California throughout the year. These models often use default N mineralization values resulting in poor prediction outcome. Our results will provide for adjustments of nutrient management guidelines depending on organic fertilizer sources, soil type, and climate data. The information generated in this research will be used by UC ANR Extension, CCAs and farmers to reassess nitrogen management across a variety of crops. This is a three-year project accomplished literature review, multiple laboratory incubations and one season field trial.

Findings:

Project outcomes include 1) The commonly used single pool nitrogen mineralization model varies in its ability to characterize organic fertilizers across a wide range of amendment C/N characteristics. 2) High C/N ratio amendments such as compost or aged manure may result in positive plant available N in the long-term, likely due to initial immobilization and subsequent N recycling through the organic pool. Further research will evaluate uncertainty between each study in addition to other factors such as temperature and soil type, using a hierarchical modeling approach. DayCent model projections of mineralized N from selected organic

fertilizers will then be compared to selected common N mineralization models. With a better understanding of how accurately biogeochemical models such as DayCent describe N mineralization, future research can work to improve these important agroecosystem impact assessment tools and refine grower recommendations.