DAIRY MANURE APPLICATIONS AND SOIL HEALTH IMPLICATIONS

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BACKGROUND

Dairy manure applications can potentially improve soil health by adding organic matter (OM) to the soil. However, intensive dairy manure applications can cause salt accumulations on arid, irrigated soils, impairing soil health, which can reduce crop growth and yield. There are several soil health tests (Solvita test, water soluble extractions, etc.) that have been introduced as an alternative method for evaluating soil health, but have not been well studied in Idaho. In this paper, we will discuss the effect of dairy manure application treatments on soil organic matter, soluble salts, and plant available N, focusing both on traditional and newly proposed methods for soil health testing.

EXPERIMENTAL DESIGN

Dairy manure was fall applied at rates of 7.7, 15.4, and 23.2 dry ton/acre (average manure moisture content = 50%) either annually or biennially from 2012 to 2015 on irrigated research plots located on the USDA ARS research station in Kimberly, Idaho. Annual treatments were applied every year, while biennial treatments were applied every other year prior to planting of the small grain crop. Cumulative manure nutrient loading amounts (as of spring of 2015) are listed in table 1. A fertilizer-only treatment based on current University of Idaho Extension recommendations for each crop was also included to compare manured systems to non-manured systems. A control treatment (no nutrients applied) was also included. All treatments are scheduled to continue until 2020.

Table 1. Cumulative amount of nutrient applied with dairy manure treatments applied from study period of 2012 to 2014. Kimberly, Idaho.

Dairy manure rate (ton/acre, dry basis)	Frequency of Application	Total N	Organic C	P_2O_5	K_2O	Na	Cl
		lb/acre					
7.7	Biennial (Applied in 2012 and 2014)	488	7,817	397	1,566	299	412
15.4		983	15,735	799	3,153	601	829
23.2		1,472	23,552	1,195	4,719	900	1,241
7.7	Annual (Applied in 2012, 2013, and 2014)	1,171	17,095	879	2,680	628	1,420
15.4		2,358	34,411	1,770	5,395	1,263	2,858
23.2		3,530	51,506	2,649	8,075	1,891	4,278

RESULTS AND DISCUSSION

Soil organic matter accumulations

Soil organic matter (OM) is a major contributor to soil health, with benefits including improved soil moisture retention, improved infiltration, increased microbial and biological activity, and improved soil structure. When we compared manure OM loading rate means to pre-plant soil organic matter content means by treatment and by year (2013, 2014, and 2015 preplant soil samples) (0-24 inch soil depth), soil OM increased by 0.02% for every ton of manure-derived organic matter applied (figure 1). It should be noted that soil OM content was tested within two years of the most recent manure application. Approximately 80% of the manure-applied organic matter was accounted for in the 0-24 inch soil depth, assuming a bulk density of 4,000,000 lb soil/acre-foot. Having initially high rates of organic matter retention from manure applications may influence growers to apply manure or compost as a means to significantly increase soil organic matter on their fields.

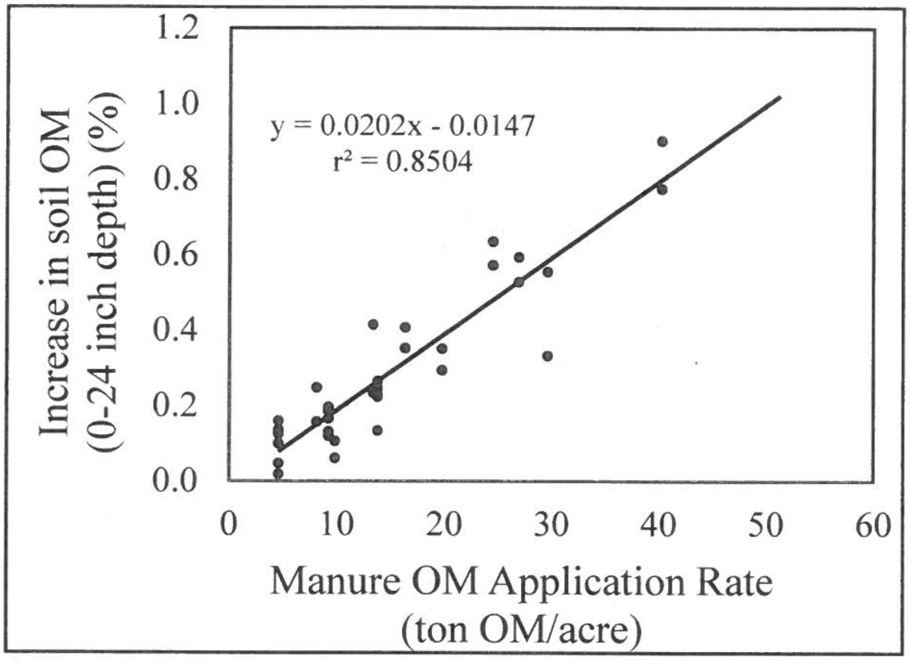

Figure 1. Relationship between manure organic matter (OM) loading rate and soil OM concentration (0-24 inch depth). Manure and soil data were collected over a three-year period from plots that received varying rates and frequencies of dairy manure (2012-2015). Portneuf silt loam. Kimberly, Idaho.

Soluble salt and sodium adsorption ratio (SAR)

While soil organic matter increases typically improve soil health, salt accumulations from manure applications can have an antagonistic effect on soil health. Soil organic matter, salinity, and sodicity parameter treatment means collected from 2015 preplant soil sample (0-12 inch depth) are listed in table 2. As manure application rates and frequencies increased, soil properties became increasingly saline-sodic (as indicated by EC and SAR values, listed in table 2).

Aggregate stability also decreased at the heaviest annual manure application rate, likely a consequence of clay dispersion caused by sodium in the added manure.

One concern with some of the new soil health tests is that they do not account for the negative effects of salt accumulations. For example, the Haney "soil health score" listed in table 2 appears to increase with increasing organic matter and nutrient content, not taking into account the fact that EC and SAR are also increasing to levels that are above recommended salinity/sodicity thresholds for salt sensitive and even salt tolerant crops. The developers of the Haney test claim that a score above "7" indicates that a soil is "healthy". The decline in aggregate stability reveals that soil structure is compromised at these higher soil health score values. Including salinity and sodicity parameters should be considered in future soil health evaluation programs, especially in semi-arid irrigated regions like Southern Idaho where saline and sodic soil conditions can occur.

Table 2. Preplant soil characteristics in year three of the manure application study (March 2015). Analyses were conducted on soils sampled at a 0-12 inch depth, excluding aggregate stability, which was measured on samples collected from the 0-4 inch depth. Portneuf silt loam. Kimberly, Idaho.

Dairy manure rate (ton/acre, dry basis)	Frequency of Applications	Soil Organic Matter (%)	Soil EC (dS/m)	Soil SAR	Aggregate Stability % (0-4 inch depth)	"Soil Health Score"
Control	NA	1.3 e	0.8 e	1.3 e	80.2 a	4.1 d
Fertilizer	NA	1.3 e	0.8 e	1.6 de	79.9 a	4.7 cd
7.7	Biennial (Applied in 2012 and 2014)	1.6 d	1.4 d	2.2 cd	78.0 ab	5.4 c
15.4		2.0 c	1.8 cd	3.0 b	79.7 a	7.0 b
23.2		2.3 ab	2.7 b	4.1 a	75.6 ab	7.9 ab
7.7	Annual (Applied in 2012, 2013, and 2014)	1.7 d	1.4 d	2.3 c	79.2 a	5.6 c
15.4		2.2 bc	2.2 c	3.2 b	80.0 a	7.8 ab
23.2		2.5 a	3.0 a	4.1 a	72.3 b	8.4 a

Plant available N evaluations

One of the critical aspects of this study has been the evaluation of N mineralization, which is poorly understood for southern Idaho soils that receive dairy manure applications. These evaluations have been conducted by aerobically incubating soils from study plots in an incubator at 22 degrees C for 100 days, as described by Hart et al. (1994). The aerobic incubation method is an established method that provides a relatively accurate estimate of the potentially mineralizeable N pool, and is therefore often used as a standard when evaluating newly proposed N mineralization methods. One of these new tests under evaluation by NRCS and other groups is the "Haney – Additional N" test, which relates CO_2 respiration measurements (commonly referred to as the "Solvita test") and soil organic C to organic N ratios to estimate how much N will be available to plants in addition to the nitrate and ammonium traditionally measured in preplant soil tests (Haney et al., 2015).

Preplant soils collected in 2013, 2014, and 2015 from the study plots described above were analyzed for N mineralization potential using both the aerobic incubation method and Haney – Additional N test. All treatments (control, fertilizer, and manure treatments) were included in the evaluation. Mean values by treatment and by year were compared using a linear regression (figure 2). A coefficient of determination (r^2 value) of 0.58 suggests that there may be a moderate correlation between the two tests. Unfortunately, the "Haney – Additional N" tests severely under-predicted mineralizeable N pools by 20-fold (figure 2). Thus, use of this test for estimating N fertilizer applications would drastically under-estimate plant available N in the soil, which would lead to greatly over estimating the N requirement of a crop to be grown on that field.

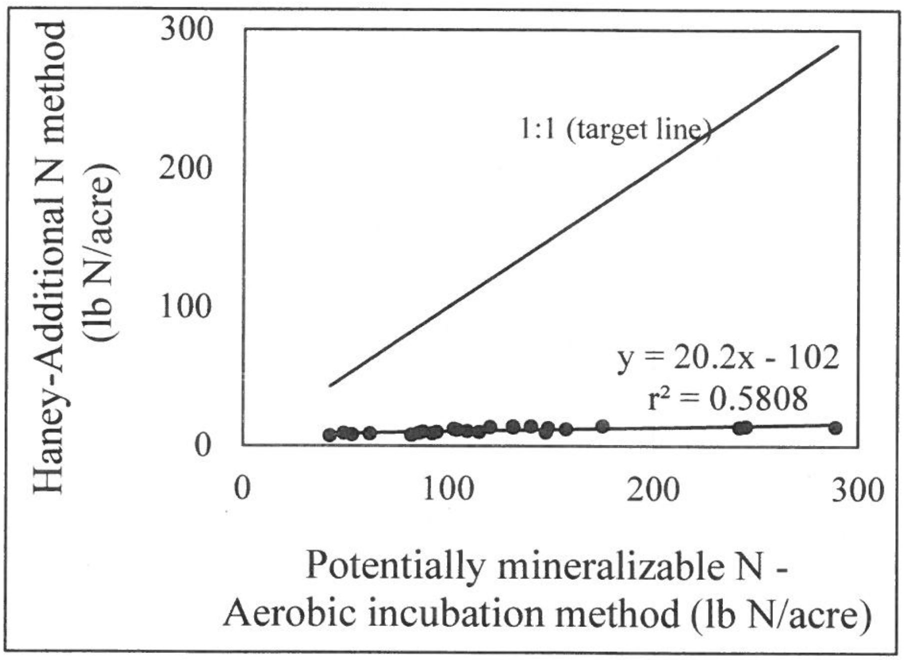

Figure 2. The relationship between potentially mineralizable N, measured via aerobic incubation (Hart et al. 1994) and the "Haney – Additional N" test estimate of potentially mineralizable N. The Haney test – Additional N estimate is derived from CO_2 respiration (Solvita) and the soil organic C to organic N ratio. Soil samples were collected at a 0-12 inch soil depth over a three-year period from plots that received varying rates and frequencies of dairy manure (2012-2015). Portneuf silt loam. Kimberly, Idaho.

In addition to the Haney test, we also compared potentially mineralizeable N via aerobic incubation to 1) preplant soil organic matter (colorimetric method, Sim and Habey (1971)), 2) total N (combustion method), and 3) soil nitrate. Of these three tests, soil organic matter had the strongest correlation to potentially mineralizeable N, measure via aerobic incubation method N (figure 3). This finding is encouraging, suggesting that preplant soil organic matter maybe useful to predict N mineralization potential at this site. We will be evaluating these relationships on sandy soils to determine if this model can be applied at other locations beyond the field site.

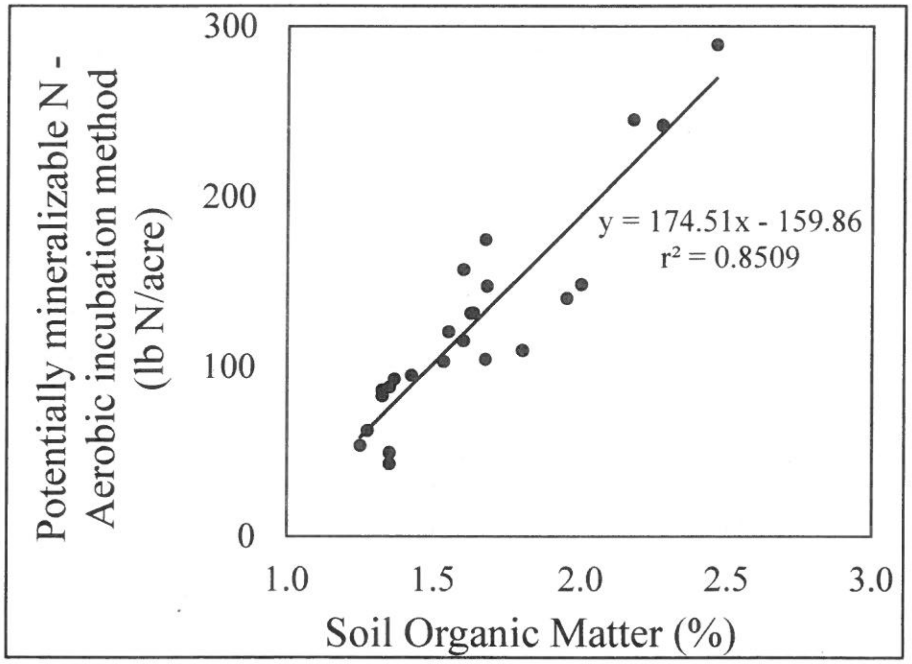

Figure 3. The relationship between potentially mineralizable N, measured via aerobic incubation (Hart et al. 1994) and soil organic matter content (colorimetric method, UI-ASL) measured on preplant soil samples collected from the 0 to 12 inch depth. Soil samples were collected over a three-year period from plots receiving varying rates and frequencies of dairy manure (2012-2015). Portneuf silt loam. Kimberly, Idaho.

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