PROJECT NO: BJKX38
TITLE: Long-Term Impacts of Manure Application on Production of Wheat and Other Crops
PERSONNEL: Amber Moore, Juliet Marshall, Olga Walsh, and Xi Liang
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JUSTIFICATION: Dairy manure is commonly applied to irrigated crops in Southern Idaho. Fields that are nearer dairies commonly receive the highest rates of applications, as a means to dispose of the manure while avoiding expensive transportation costs to move the manure to fields further away from the dairies. Alternatively, many Idaho growers are realizing the benefit of manure/compost as a nutrient source and soil amendment, and are applying manure to their fields as an affordable source of phosphorus, potassium, and micronutrients. At the higher rates used for waste disposal, there are concerns with degraded soil quality due to salt and copper accumulations, degraded water quality due to phosphorus accumulation and nitrate leaching, crop yield losses, and crop nutrient toxicities. At low and high rates, growers are concerned about pathogen persistence, and increased disease, insect, and weed pressure. To avoid some of the issues related pest and pathogen pressure, sugar beet and potato growers commonly apply manures prior to establishing the grain crop in their rotation, and not before sugar beets or potatoes, due to the perception that root crops are more susceptible to pathogen and disease issues than grain crops. Some fields near dairies continue to receive manure applications on a yearly basis, regardless of crop. The majority of the research regarding manure applications and plant growth in southern Idaho has been focused on only one, two, or three annual manure applications (Moore et al., 2011; Lentz et al., 2011; Leytem and Bjorneberg, 2009;). While this research is very useful for understanding the immediate impacts of manure applications, it does not capture the impact of repeated manure applications over several years (8 years or more). These types of applications are more realistic to the common practices of a dairy operation, and will better reflect soil quality, soil nutrient, crop yield, crop quality, microbial, and pest pressure responses than shorter-term manure applications.

HYPOTHESIS & OBJECTIVES:
Objective – Develop recommendations for optimal manure application rates and timing (annual or biennial, for a few years or several years of manure application), on the basis of yield potential, grain quality, soil quality, disease pressure, and nutrient uptake.
Hypothesis – Manure applications at agronomic rates that meet plant requirements for optimum economic yield will improve grain yields, due to the adequate concentrations of nitrogen, phosphorus, potassium, and increase of organic matter in the soil. Applications at rates in excess of plant nutrient requirements may lower crop quality.

PROCEDURES: This study is currently being conducted on two adjacent 2.5 acre sized sprinkler irrigated fields at the USDA ARS NWISRL station in Kimberly, Idaho. The soil is Portneuf silt loam, which is the most commonly farmed soil in Southern Idaho.

This eight-year study is entering its third year. The selected crop rotation for field #1 is wheat-potatoes-barley-sugar beets, and was planted to wheat in 2013 (completed) and will be planted to wheat in 2017. The selected crop rotation for field #2 is barley-sugar beets-wheat-potatoes, and was planted to wheat in 2015 (completed) and will be planted to wheat in 2019. Having two fields with the same experimental designs will allow us to gather data for wheat (and other specific crops) every other year instead of once every four years. Treatments are application timing (manure will be applied prior to grain establishment every year or every other

year) and rate (9, 18, and 27 ton/acre, dry weight basis). The lower rates (9 and 18 ton/acre) are typical rates used by sugar beet growers, based on an internal survey conducted by the Snake River Sugar Beet Growers. The higher rate (27 ton/acre) is intended to simulate a waste disposal scenario, similar to what is commonly seen on fields that are near dairies. Additional fertilizer treatment (chemical sources applied at agronomic rates based on UI fertilizer guides) and a control treatment (no nutrient source applied) is also included, for a total of 8 treatments per field (2 application timings at 3 rates + 1 standard chemical fertilizer trt + 1 control trt). Treatments are replicated four times in a randomized complete block, for a total of 32 treatments per field. Plot size is 40 ft. wide by 60 ft. long.

The manure source will continue to be stockpiled dairy manure. The manure for this project continues to be provided by Magic Valley Compost Inc. to eliminate traceability to a specific dairy. Manure samples are for moisture, soluble salts (EC), pH, organic matter, carbon, nitrogen, ammonium, and other agronomic macro- and micronutrients. Manure is applied in October by pre-weighing the amount of manure equivalent to the treatment rate, and applying the manure using a small-plot manure spreader from the USDA ARS Kimberly station. Manure is incorporated on the same day as application to avoid ammonia volatilization losses. Hard red spring wheat (Jefferson) will be planted into field #1 in 2017 as soon as the ground is safely workable in early April. Seed will be planted using the USDA ARS small grain planter at standard irrigated rate of 1million seeds per acre. Response variables will include soil tests, tissue tests, disease reactions, and grain quality. Soil tests will include a spring comprehensive soil test prior to fertilization and planting at 0-12 and 12-24 inch depths. The tests will allow us to follow the change in soil properties through time. Soil testing will be conducted at the UI Analytical Sciences Lab in Moscow, Idaho.

Wheat plant uptake of N, P, K, and other macro/micronutrients will be analyzed through destructive sampling of above soil-line plant biomass near harvest. Approximately one week prior to harvest, whole plant samples will be collected from a 3 ft. X 5 ft. section in non-yield rows in each plot. Plants will be clipped at the soil surface and weighed. A subsample will be collected, dried, and weighed again. Dried tissue subsamples will be analyzed for total N, P, and K content. These values will be used to estimate nutrient removal potential, and how it is affected by the manure application treatments. Disease pressure will be monitored throughout the growing season, with samples collected in the seedling stage prior to tillering and at harvest to measure soil-borne disease pressure. Foliar diseases will be controlled with an appropriate fungicide in order to protect economic yield, to reflect standard BMP. Plots will be harvested in mid-August using the UI Wintersteiger harvester, harvesting 5-foot wide by 30-foot length. Test weight and moisture will be measured using the Juniper System Grain Gauge on the combine. Protein analysis of grain will be conducted at the UI Aberdeen Wheat Quality Lab. Yield will be determined using designated row areas in each plot, and will not be sampled or disturbed as not to compromise yield potential or quality traits.

Funds for yield component, disease, root health, and quick N testing are not being requested this year, as the analyses will not occur during the 2016-2017 funding cycle.
We are requesting $11,432 in operating costs, which will be primarily directed toward manure applications, manure nutrient analysis, and intensive pre-plant soil analyses during the FY 2016-2017 funding cycle. Operating costs may also be used toward food costs, bus services, and other miscellaneous office and field supplies that specifically support field day and workshop events that promote wheat production-related findings from this study. Operating cost may also directed toward private temporary help agencies to occasionally help with soil sampling, harvest, and

other infrequent and intensive tasks that require more people than we have on our team. Travel funds are requested to cover frequent trips between Twin Falls and the study site in Kimberly, and toward travel for wheat-related research meetings in Idaho throughout the year.

DURATION: Fourth year of an eight year project.

COOPERATION: David Bjorneberg, April Leytem, and David Tarkalson from USDA ARS will facilitate with experimental design, experimental setup, and maintenance of this project. A wide variety of scientists will be invited to collect data from non-yield areas within these plots, using funding from their own projects to support data collection and analysis, Gary Lehrsch, USDA ARS soil physicist, aggregate stability; Rob Dungan, USDA ARS soil microbiologist, nitrifying bacteria populations; April Leytem, USDA ARS soil chemist, downward nitrate movement, nitrous oxide emissions; Lisa Russo, USDA ARS soil microbiologist (Lincoln, Nebraska), E. coli survival; Matt Morra, University of Idaho soil biogeochemist, pharmaceutical leaching; Dan Strawn, University of Idaho soil chemist, soil P speciation.

ANTICIPATED BENEFITS/EXPECTED OUTCOMES/INFORMATION TRANSFER: Provide accurate and up-to-date recommendations for rates and timing of manure application for growers working on silt loam or loam soils, to improve best management practices for maximum economic yield, improve seed quality, improve soil quality, reduce disease pressure, avoid salt accumulations, avoid excessive P buildup, avoid nitrate leaching, and improve nutrient uptake. This information will be relayed through popular press articles and at small grain commodity schools. We will develop an extensive UI extension guide on the long-term impacts of manure applications on small grain production, and will update the bulletin biennially to include results and changes to existing recommendations, based on our findings from this study. At the eight-year conclusion of this study, this research will be published in several peer-reviewed research journal articles.

LITERATURE REVIEW: Influence of manure applications on small grain yield in comparison to fertilizers applied at comparable rates vary from increased yields (Lentz et al., 2011), no effect on yield (Matsi et al., 2003; Lentz et al., 2011), and significant decreases in grain yield (Boman et al., 1996). In regards to decreased grain yields, some researchers have shown that cattle manure can decrease germination of barley seeds, due to high concentrations of bile salts in the manure (Bell, 1976).

Bell, R.G. 1977. Characterization of an agent in aqueous extracts of beef cattle manure that inhibits the germination of barley seeds. *Journal of Environmental Quality*. 6:163-164.

Boman, R.K., S.L. Taylor, W.R. Rau, G.V. Johnson, D.J. Bernardo, and L.L. Singleton. 1996. The Magruder plots: A century of wheat research in Oklahoma. Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma.

Lentz, R.D., G.A. Lehrsch, B. Brown, J. Johnson-Maynard, and A.B. Leytem. 2011. Dairy manure nitrogen availability in eroded and non-eroded soil for sugar beet followed by small grains. *Agronomy Journal*. 103:628-643.

Leytem, A.B. and D. Bjorneberg. 2009. Changes in soil test phosphorus and phosphorus in runoff from calcareous soils receiving manure, compost, and fertilizer application with and without alum. *Soil Science*. 174:445-455.

Matsi, T., A.S. Lithourgidis, and A.A. Gagianas. 2003. Effects of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics. *Agronomy Journal*. 95:592-596.

Moore, A.D., N.L. Olsen, A.M. Carey, and A.B. Leytem. 2011. Residual effects of fresh and composted dairy manure applications on potato production. *American Journal of Potato Research*. 88:324-332.

IDAHO WHEAT COMMISSION - BUDGET FORM

Allocated by	Idaho Wheat Commission	during FY 2015	$	19,110
Allocated by	Idaho Wheat Commission	during FY 2016	$	18,849

REQUESTED FY 2017 SUPPORT:

	Salary	Temporary Help	Fringe	Travel	OE	Graduate Tuition/Fees	TOTALS
Idaho Wheat Commission	$ -	$ 4,000	$ 1,568	$ 1,000	$ 11,432	$ -	$ 18,000

OTHER RESOURCES (not considered cost sharing or match):

TOTAL OTHER RESOURCES	$	114,000

TOTAL PROJECT ESTIMATE FOR FY 2017:	$ 18,000 *(Requested)*	$ 114,000 *(Other)*	$ 132,000 *(Total)*

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

	Moore	*(PI name)*	*(PI name)*	*(PI name)*
Salary	$ -	$ -	$ -	$ -
Temporary Help	$ 4,000	$ -	$ -	$ -
Fringe Benefits	$ 1,568	$ -	$ -	$ -
Travel	$ 1,000	$ -	$ -	$ -
Operating Expenses	$ 11,432	$ -	$ -	$ -
Graduate Student Fees	$ -	$ -	$ -	$ -
TOTALS	$ 18,000	$ -	$ -	$ -

Total Sub-budgets	$ 18,000

10.7.2015 - Version

ANNUAL REPORT

PROJECT NO: BJKX38

TITLE: Long-Term Impacts of Manure Applications on Production of Wheat and Other Crops

PERSONNEL: Amber Moore, Nutrient Management Specialist, Twin Falls
Juliet Marshall, Smalls Grains Specialist, Aberdeen
Xi Liang, Cropping Systems Specialist, Aberdeen
Olga Walsh, Cropping Systems Specialist, Parma

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ACCOMPLISHMENTS:

Soil nutrient accumulations

In the third year of this eight year study, soil nutrients continued to accumulate with increasing manure rates and/or manure application frequency (table 1). In year 3 (March 2015), soil Olsen P levels finally increased over the code 590 threshold of 40 ppm of the study for both annual and biennial applications of dairy manure at rates of 40 and 60 wet ton/acre, suggesting these application rates and frequency are greater than P removal potential of the barley, sugar beets, and wheat that had been grown in this field since 2013. Relationships between soil nutrients and wheat yield components are currently being evaluated.

Table 1. Spring 2015 preplant soil nutrient and salts response to repeated dairy manure applications in Kimberly, Idaho at the 0-12 inch soil depth.

Dairy manure rate (wet ton/acre)	Frequency of applications	Total N (%)	Soil organic matter (%)	Soil Nitrate-N (ppm)	Olsen P (ppm)	Olsen K (ppm)	Soil EC (Soluble Salts) (ds/m)
Control	NA	0.09 de	1.3 e	12.0 f	9.6 e	133 e	0.8 e
Fertilizer	NA	0.09 e	1.3 e	13.8 f	15.8 e	145 e	0.8 e
20	Biennial (Applied in 2012 and 2014)	0.11 cd	1.6 de	24.3 e	36.0 d	263 d	1.4 d
40		0.15 ab	2.0 c	32.5 d	65.8 c	478 c	1.8 c
60		0.15 ab	2.3 ab	53.0 b	90.8 b	730 b	2.7 a
20	Annual (Applied in 2012, 2013, and 2014)	0.12 c	1.7 d	27.5 de	39.3 d	350 d	1.4 d
40		0.14 b	2.2 bc	45.5 c	75.5 bc	660 b	2.2 b
60		0.16 a	2.5 a	59.8 a	112.5 a	1,033 a	3.0 a
p-value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Grain yields and yield components

The 2015 wheat grain yields and yield components are listed in table 2. Similar to 2013, the 2015 manure application treatment rates of 20 and 40 ton/acre (annual and biennial) continued to increase grain yield and protein content in comparison to fertilizer treatments. In contrast to 2013, the 2015 grain yields trended lower at the highest manure application rates of 60 ton/acre in comparison to fertilizer treatment plots. The repeated manure applications at the annual 60 ton/acre also significantly increased lodging and decreased weight (g) per 1000 kernels, which may have contributed to lowered yields. Again, we are currently evaluating the impact of soil nutrient accumulations on yield components to further understand how and why manure application affect wheat yield and wheat protein levels. Plant nutrient uptake and nutrient partitioning will also be included in this evaluation once tissue analysis in completed in March of 2016 by the UI ASL labs in Moscow, Idaho.

Table 2. Hard red spring wheat (Jefferson variety) responses in 2015, year 3 of an eight year long term dairy-manure application study in Kimberly, Idaho. Soil nutrients tested at the 0-12 inch soil depth.

Dairy manure rate (wet ton/acre)	Freq. Of applications	Lodge rating (July 22nd)	Grain yield (bu/acre)	Grain protein (%)	Plant height at harvest (inches)	No. Of kernels per head	Heads per 3 ft. Row	Weight (g) per 1000 kernels
Control	NA	1.0 d	66 d	11.1 d	30 c	31	78	37 a
Fertilizer	NA	4.0 c	98 abc	13.0 c	34 ab	35	95	34 bc
20	Biennial (Applied in 2012 and 2014)	5.2 bc	104 a	14.2 b	33 ab	32	117	33 cd
40		4.2 c	106 a	14.3 b	33 ab	38	109	32 cd
60		6.7 ab	94 bc	15.2 a	34 ab	38	95	33 cd
20	Annual (Applied in 2012, 2013, and 2014)	4.0 c	105 a	14.2 b	32 b	36	112	35 ab
40		5.2 bc	101 ab	15.0 a	35 a	40	123	34 bc
60		8.0 a	91 c	15.3 a	33 ab	38	115	32 d
p-value		<0.0001	<0.0001	<0.0001	0.0010	0.0962	0.1124	0.0006

Chlorophyll meter evaluation

Plants were evaluated in-season for chlorophyll content using the SPADmeter chlorophyll meter. Chloropyll readings were taken from the flag leaves of five plants on both May 28th and July 1st (figure 1), while protein data was collected at harvest. Correlations between in-season chlorophyll readings and end-of-season grain content are shown in figure 1. The strongest relationship between the two variables was detected during the July 1st meter reading event, with an r-square value of 0.96. It appears that the chlorophyll meter is detecting the late-June release of plant available N from the manured plots (N mineralization data was collected but is not shown). The late-season release of N has been attributed to increasing protein content in wheat. The late May readings were poorly correlated to grain protein, suggesting that chlorophyll

readings are more effective later in the season once late season N releases have occurred. These findings suggest that chlorophyll could be useful tools for predicting grain protein content prior to harvest on both manured and non-manured soils.

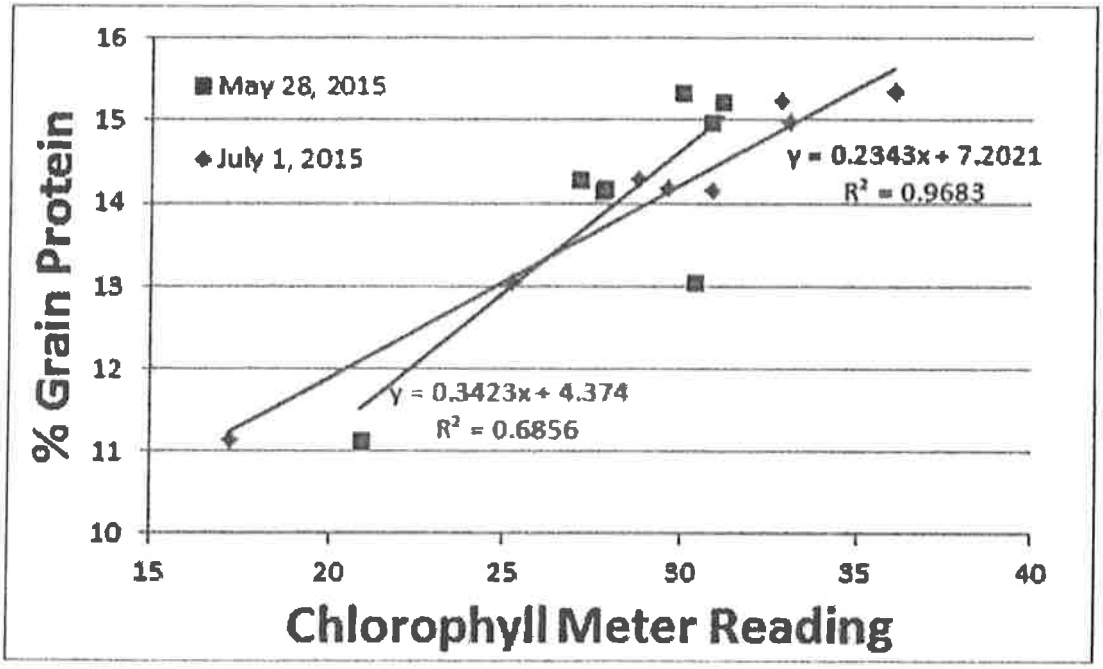

Figure 1. Comparison between chlorophyll meter readings and percent grain protein at harvest for Hard Red Spring wheat (Jefferson variety) grown in Kimberly, Idaho. Individual data points represent treatment means (control, fertilizer, and varying manure rates).

PROJECTIONS:

Results from this study will allow us to develop recommendations for Idaho wheat growers on how to manage manure applications to wheat production systems and manured soils in wheat production systems to achieve optimum yield and grain proteins without compromising soil health. Recent findings also suggest that chlorophyll meter technologies may have a place in Idaho wheat production, especially in terms of predicting grain protein at least one month prior to wheat harvest.

PUBLICATIONS:

Findings and recommendations have been published in Idaho Potato Commission newsletter (Potato Progress), Idaho Dairymen's Association newsletter (FOCUS), and a barley commodity newsletter publications in 2015. Two ASA Abstracts on the N mineralization aspect of this study were also published in the 2015 ASA/SSSA/CSSA abstracts publication.