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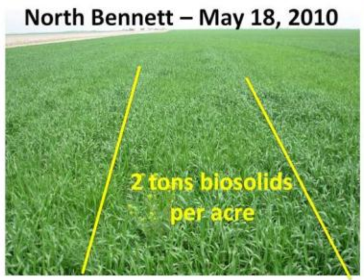

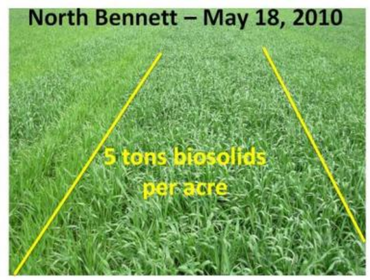

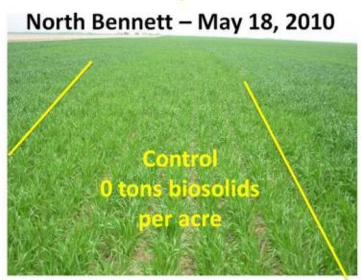

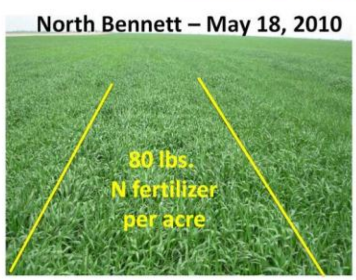

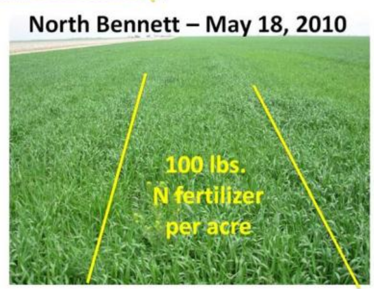

APPLICATION OF ANAEROBICALLY DIGESTED BIOSOLIDS TO DRYLAND WINTER WHEAT 2009-2010 RESULTS

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INTRODUCTION

Approximately 41% of biosolids are land applied in the U.S. (Brobst, Robert. 2011. USEPA, Personal Communication). Land application can greatly benefit municipalities and farmers by recycling plant nutrients in an environmentally sound manner (Barbarick et al., 1992).

Our long-term biosolids project, now in its twenty-eighth year, has provided valuable information on the effects of continuous biosolids applications to dryland winter wheat (*Triticum aestivum* L.). Previous research has shown that Littleton/Englewood biosolids are an effective alternative to commercial nitrogen (N) fertilizer with respect to grain production and nutrient content of winter wheat (Barbarick et al., 1992). As with other N fertilizers, however, application rates of biosolids exceeding the N needs of the crop result in an accumulation of soil nitrate-nitrogen. Excess soil nitrate-nitrogen may move below the root zone or off-site and contaminate groundwater or surface waters. The potential benefit of biosolids is that they contain organic N, which can act like a slow-release N source and provide a more constant supply of N during the critical grain-filling period versus commercial N fertilizer.

A 2 dry tons biosolids A^{-1} application rate will supply approximately 40 lbs N A^{-1} over the growing season, the amount typically required by dryland winter wheat crops in our study area. Previous research has shown no detrimental grain trace-metal accumulation with this application rate (Barbarick et al., 1995). Therefore, we continue to recommend a 2 dry tons biosolids A^{-1} rate as the most sustainable land-application rate for similar biosolids nutrient characteristics and crop yields.

The overall objective of our research is to compare the effects of Littleton/Englewood (L/E) biosolids and commercial N fertilizer rates on: a) dryland winter wheat ('Ripper') grain production, b) estimated income, c) grain and straw total nutrient and trace-metal content, and (d) soil NO_3-N accumulation and movement.

MATERIALS AND METHODS

The North Bennett experimental plots used in the 2009-2010 growing season were established in August 1993. The soil is classified as a Weld loam, Aridic Argiustoll. The land is farmed using minimum-tillage practices.

We applied N fertilizer (46-0-0; urea) at rates of 0, 20, 40, 60, 80, and 100 lbs N A^{-1} and biosolids (93% solids, Table 1) at rates of 0, 1, 2, 3, 4, and 5 dry tons A^{-1} on 27 and 28 July 2009, respectively. The same plots received biosolids and N fertilizer, at the above rates, in July or August 1993, 1995, 1997, 1999, 2001, 2003, and 2005. We did not apply biosolids in 2007 since the farmer grew proso millet (*Panicum miliaceum* L.) to help control an infestation of jointed goat grass (*Aegilops cylindrica* Host). According to the 1996 Colorado Department of Public Health and Environment Biosolids Regulations, L/E biosolids are classified as Grade I and are suitable for application to agricultural and disturbed lands (Table 1). We uniformly applied both biosolids and N fertilizer, and incorporated with a rototiller to a depth of 4 to 6 inches. The North Bennett site was cropped with the winter wheat cultivar 'TAM 107' during the 1993-4, 1995-6, and 1997-8 growing seasons, 'Prairie Red' during the 1999-2000, 2001-2, 2003-4, and 2005-6 seasons, and 'Ripper' in 2007-8 and 2009-2010.

At harvest (19 July 2010), we measured grain yield and protein content. We estimated net income using $8.15 per bushel for wheat, subtracted the cost for either fertilizer or biosolids, and considered all other costs equal. Although we applied urea fertilizer, we based our estimated gross income calculations on the cost of anhydrous ammonia. The biosolids and its application are currently free. Grain and straw were also collected and analyzed for total copper (Cu), phosphorus (P), and zinc (Zn) concentrations. Following harvest, we collected soil samples from the 0-8, 8-24, 24-40, 40-60, and 60-80-inch depths in the control, 40 lbs N A^{-1}, and 2 and 5 dry tons biosolids A^{-1} treatments and analyzed them for NO_3-N accumulation.

This report provides data for the 2009-2010 crop year only. The reader is reminded that the 2009-2010 North Bennett plots received biosolids at the same application rates in July or August 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2009. Considering these seven prior plus the current application, the recommended 2 dry tons A^{-1} biosolids rate for the 2009-2010 growing season represents a cumulative addition of 16 dry tons A^{-1} biosolids for the life of the experiment.

RESULTS AND DISCUSSION

Grain Yields, Protein Content, and Estimated Income

The average North Bennett grain yields were above the Adams County average yield of 30 bu A^{-1} (Table 2). Biosolids and N fertilizer application did not significantly affect grain production. The biosolids average economic return was greater than the average N fertilizer economic return (Table 2). This finding was similar to our previous observations at this site that showed biosolids produced a greater estimated net income versus that from the N-treated plots.

This trend was also similar to previous years where economic return differences resulted since the biosolids were free and N fertilizer was an input cost.

Biosolids Application Recommendation

To better determine the N equivalency of the biosolids, we compared yields from N and biosolids plots at North Bennett. However, we did not find any significant N equivalency relationships for the biosolids or N-fertilizer treatments (Figure 1). During past growing seasons we have estimated that 1 dry ton of biosolids would supply the equivalent of 16 lbs of fertilizer N (Barbarick and Ippolito, 2000). This approximation helps in planning long-term biosolids applications.

Grain and Straw Nutrients and Trace Metals

We observed that increasing biosolids produced higher grain and straw P concentrations in the than N fertilizer (Tables 3 and 4). All grain and straw metal concentrations were well below the levels considered harmful to livestock (National Research Council, 1980).

Residual Soil NO_3-N

Neither the recommended 2 dry tons biosolids A^{-1} nor the 5 dry tons biosolids A^{-1} application rate significantly affected NO_3-N throughout the profile as compared to either the control or the 40 lbs N A^{-1} fertilizer application rate (Figure 2).

SUMMARY

North Bennett grain yields were above the Adams County average yield of 30 bu A^{-1}. On average, the estimated net return to biosolids was greater than the N fertilizer application. This trend was similar to previous findings where biosolids usage provided a greater economic advantage.

Increasing biosolids rates resulted in increased grain and straw P but did not affect Cu, Ni, or Zn concentrations. All grain and straw metal concentrations were well below the levels considered harmful to livestock, and all findings were relatively similar to previous years.

The 2 and 5 dry tons biosolids A^{-1} application rate did not affect NO_3-N throughout the profile as compared to either the control or the 40 lbs N A^{-1} fertilizer application rate.

We continue to recommend 2 dry tons biosolids application A^{-1}. Previous growing season results show that 1 dry ton biosolids A^{-1} is equivalent to 16 lbs N A^{-1} of fertilizer (Barbarick and Ippolito, 2000). These approximations could help in planning long-term biosolids applications. We recommend that soil testing, biosolids analyses, and setting appropriate yield goals must be used with any fertilizer program to ensure optimum crop yields along with environmental protection.

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Table 1. Average composition of Littleton/Englewood biosolids applied in 2009-2010 compared to the Grade I and II biosolids limits.

Property	Dry Weight Concentration Littleton/Englewood	lbs. added per ton	Grade I Biosolids Limit[¶]	Grade II Biosolids Limit
Organic N (%)	4.83	97		
NO_3-N (%)	<0.01	---		
NH_4-N (%)	0.88	18		
Solids (%)	71.6	---		
P (%)	2.45	49		
Ag (mg kg^{-1}) [†]	12.8	0.026		
As "	10.6	0.021	41	75
Ba "	238	0.48		
Be "	0.15	0.00030		
Cd "	3.6	0.0072	39	85
Cr "	40	0.080	1200	3000
Cu "	880	1.8	1500	4300
Pb "	23	0.046	300	840
Hg "	0.09	0.00018	17	57
Mn "	256	0.51		
Mo "	32	0.064	Not finalized	75
Ni "	15	0.030	420	420
Se "	31	0.062	36	100
Zn "	872	1.7	2800	7500

¶ Grade I and II biosolids are suitable for land application (Colorado Department of Public Health and Environment, 1996).

† mg kg^{-1} = parts per million.

Table 2. Effects of N fertilizer and biosolids on wheat yield, and projected income at North Bennett, 2009-2010.

N fert. lbs. A^{-1}	Biosolids† dry tons A^{-1}	Yield bu A^{-1}	Fert. cost‡ \$ A^{-1}	Income - fert. cost \$ A^{-1}
0		46	0	375
20		66	39	499
40		50	69	338
60		59	99	382
80		47	129	254
100		46	159	216
Mean§		54	99	338
LSD N rate§		NS¶		
	0	59	0	481
	1	48	0	391
	2	47	0	383
	3	43	0	350
	4	41	0	334
	5	45	0	367
Mean§		45	0	365
LSD biosolids rate		NS		
N vs. biosolids§		NS		

† Identical biosolids applications were made in 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2009; therefore, the cumulative amount is 8 times that shown.

‡ The price for anhydrous NH_3 was considered to be \$1.50 lb^{-1} N plus \$9.00 A^{-1} application charge. The biosolids and its application are currently free. We used a grain price of \$8.15 bu^{-1} for wheat.

§ Means/LSD/N vs. biosolids do not include the controls.

¶ NS = not significant at 5% probability level; * = significant at the 5% probability level.

Table 3. Effects of N fertilizer and biosolids rates on elemental concentrations of dryland winter wheat grain at North Bennett, 2009-2010.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}†	P g kg^{-1}	Cu --------	Ni mg kg^{-1}	Zn -----------
0		2.8	4.1	0	11
20		2.9	4.6	0	11
40		3.0	4.1	0.16	14
60		2.8	4.0	0	11
80		3.1	4.3	0.12	15
100		3.1	4.5	0	14
Mean§		3.0	4.3	0.06	13
Sign. N rates		NS	NS	NS	NS
LSD					
	0	2.9	4.0	0	11
	1	3.0	4.1	0.13	11
	2	3.3	5.0	0.23	17
	3	3.5	4.0	0.13	15
	4	3.3	4.2	0.12	16
	5	3.4	4.4	0.09	18
	Mean	3.3	4.3	0.14	15
	Sign. biosolids rates	NS	NS	NS	NS
	LSD				
	N vs bio-solids	*	NS	NS	NS

† Identical biosolids applications were made in 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2009; therefore, the cumulative amount is 8 times that shown.

§ Means/LSDs/N vs biosolids do not include the controls (the zero rates).

¶ NS = not significant, * = significance at 5% probability level, ** = significance at 1% probability level, ND = non-detectable.

Table 4. Effects of N fertilizer and biosolids rates on elemental concentrations of dryland winter wheat straw at North Bennett, 2009-2010.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1} [†]	P g kg^{-1}	Cu ----------	Ni mg kg^{-1}	Zn -----------
0		0.52	1.9	0.08	2.8
20		0.36	1.5	0	1.7
40		0.42	1.6	0.08	2.2
60		0.46	1.7	0.06	1.9
80		0.88	3.3	0.22	4.6
100		0.51	1.8	0	2.4
Mean[§]		0.53	2.0	0.07	2.6
Sign. N rates		NS	**	NS	*
LSD			1.0		1.5
	0	0.47	1.7	0	2.1
	1	0.49	1.9	0	2.3
	2	0.84	2.3	0.18	3.6
	3	0.76	1.9	0	3.1
	4	0.93	2.3	0	3.9
	5	1.29	3.0	0	5.1
	Mean	0.86	2.3	0.04	3.6
	Sign. biosolids rates	NS	NS	NS	NS
	LSD				
	N vs bio-solids	*	NS	NS	NS

† Identical biosolids applications were made in 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2009; therefore, the cumulative amount is 8 times that shown.

§ Means/LSDs/N vs biosolids do not include the controls (the zero rates).

¶ NS = not significant, * = significance at 5% probability level, ** = significance at 1% probability level, ND = non-detectable.

Figure 1. North Bennett wheat yields in 2009-2010 as affected by either N fertilizer or biosolids application.

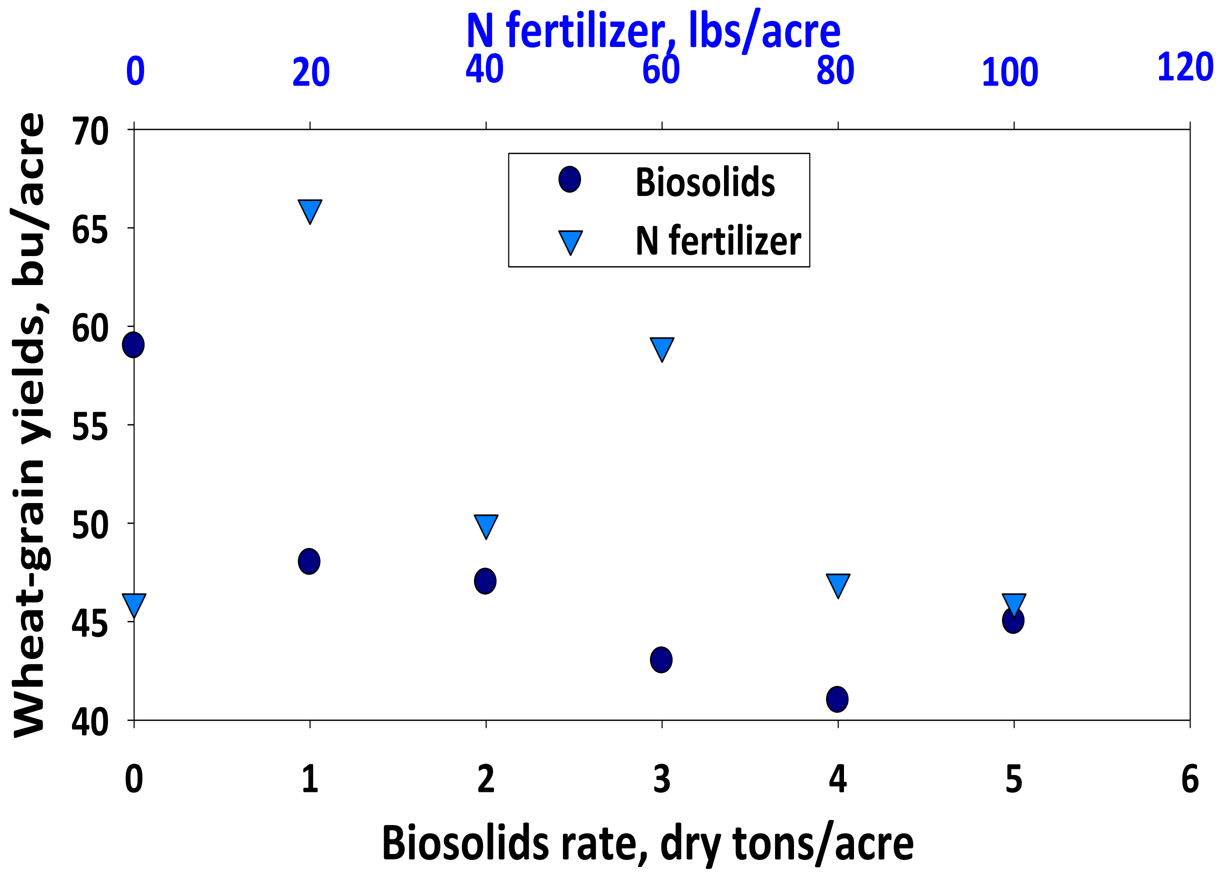
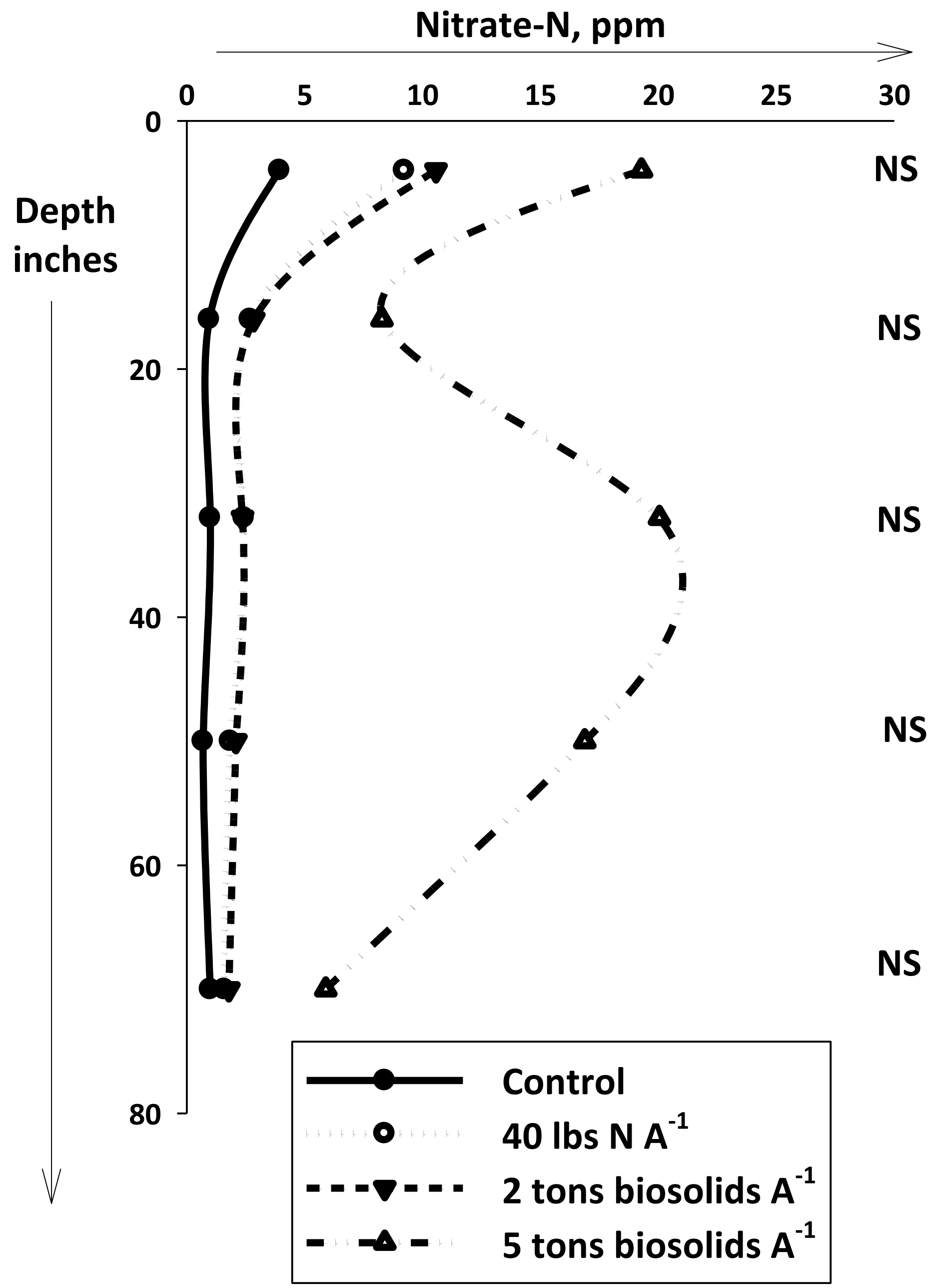


Figure 2. North Bennett harvest soil nitrate-N, 2009-2010.



NS = non significant.