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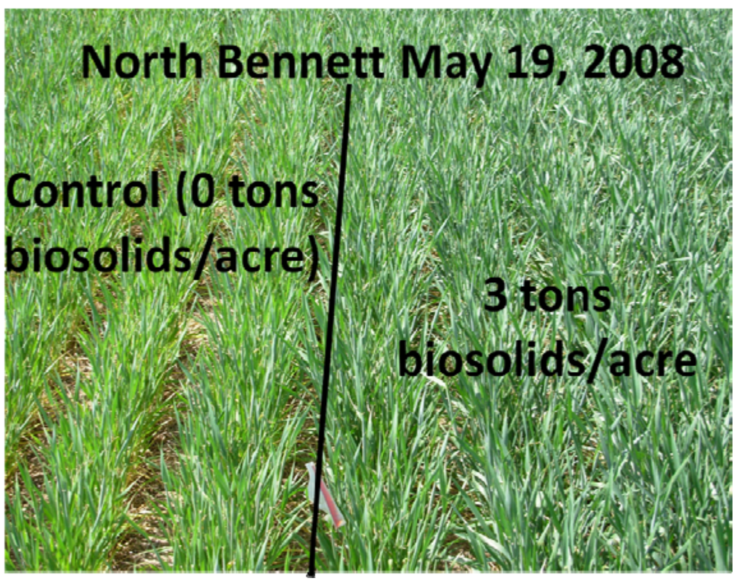
APPLICATION OF ANAEROBICALLY DIGESTED BIOSOLIDS TO DRYLAND WINTER WHEAT 2007-2008 RESULTS



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INTRODUCTION

The application of biosolids to lands in EPA Region 8 (includes Colorado) is the major method of biosolids recycling, with 85% of the material being reused (USEPA, 2003). 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-seventh 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 to 3 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 2007-8 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 23 and 24 July 2007, respectively. The same plots received biosolids and N fertilizer, at the above rates, in July or August 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2007. 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, 1995-66, and 1997-8 growing seasons, ‘Prairie Red’ during the 1999-2000, 2001-2, 2003-4, and 2005-6 seasons, and ‘Ripper’ in 2007-8.

At harvest (14 July 2008), we measured grain yield and protein content. We estimated net income using $6.00 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 2007-8 crop year only. The reader is reminded that the 2007-8 North Bennett plots received biosolids at the same application rates in July or August 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2007. Considering these seven prior years and the current application, the recommended 2 dry tons A^{-1} biosolids rate for the 2007-8 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). Increasing biosolids rates significantly decreased grain production and while N fertilizer had no effect. Nutrient application with the biosolids application probably caused more vegetative growth, which used soil moisture earlier in the growing season, but this vegetative growth did not contribute to the grain yield. 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

As shown in Table 3, both the N fertilizer and biosolids increased grain protein as the application rate increased. We observed that increasing biosolids rate only affected the Zn concentrations in the grain (Table 3) and straw (Table 4). The increase in grain Zn content due to increasing biosolids application can be viewed as positive since this soil could be considered Zn-deficient. 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}. Increasing biosolids rates decreased grain yields. Both N fertilizer and biosolids increased the grain protein content.

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 Zn but did not affect P, Cu, or Ni concentrations. The increase in grain Zn content due to increasing biosolids application rates can be viewed as positive since the soil at this research site is Zn deficient. 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 expect increases in grain yield and protein content when we apply biosolids or N fertilizer at recommended rates on N-deficient soils. During most growing seasons, biosolids could supply slow-release N, P, Zn, and other beneficial nutrients. 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 2007-8 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 (%)	4.54	91		
NO_3-N (%)	<0.01	---		
NH_4-N (%)	0.42	8		
Solids (%)	93.3	---		
P (%)	1.70	34		
Ag (mg kg^{-1}) [†]	<0.05	<0.0001		
As "	0.57	0.0011	41	75
Ba "	44.4	0.089		
Be "	0.04	0.00008		
Cd "	2.00	0.0040	39	85
Cr "	17.4	0.035	1200	3000
Cu "	656	1.31	1500	4300
Pb "	20.0	0.040	300	840
Hg "	0.14	0.0028	17	57
Mn "	181	0.36		
Mo "	5.9	0.012	Not finalized	75
Ni "	10.6	0.021	420	420
Se "	0.60	0.0012	36	100
Zn "	270	0.54	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, 2007-8.

N fert. lbs. A^{-1}	Biosolids† dry tons A^{-1}	Yield bu A^{-1}	Fert. cost‡ \$ A^{-1}	Income - fert. cost \$ A^{-1}
0		32	0	192
20		36	16	200
40		40	37	203
60		34	51	153
80		37	65	157
100		37	79	143
Mean§		37	34	188
LSD N rate§		NS ¶		
	0	40	0	240
	1	41	0	246
	2	31	0	186
	3	35	0	210
	4	29	0	174
	5	31	0	186
Mean§		33	0	198
LSD biosolids rate		7*		
N vs. biosolids§		NS		

† Identical biosolids applications were made in 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2007; therefore, the cumulative amount is 8 times that shown.

‡ The price for anhydrous NH_3 was considered to be \$.70 lb^{-1} N plus \$9.00 A^{-1} application charge. The biosolids and its application are currently free. We used a grain price of \$6.00 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, 2007-8.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}†	Protein %	P g kg^{-1}	Cu --------	Ni mg kg^{-1}	Zn -----------
0		13.9	3.3	5.0	0.51	15
20		14.2	3.0	4.7	0.63	15
40		14.6	2.9	4.7	0.52	14
60		15.5	3.0	5.1	0.56	17
80		15.6	3.0	5.1	0.65	16
100		15.2	2.9	5.2	0.84	16
Mean§		15.0	3.0	5.0	0.64	16
Sign. N rates		1.3*	NS	NS	NS	NS
LSD						
	0	12.9	3.2	4.5	0.60	14
	1	14.6	3.2	4.9	0.57	17
	2	15.6	3.2	5.0	0.53	19
	3	15.8	3.2	4.9	0.64	19
	4	15.9	3.2	5.0	0.50	21
	5	16.2	3.3	5.3	0.56	22
	Mean	15.6	3.2	5.0	0.56	20
	Sign. biosolids rates	1.1**	NS	NS	NS	**
	LSD					3
	N vs bio-solids	NS	NS	NS	NS	NS

† Identical biosolids applications were made in 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2007; 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, 2007-8.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}[†]	P g kg^{-1}	Cu ----------	Ni mg kg^{-1}	Zn -----------
0		0.92	2.9	0.10	4.9
20		0.86	3.1	0.10	4.6
40		0.85	3.2	0.23	4.6
60		0.91	3.2	0.14	5.5
80		0.90	3.5	0.25	5.6
100		0.81	3.0	0.26	4.9
Mean[§]		0.87	3.2	0.20	5.0
Sign. N rates		NS	NS	NS	NS
LSD					
	0	0.97	2.8	0.14	4.7
	1	1.03	3.2	0.24	5.9
	2	1.68	4.0	0.31	10.6
	3	1.69	4.0	0.27	10.2
	4	1.71	4.1	0.21	12.1
	5	1.77	4.5	0.33	12.6
	Mean	1.57	3.9	0.27	10.3
	Sign. biosolids rates	NS	NS	NS	*
	LSD				6.6
	N vs bio-solids	NS	NS	NS	NS

† Identical biosolids applications were made in 1993, 1995, 1997, 1999, 2001, 2003, 2005, and 2007; 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 2008 as affected by either N fertilizer or biosolids application.

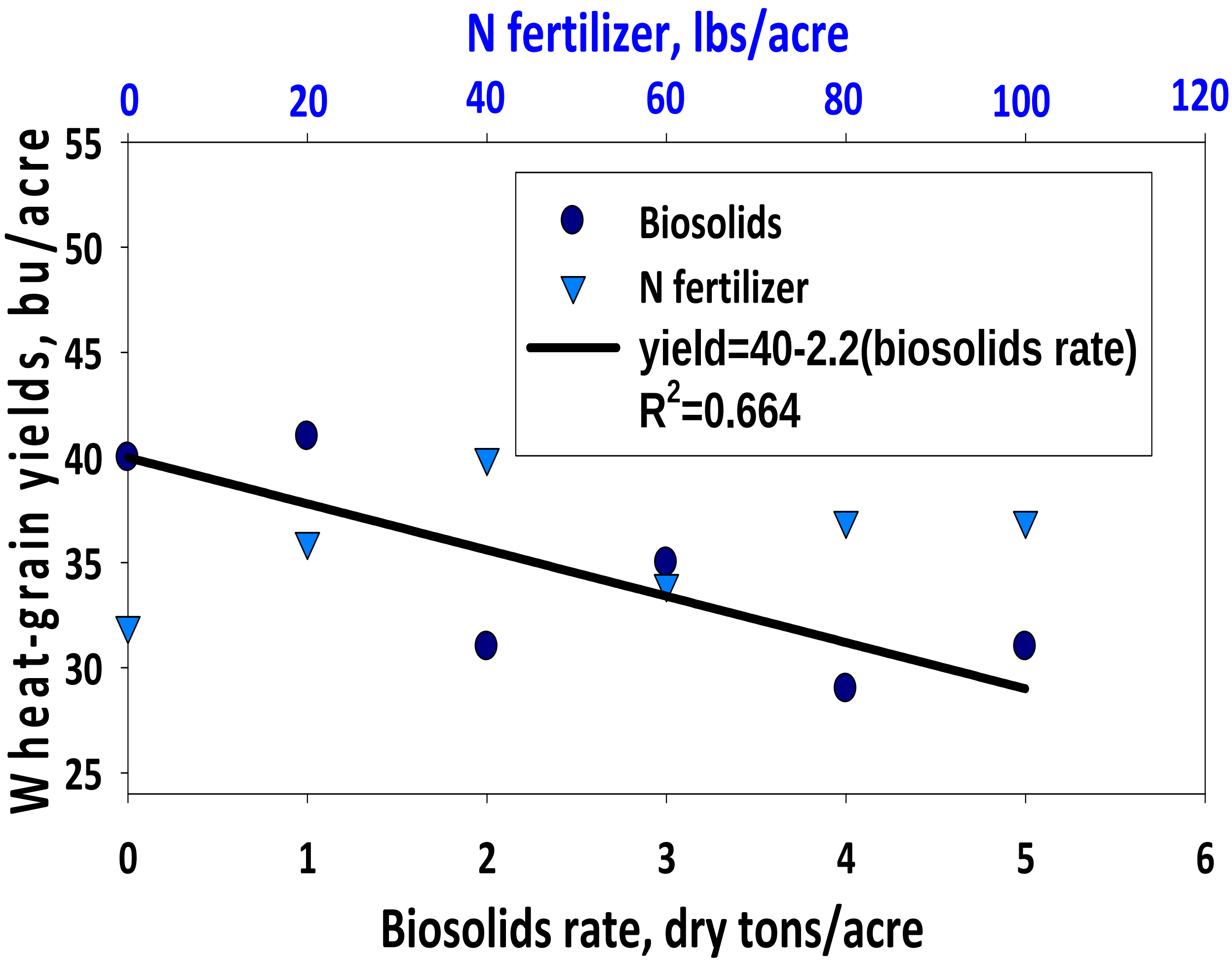
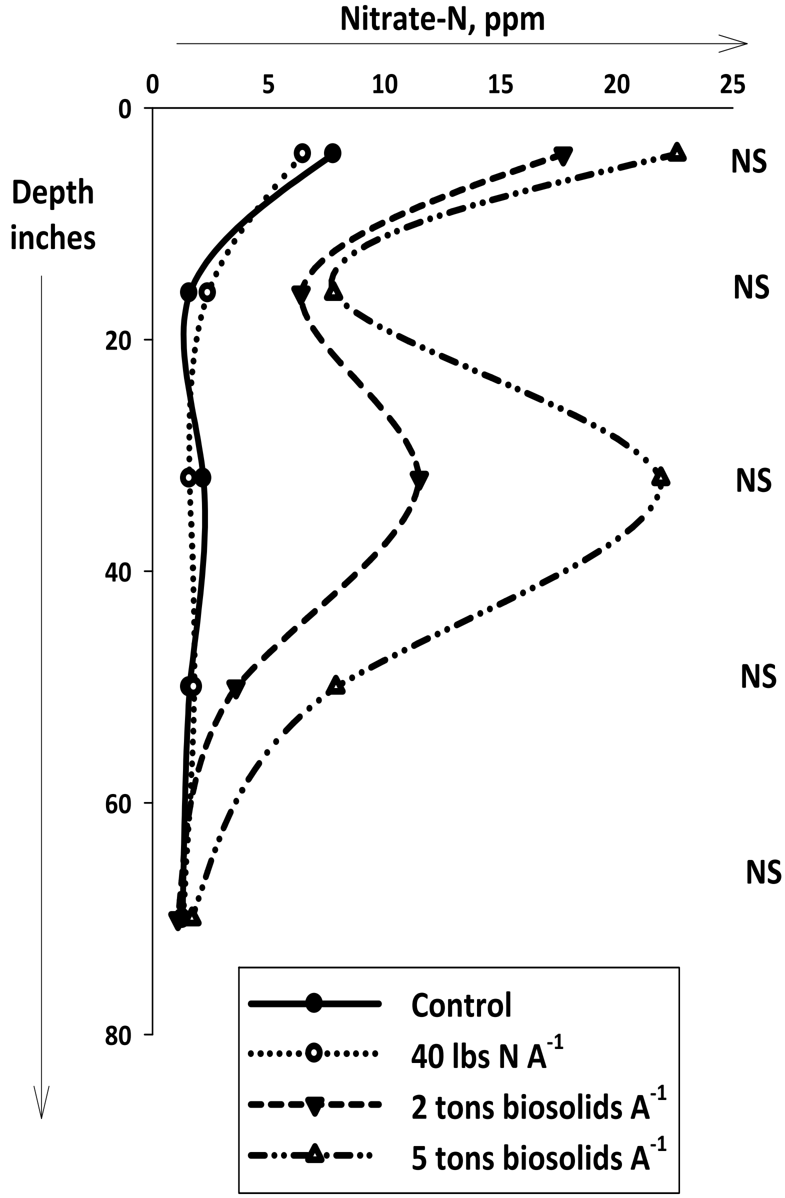


Figure 2. North Bennett harvest soil nitrate-N, 2007-8.



NS = non significant; * = significance at the 5% probability level.