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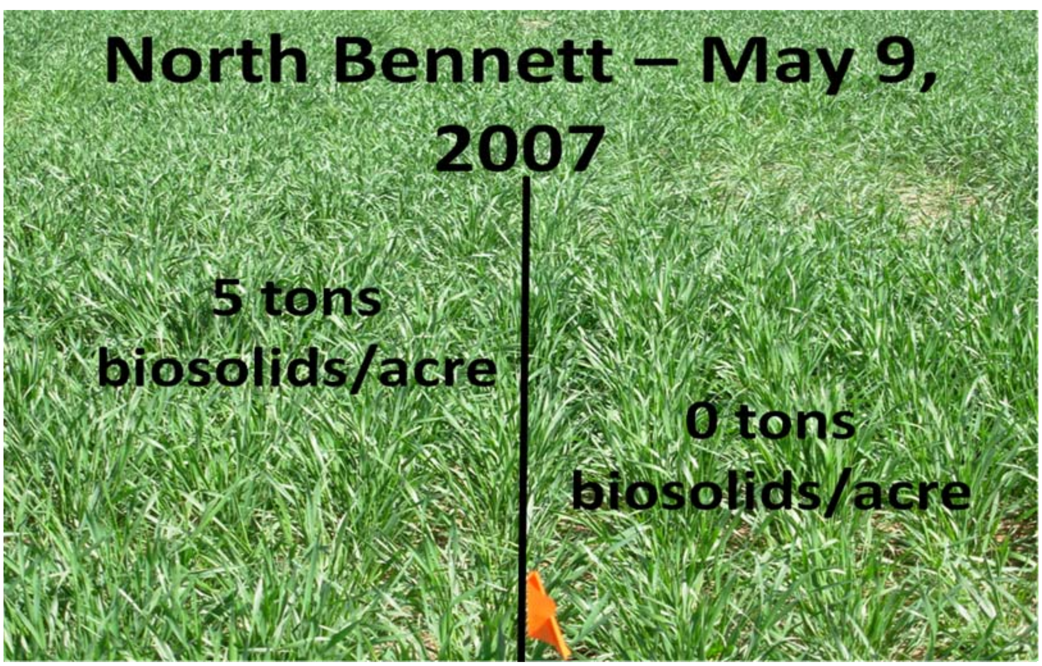
Application of Anaerobically Digested Biosolids to Dryland Winter Wheat 2006-2007 Results



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APPLICATION OF ANAEROBICALLY DIGESTED BIOSOLIDS TO DRYLAND WINTER WHEAT 2006-2007 RESULTS

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INTRODUCTION

The application of biosolids to lands in EPA Region 8 (includes Colorado) is the major method of biosolids disposal, with 85% of the material being reused (USEPA, 2003). This disposal method 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-sixth year, has provided valuable information on the effects of continuous biosolids applications to dryland winter wheat. Previous research has shown that Littleton/Englewood biosolids is an effective alternative to commercial nitrogen (N) fertilizer with respect to grain production and nutrient content of winter wheat (Barbarick et al., 1992). However, as with other N fertilizers, 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 to 3 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 (*Triticum aestivum* L., 'Prairie Red') 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 2006-07 growing season were established in August 1994. 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 (80% solids, Table 1) at rates of 0, 1, 2, 3, 4, and 5 dry tons A^{-1} on 31 July and 1 August 2006, respectively. The same plots received biosolids and N fertilizer, at the above rates, in August 1994, 1996, 1998, 2000, 2002, 2004, and 2006. 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 1994, 1996, and 1998 growing seasons, and 'Prairie Red' during the 2000, 2002, 2004, and 2006 seasons.

At harvest (12 July 2007), we measured grain yield and protein content. We estimated net income using $9.65 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, since this is the most common N fertilizer used by wheat-fallow farmers in Eastern Colorado. The biosolids and its application are currently free. Grain and straw were also collected and analyzed for total cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), molybdenum (Mo), nickel (Ni), 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 2006-07 crop year only. The reader is reminded that the 2006-7 North Bennett plots received biosolids at the same application rates in August 1994, 1996, 1998, 2000, 2002, 2004, and July 2006. Considering these six prior years and the current application, the recommended 2 dry tons A^{-1} biosolids rate for the 2006-07 growing season represents a cumulative addition of 14 dry tons A^{-1} biosolids for the life of the experiment.

RESULTS AND DISCUSSION

Grain Yields, Protein Content, and Estimated Income

Most of the North Bennett grain yields were above the Adams County average yield of 30 bu A^{-1} (Table 2). Increasing nitrogen rates significantly decreased grain production and increased grain-protein content while biosolids had no effect. Nutrient application as N fertilizer 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 decrease in yield with increasing N fertilizer application resulted in greater grain protein content, illustrated as a concentrating effect. Although not significant, a similar trend was observed with increasing biosolids application.

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. The recommended rate of 2 dry tons biosolids A^{-1} produced a return greater than that of the 40 lbs N fertilizer A^{-1} treatment (a comparable N application rate; \$386 versus \$331 A^{-1}, respectively). This trend was also similar to previous years where economic return differences resulted from the fact that 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 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

Increasing N fertilizer significantly increased grain Cu and Zn, and decreased Mo concentrations (Table 3); N fertilizer increased straw Cu content (Table 4). Increasing biosolids rate increased grain Zn content and straw Cu and Zn concentrations. Overall, biosolids-treated plots had greater amounts of grain Zn and straw Cr and Ni as compared to those on N-treated plots. 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

The recommended 2 dry tons biosolids A^{-1} application rate did not significantly affect NO_3-N throughout the profile as compared to either the control or the 40 lbs N A^{-1} rate (Figure 2). This rate resulted in approximately less than 5 ppm NO_3-N throughout the soil profile. Applicators could fertilize with biosolids if soil NO_3-N concentrations within the top foot of soil are less than approximately 15 mg kg^{-1}, according to Colorado State University fertilizer recommendation guidelines (Davis et al., 2005).

As compared to other treatments, the 5 dry tons biosolids A^{-1} application rate significantly increased NO_3-N in the 0-8, 8-24 and 60-80-inch depths. This continuous application rate produced soil NO_3-N levels from 5 to 10 ppm throughout the profile. The NO_3-N is moving into the root zone and possibly below the root zone as compared to the control.

SUMMARY

North Bennett grain yields were above the Adams County average yield of 30 bu A^{-1}. Increasing N fertilizer decreased grain yields and increased the grain protein while biosolids had no significant effect.

On average, the estimated net return to biosolids was greater than N fertilizer application. The recommended 2 dry tons A^{-1} rate produced an economic return greater than that of the 40 lbs N A^{-1} treatment. This trend was similar to previous findings where biosolids usage provided a greater economic advantage.

Increasing N fertilizer rates affected grain Cu, Mo, and Zn and straw Cu concentrations. Increasing biosolids rates resulted in increased grain Zn but did not affect straw metal concentrations. Increasing biosolids rate caused an increase in grain Zn concentration and straw Cu and Zn. Compared to N fertilizer, biosolids produced higher grain Zn and higher straw Cr and Ni levels. The increase in grain Zn content due to increasing biosolids application can be viewed as positive since this soil 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 recommended 2 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} rate. Application of 5 dry tons biosolids A^{-1} at the North Bennett site resulted in increased NO_3-N at 0-8, 8-24, and 60-80 inches. All NO_3-N concentrations were less than 10 ppm.

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 a 2 to 3 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} (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 2006-7 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 (%)	4.28	86		
NO_3-N (%)	<0.01	---		
NH_4-N (%)	0.52	10		
Solids (%)	80.3	---		
P (%)	2.43	49		
Ag (mg kg^{-1})[†]	0.33	0.00066		
As "	2.1	0.0042	41	75
Ba "	62.9	0.13		
Be "	0.03	0.00006		
Cd "	1.54	0.0031	39	85
Cr "	14.3	0.029	1200	3000
Cu "	458	0.92	1500	4300
Pb "	11.8	0.024	300	840
Hg "	0.19	0.0038	17	57
Mn "	174	0.35		
Mo "	23.4	0.047	Not finalized	75
Ni "	7.1	0.014	420	420
Se "	0.13	0.00026	36	100
Zn "	165	0.33	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, protein, and projected income at North Bennett, 2006-7.

N fert. lbs. A^{-1}	Biosolids[†] dry tons A^{-1}	Yield bu A^{-1}	Protein %	Fert. cost[‡] \$ A^{-1}	Income - fert. cost \$ A^{-1}
0		49	11.6	0	473
20		44	12.9	8	417
40		36	15.0	16	331
60		33	14.5	24	294
80		28	17.6	32	238
100		28	16.6	40	230
Mean[§]		34	15.3	18	308
LSD N rate[§]		9** [¶]	2**		
	0	49	11.0	0	473
	1	46	13.8	0	444
	2	40	16.3	0	386
	3	42	15.4	0	405
	4	36	17.3	0	347
	5	39	16.9	0	376
Mean[§]		41	15.9	0	332
LSD biosolids rate		NS	NS		
N vs. biosolids[§]		NS	NS		

† Identical biosolids applications were made in 1994, 1996, 1998, 2000, 2002, 2004, and 2006; therefore, the cumulative amount is 7 times that shown.

‡ The price for anhydrous NH_3 was considered to be \$.38 lb^{-1} N. The biosolids and its application are currently free. We used a grain price of \$9.65 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, 2006-07.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}†	Cd	Cr	Cu	Pb	Mo	Ni	Zn
		-----------	-----------	mg kg^{-1}	------	-----------	----------	-----------
0		0.076	ND	5.8	ND	0.65	1.00	14
20		0.061	ND	4.2	ND	0.50	0.65	12
40		0.065	ND	4.8	ND	0.39	0.90	14
60		0.063	ND	4.6	ND	0.56	1.12	14
80		0.062	ND	5.8	ND	0.31	0.79	19
100		0.073	ND	5.5	ND	0.36	0.87	18
Mean§		0.065		5.0		0.42	0.86	15
Sign. N rates		NS		*		*	NS	**
LSD				1.2		0.16		6
	0	0.067	ND	3.7	ND	0.72	0.61	13
	1	0.063	ND	4.6	ND	0.51	0.71	15
	2	0.076	ND	5.1	ND	0.40	0.91	17
	3	0.068	ND	5.4	ND	0.39	1.24	18
	4	0.046	ND	5.5	ND	0.40	0.77	19
	5	0.067	ND	5.3	ND	0.31	0.82	19
	Mean	0.064		5.2		0.40	0.89	17
	Sign. biosolids rates	NS		NS		NS	NS	**
	LSD							3
	N vs bio-solids	NS		NS		NS	NS	*

† Identical biosolids applications were made in 1994, 1996, 1996, 2000, 2002, 2004, and 2006; therefore, the cumulative amount is 7 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, 2006-07.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}†	Cd -----------	Cr -----------	Cu mg kg^{-1}	Pb ------	Mo -----------	Ni ----------	Zn -----------
0		0.041	0.30	2.0	ND	0.73	0.46	1.8
20		0.052	0.13	2.0	ND	0.63	0.37	1.3
40		0.050	0.17	2.5	ND	0.72	0.46	2.4
60		0.035	ND	2.4	ND	0.96	0.42	2.7
80		0.056	0.08	2.9	ND	0.45	0.42	2.5
100		0.072	0.07	3.0	ND	0.71	0.42	2.5
Mean§		0.053	0.09	2.5		0.69	0.42	2.3
Sign. N rates		NS	NS	*		NS	NS	
LSD				0.8				
	0	0.032	0.16	1.4	ND	0.85	0.40	1.0
	1	0.046	0.07	2.2	ND	0.64	0.40	2.3
	2	0.033	0.29	2.8	ND	0.66	0.48	2.6
	3	0.070	0.19	3.2	ND	0.33	0.45	3.3
	4	0.043	0.14	3.2	ND	0.77	0.46	4.2
	5	0.069	0.16	3.4	ND	0.77	0.47	4.9
	Mean	0.052	0.17	3.0		0.63	0.45	3.5
	Sign. biosolids rates	NS	NS	**		NS	NS	**
	LSD			0.7				2.1
	N vs bio-solids	NS	*	NS		NS	*	NS

† Identical biosolids applications were made in 1994, 1996, 1996, 2000, 2002, 2004, and 2006; therefore, the cumulative amount is 7 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 2007 as affected by either N fertilizer or biosolids application.

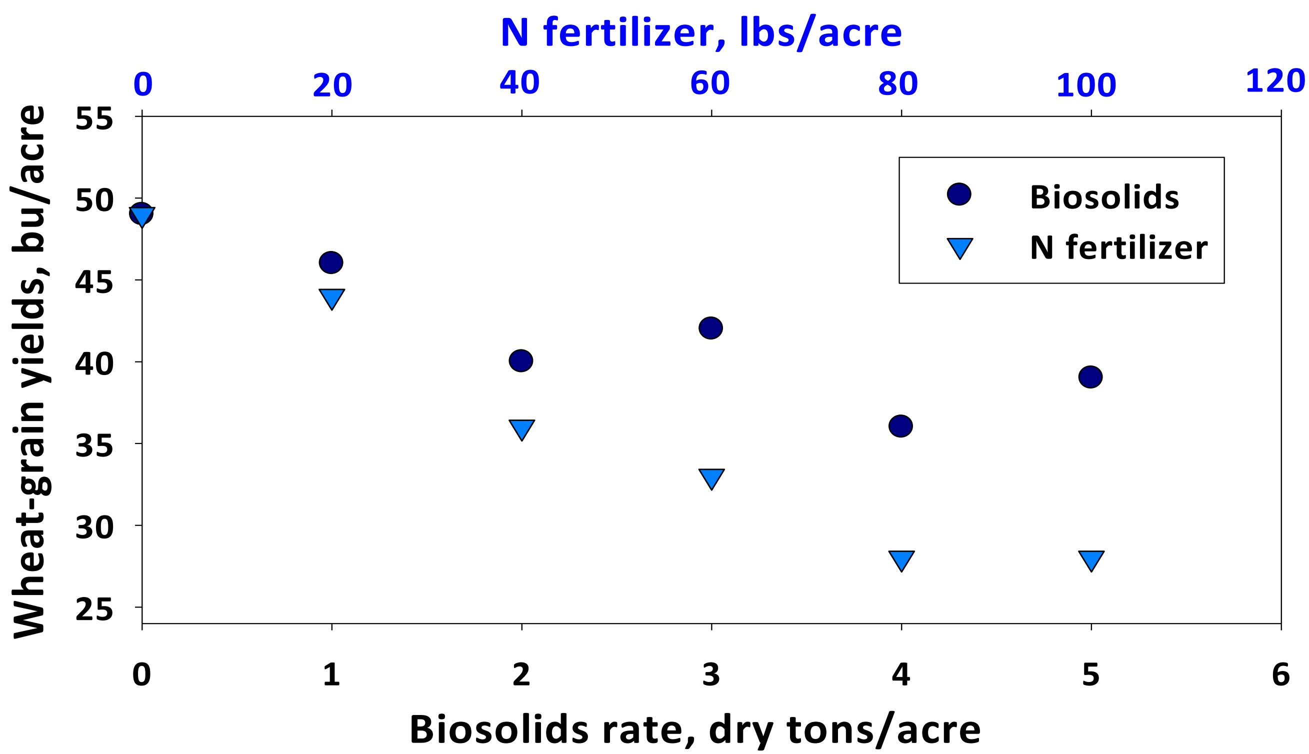
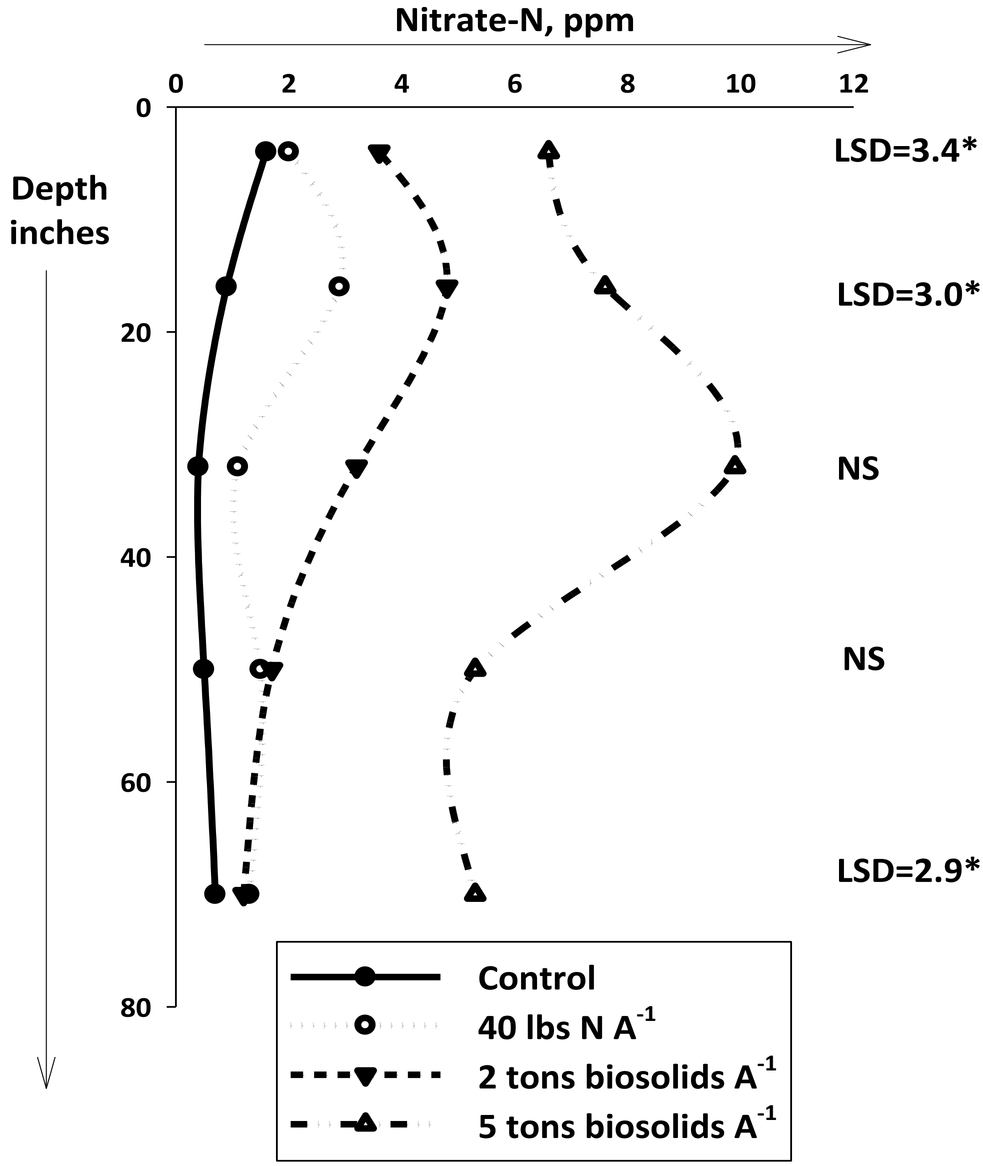


Figure 2. North Bennett harvest soil nitrate-N, 2006-7.



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