TR 01-5

APPLICATION OF ANAEROBICALLY DIGESTED BIOSOLIDS TO DRYLAND WINTER WHEAT[ð]

1999-00 Technical Report

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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 80% of the material being reused (NBP, 1999). This recycling method can greatly benefit municipalities by recycling plant nutrients in an environmentally sound manner (Barbarick et al., 1992).

Our long-term biosolids project, now in its nineteenth year, has provided valuable information on the effects of continuous biosolids application 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 exceeding the N needs of the crop result in an accumulation of soil nitrate. Biosolids contain organic N, which acts as a slow release N source and provides a more constant supply of N during the critical grain-filling period versus commercial nitrogen fertilizer. We continue to recommend a 2 to 3 dry tons biosolids A^{-1} as the most viable land-application rate for similar biosolids nutrient characteristics and crop yields.

The overall objective of our research is to compare the effect of Littleton/Englewood (L/E) biosolids and commercial N fertilizer rates on: (a) dryland winter wheat (<u>Triticum</u> <u>aestivum</u> L., 'Prairie Red') grain production, (b) estimated income, (c) grain and straw elemental content, and (d) soil NO_3-N accumulation.

MATERIALS AND METHODS

The North Bennett experimental plots used in the 1999-00 growing season were established in August 1993; treatments were applied for the fourth time on 4 May 1999 when we acquired the baseline soil samples. The soil is classified as a Weld loam, Aridic Argiustoll. The land is farmed using minimum-tillage practices.

We applied biosolids (78% solids, Table 1) at rates of 0, 1, 2, 3, 4, and 5 dry tons A^{-1} and N fertilizer (urea) at rates of 0, 20, 40, 60, 80, and 100 lbs N A^{-1} on 26 and 27 July 1999. The same plots received biosolids and N fertilizer (46-0-0), at the above rates, in August 1993, 1995, and 1997. 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 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, 1995, and 1997 growing season. During the 1999-00 growing season the site was cropped with the winter wheat cultivar 'Prairie Red'.

At harvest (5 July 2000), we measured grain yield and protein content. Grain and straw were analyzed for nitrogen (N), phosphorus (P), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) concentrations. We estimated gross income using prices paid for wheat in January 2001 and subtracted the cost for either fertilizer or biosolids. We applied urea fertilizer, but based our estimated gross income calculations on the cost of anhydrous ammonia, since this is the main N fertilizer used by wheat-fallow farmers in Eastern Colorado. The biosolids and its application are currently free.

Following harvest in July 2000, 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 1999-00 crop year only. The reader is reminded that the 1999-00 North Bennett plots received biosolids at the same application rates in August 1993, 1995, and 1997. Considering these three prior years and the current application, the recommended 2 dry tons A^{-1} biosolids rate for the 1999-00 growing season represents a cumulative addition of 8 dry tons A^{-1} biosolids for the life of the experiment.

RESULTS AND DISCUSSION

Grain Yields, Protein Content, and Estimated Income

Since its inception, North Bennett yield and protein content averages from both N fertilizer and biosolids plots are 43 bu A^{-1} and 13.2%, respectively. Overall, the 1999-00 crop had a yield equal to the site average and a protein content (13.8%) greater than the site average. Grain yields averaged higher than the long-term Adams County average (30 bu A^{-1}) on both N fertilizer (44 bu A^{-1}) and biosolids (41 bu A^{-1}) treated plots (Table 2). This is attributable to the well-managed crop residue which promoted efficient precipitation storage during fallow and by precipitation received in the Spring 2000. Increasing N fertilizer rate did not increase grain yield, but did increase protein content. Increasing biosolids rate increased both yield and protein content. There were no yield or protein differences between the N fertilizer and biosolids treatments.

On average, the biosolids treated plots produced a \$7 A^{-1} greater estimated income versus the N-treated plots (Table 2). This finding is similar to all previous observations at this site which showed that biosolids produced a greater estimated income versus the N-treated plots. The recommended rate of 2 dry tons biosolids A^{-1} produced a similar return (\$150 A^{-1}) compared to the 40 lbs N fertilizer A^{-1} (\$152 A^{-1}) treatment. This trend was similar to the 1993-94 and 1995-96 findings.

Biosolids Application Recommendation

To better determine the N equivalency of the biosolids, we compared yields from N and biosolids plots at North Bennett. The 2000 data (Figure 1) indicates that one dry ton of biosolids was equivalent to 19 lbs N A^{-1}, as determined by comparing both equations on Figure 1 to each other. In both 1995 and 1999 we found one dry ton biosolids A^{-1} to be equivalent to 18 lbs N A^{-1}. These values could help in planning long-term biosolids applications.

Grain and Straw Nutrients and Trace Metals

Increasing N fertilizer only affected grain P, while increasing biosolids rate increased grain Ni and N concentration (Table 3). There were no observed differences between grain from the N fertilized and biosolids plots.

Increasing N fertilizer rate increased straw Cu and N concentrations, while increasing biosolids rate increased straw Zn, Cu, Pb, and N concentrations (Table 4). Compared with N fertilizer, biosolids resulted in slightly higher straw P and Zn concentrations.

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 affect NO_3-N throughout the profile as compared to the control or the 40 lbs N A^{-1} rate (Figure 2). In addition, this rate did not increase NO_3-N above 3 ppm anywhere in the profile.

The 5 dry tons biosolids A^{-1} application rate significantly increased NO_3-N within the top 24 inches of soil as compared to the control, 40 lbs N A^{-1}, and 2 dry tons biosolids A^{-1} application rate. However, the 5 dry tons biosolids A^{-1} application rate did not produce any NO_3-N levels above 6 ppm.

SUMMARY

Nitrogen fertilizer and biosolids applications produced higher yields at the 1999-2000 North Bennett site than the long-term Adams County average and exceeded the North Bennett site average yields (1993-2000). This was primarily attributable to good residue management which resulted in good precipitation storage during fallow and the Spring 2000. Estimated income was higher, on average, with biosolids application versus N fertilizer, and the 2 dry tons A^{-1} rate produced an economic return comparable to the 40 lbs N fertilizer A^{-1} treatment. Protein content was higher than the long-term average, and resulted in protein premiums being paid for both N and biosolids treated plots.

Increasing N fertilizer rate affected grain P concentration, and increased straw Cu and N concentrations. Increasing biosolids rate resulted in increased grain Ni and N concentrations, and increased straw Zn, Cu, Pb, and N concentrations. Compared to N fertilizer, biosolids application only increased straw P and Zn concentrations. All metal concentrations in wheat plants were below the levels considered harmful to livestock.

The recommended application rate of 2 dry tons biosolids A^{-1} resulted in soil NO_3-N accumulations comparable to the control or 40 lbs N A^{-1} rate. Application of 5 dry tons biosolids A^{-1} at the North Bennett site resulted in a greater NO_3-N accumulation within the top 24 inches of soil as compared to the control, 40 lbs N A^{-1}, and 2 dry tons biosolids A^{-1} application rate. However, the NO_3-N concentration did not exceed 6 ppm for any treatment at any depth throughout the profile. Three applications of biosolids have not led to soil NO_3-N accumulation.

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, and Zn as beneficial nutrients. We continue to recommend a 2 to 3 dry tons biosolids application A^{-1}. The 1999-00 growing season results show that 1 dry ton biosolids A^{-1} is equivalent to 19 lbs N A^{-1}. In both 1995 and 1999 we found one dry ton biosolids A^{-1} to be equivalent to 18 lbs N A^{-1}. These values 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.

REFERENCES

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Table 1. Average composition of Littleton/Englewood sludge applied in 1999-00 compared to the Grade I and II biosolids limits.

Property	Dry Weight Concentration Littleton/Englewood	Limit Grade I Biosolids[¶]	Grade II Biosolids
Organic N (%)	0.74		
NO_3-N (%)	<0.01		
NH_4-N (%)	0.34		
Solids (%)	78		
P (%)	1.02		
As (mg kg^{-1})[ð]	2.72	41	75
Cd "	5.6	39	85
Cr "	36	1200	3000
Cu "	256	1500	4300
Pb "	46.3	300	840
Hg "	1.23	17	57
Mo "	8.0	Not finalized	75
Ni "	15.2	420	420
Se "	4.6	36	100
Zn "	198	2800	7500

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

ð mg kg^{-1} = parts per million.

Table 2. Effects of N fertilizer and biosolids on wheat yield, protein, and projected income at North Bennett, 1999-00.

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		26	11.9	0	91
20		40	12.5	9	131
40		47	12.9	13	152
60		46	13.8	18	151
80		42	15.0	22	132
100		45	14.4	26	139
Mean§		44	13.9	18	143
LSD N rate§		NS¶	1.8*		
	0	28	11.8	0	98
	1	34	12.0	0	119
	2	41	13.3	0	150
	3	44	13.8	0	161
	4	42	14.6	0	154
	5	44	14.4	0	161
	Mean	41	13.6	0	150
	LSD biosolids rate	8*	1.6*		
	N vs. biosolids§	NS	NS		

† Identical biosolids applications were made in 1993, 1995, and 1997; therefore, the cumulative amount is 4 times that shown.

‡ The price for anhydrous NH_3 was considered to be \$.22 lb^{-1} N plus \$4.50 A^{-1} application charge. The biosolids and its application are currently free. The grain price was \$3.51 bu^{-1} for wheat with less than 13% protein and 3.67 bu^{-1} for wheat with greater than 13% protein.

§ 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.

Table 3. Effects of N fertilizer and biosolids rates on elemental concentrations of dryland winter wheat grain at North Bennett, 1999-00.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1} †	P g kg^{-1}	Zn	Cu	Ni mg kg^{-1}	Cd	Pb	N %
0		3.60	22	5.4	0.49	ND	ND	1.94
20		3.46	21	9.0	0.48	ND	0.09	2.07
40		3.44	19	5.9	0.49	ND	0.10	2.15
60		3.42	20	6.3	0.52	ND	0.08	2.33
80		3.56	26	5.1	0.54	ND	0.10	2.49
100		3.29	23	6.0	0.51	ND	0.15	2.40
Mean§		3.43	22	6.5	0.51	ND	0.10	2.29
Sign. N rates		*¶	NS	NS	NS		NS	NS
LSD		0.24						
	0	3.53	28	5.1	0.48	ND	0.15	1.89
	1	3.49	22	5.3	0.45	ND	0.07	1.96
	2	3.68	23	6.8	0.48	ND	0.28	2.21
	3	3.53	24	5.5	0.48	ND	0.16	2.28
	4	3.78	25	5.8	0.52	ND	0.14	2.44
	5	3.68	26	6.5	0.55	ND	0.18	2.36
	Mean	3.63	24	6.0	0.50	ND	0.17	2.25
	Sign. biosolids rates	NS	NS	NS	**		NS	**
	LSD				0.09			0.29
	N vs bio-solids	NS	NS	NS	NS		NS	NS

† Identical biosolids applications were made in 1993, 1995, and 1997; therefore, the cumulative amount is 4 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, 1990-00.

N fert. lbs N A^{-1}	Bio-solids dry tons A^{-1}[†]	P g kg^{-1}	Zn	Cu	Ni mg kg^{-1}	Cd	Pb	N %
0		0.86	3.7	1.3	ND	ND	0.23	0.79
20		0.82	3.9	1.6	ND	ND	0.16	0.65
40		0.81	4.2	1.7	ND	ND	0.15	0.62
60		0.66	3.5	1.8	ND	ND	0.26	0.70
80		0.77	4.8	2.2	ND	ND	0.22	0.86
100		0.71	4.6	2.2	ND	ND	0.34	0.83
Mean[§]		0.75	4.2	1.9	ND	ND	0.23	0.73
Sign. N rates		NS[¶]	NS	**			NS	*
LSD				0.6				0.23
	0	0.88	3.9	1.4	ND	ND	0.31	0.54
	1	0.83	3.5	1.3	ND	ND	0.15	0.53
	2	0.95	4.7	1.8	ND	ND	0.33	0.67
	3	0.73	4.3	1.9	ND	ND	0.28	0.70
	4	1.11	7.2	2.7	ND	ND	0.30	0.97
	5	0.90	6.3	2.4	ND	ND	0.14	0.88
	Mean	0.90	5.2	2.0	ND	ND	0.24	0.75
	Sign. bio-solids rates	NS	**	**			*	**
	LSD		3.3	1.0			0.17	0.27
	N vs bio-solids	*	*	NS			NS	NS

† Identical biosolids applications were made in 1993, 1995, and 1997; therefore, the cumulative amount is 4 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. 2000 North Bennett grain yields

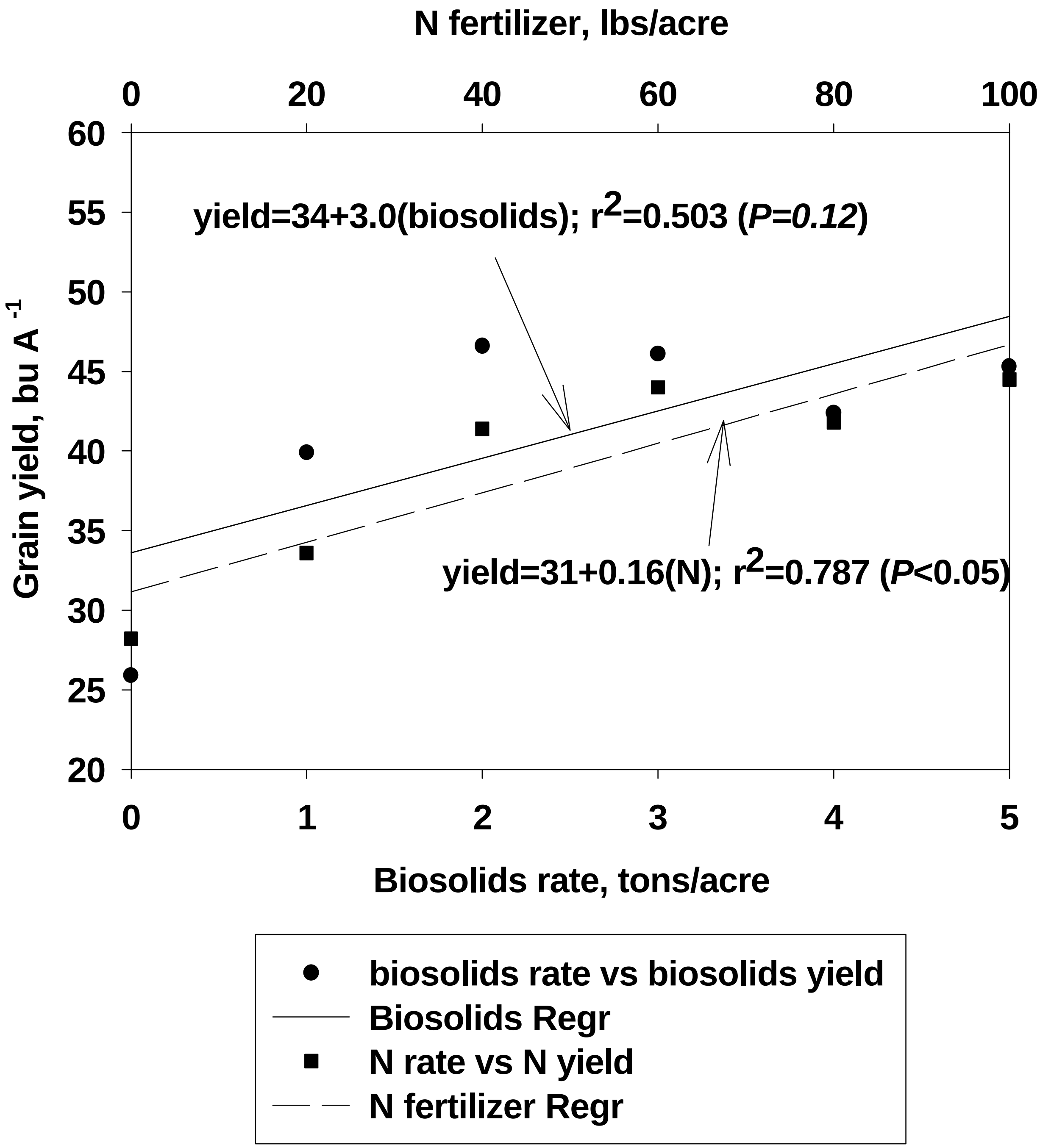
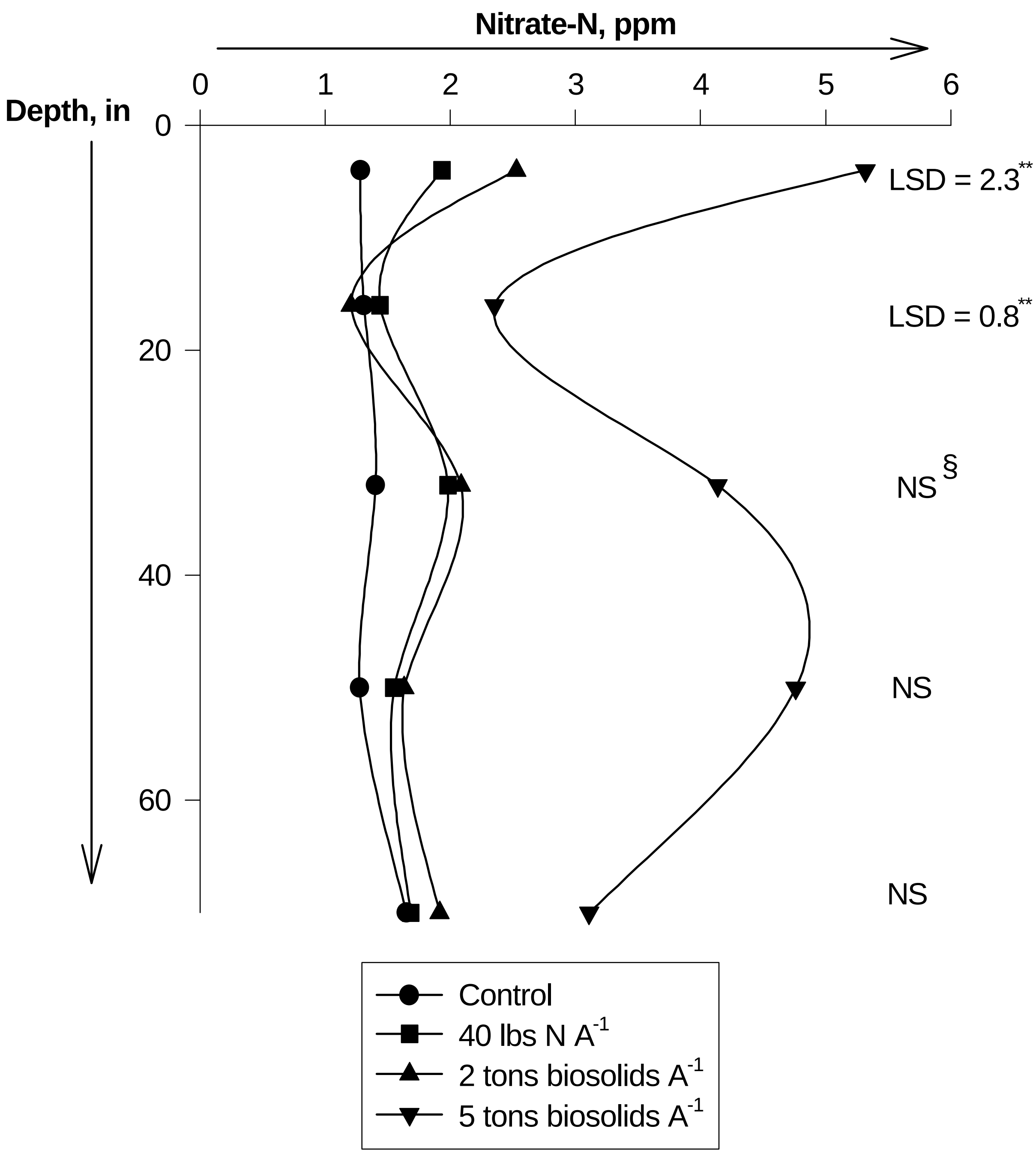


Figure 2. North Bennett Harvest Soil Nitrogen 1999-00.



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