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Application of Anaerobically Digested Biosolids to Dryland Winter Wheat

J.A. Ippolito
K.A. Barbarick
R. Jepson

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

1998-99 Technical Report

J.A. Ippolito, K.A. Barbarick, and R. Jepson[§]

[B] This project was supported by the Colorado Agricultural Experiment Station and the cities of Littleton and Englewood, Colorado.

[§] Research Associate and Professor, Department of Soil and Crop Sciences, and former Cooperative Extension Agent, Adams County, respectively.

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, 2000). 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 eighteenth 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 biosolids and commercial N fertilizer rates on: (a) dryland winter wheat (Triticum aestivum L., 'TAM 107') 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 1998-99 growing season were established in August 1994; treatments were applied for the third time on 1 June 1998 when we acquired the baseline soil samples. The soil is classified as a Weld loam, Abruptic Aridic Paleustoll. The land is farmed using minimum-tillage practices.

We applied biosolids (68% 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 27 and 28 July 1998. The same plots received biosolids and N fertilizer (46-0-0), at the above rates, in August 1994 and 1996. 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 has been cropped with the winter wheat cultivar ‘TAM 107' since inception.

At harvest (13 July 1999), we measured grain yield and protein content. Grain and straw were analyzed for 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 2000 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 1999, 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 1998-99 crop year only. The reader is reminded that the 1998-99 North Bennett plots received biosolids application rates in August 1994, 1996, and 1998. Considering these two prior years and the current application, the recommended 2 dry tons A^{-1} biosolids rate for the 1998-99 growing season represents a cumulative addition of 6 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 12.3%, respectively. Overall, the 1998-99 crop had a greater yield (82 bu A^{-1}) and a lower protein content (9.7%) as compared to the site averages. Greater yields led to a dilution of the grain protein content. Grain yields also averaged higher than the long-term Adams County average (30 bu A^{-1}) on both N fertilizer (82 bu A^{-1}) and biosolids (83 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 monsoon precipitation received in May 1999. Increasing N fertilizer rate increased both grain yield and protein content, whereas increasing biosolids rate increased only yield. There were no yield or protein differences between the N fertilizer and biosolids treatments.

On average, the biosolids treated plots produced a \$20 A^{-1} greater estimated income versus the N-treated plots (Table 2). This was similar to the 1997-98 findings, which indicated biosolids producing a \$21 A^{-1} greater estimated income versus the N-treated plots. The recommended rate of 2 dry tons A^{-1} produced a \$29 A^{-1} greater return compared to the 40 lbs N A^{-1} treatment. Again, this trend was similar to the 1997-98 findings, with the recommended rate of 2 dry tons A^{-1} producing a \$19 A^{-1} greater return compared to the 40 lbs N A^{-1} treatment.

Biosolids Application Recommendation

To better determine the N equivalency of the biosolids, we compared yields from N and biosolids plots at North Bennett. The 1999 data (Figure 1) indicates that one dry ton of biosolids was equivalent to 18 lbs N A^{-1}, as determined by comparing both equations on Figure 1 to each other. In 1994 and 1995 we found one dry ton biosolids A^{-1} to be equivalent to 40 and 25 lbs N A^{-1}, respectively. These values supply biosolids applicators with a biosolids N fertilizer equivalency.

Grain and Straw Nutrients and Trace Metals

Increasing N fertilizer only increased grain N, while increasing biosolids rate decreased grain Ni concentration (Table 3). This decrease in Ni concentration may be due to a dilution effect caused by the higher yields as biosolids rate increased (Table 2). There were no observed differences between grain from the N fertilized and biosolids plots.

Increasing N fertilizer rate increased straw Cu, Ni, Pb, and N concentrations (Table 4). Also, the addition of 20 lbs N A^{-1} increased straw P concentration as compared to the 80 and 100 lbs N A^{-1} rates. As biosolids application increased, straw P, Zn, and N concentrations were increased. Compared with N fertilizer, biosolids resulted in a slightly higher straw P concentration.

All grain and straw metal concentrations were well below the levels considered harmful to livestock except for grain Cu. According to the National Research Council (1980), the maximum tolerable dietary intake of Cu for sheep is 25 mg kg^{-1}. North Bennett grain Cu concentrations were 25 and 29 mg kg^{-1} for the 40 lbs N A^{-1} and 1 dry ton biosolids A^{-1} treatments, respectively. It is unknown why the grain Cu was higher for these two applications.

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 5 ppm anywhere in the profile.

The 5 dry tons biosolids A^{-1} application rate significantly increased NO_3-N within the top 8 inches of soil as compared to the control and 40 lbs N A^{-1} rate, but did not exceed 5 ppm in any depth increment.

SUMMARY

The 1998-99 North Bennett N fertilizer and biosolids application rates produced higher yields than the long-term Adams County average and site average yields. This was mostly attributable to residue management that resulted in good precipitation storage during fallow and excessive May 1999 precipitation. Estimated income was higher, on average, with biosolids application versus N fertilizer, and the 2 dry tons A^{-1} rate produced a higher return as compared to the 40 lbs N fertilizer A^{-1} treatment. Protein content was lower than average, due mostly to a dilution effect caused by the increased yields.

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

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 8 inches of soil as compared to the control and 40 lbs N A^{-1} rate. However, the NO_3-N concentration did not exceed 5 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}. 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 1998-99 compared to the Grade I and II biosolids limits.

Property	Dry Weight Concentration Littleton/Englewood	Limit Grade I Biosolids[¶]	Limit Grade II Biosolids
Organic N (%)	1.12		
NO_3-N (%)	<0.01		
NH_4-N (%)	0.43		
Solids (%)	68		
P (%)	1.18		
As (mg kg^{-1})[B]	2.08	41	75
Cd "	3.4	39	85
Cr "	24	1200	3000
Cu "	236	1500	4300
Pb "	31.2	300	840
Hg "	1.61	17	57
Mo "	5.5	Not finalized	75
Ni "	15.2	420	420
Se "	9.4	36	100
Zn "	301	2800	7500

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

[B] mg kg^{-1} = parts per million.

Table 2. Effects of N fertilizer and biosolids on wheat yield, protein, and projected income at North Bennett, 1998-99.

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		66	8.8	0	172
20		72	9.2	9	178
40		77	9.0	13	187
60		84	9.3	18	200
80		85	11.0	22	199
100		94	10.1	26	218
Mean[§]		82	9.7	18	196
LSD N rate[§]		10	1.4		
	0	65	9.0	0	169
	1	72	8.9	0	187
	2	83	10.0	0	216
	3	84	9.9	0	218
	4	89	9.5	0	231
	5	88	10.5	0	229
	Mean	83	9.7	0	216
	LSD biosolids rate	14	NS		
	N vs. biosolids[§]	NS[¶]	NS		

[†] Identical biosolids applications were made in 1994, 1996, and 1998; therefore, the cumulative amount is 3 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 \$2.60 bu^{-1}. No protein premium was paid in January 2000.

[§] 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, 1998-99.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}[†]	P	Zn	Cu	Ni	Cd	Pb	N
		g kg^{-1}			mg kg^{-1}			%
0		3.4	17	14	0.63	0.05	0.36	1.60
20		3.5	17	15	0.80	0.13	0.41	1.67
40		3.5	17	25	0.86	0.07	0.18	1.68
60		3.6	18	14	0.62	0.05	0.32	1.67
80		3.5	18	20	0.75	0.11	0.27	1.96
100		3.5	18	18	0.82	0.07	0.32	1.84
Mean[§]		3.5	18	18	0.77	0.09	0.30	1.76
Sign. N rates		NS[¶]	NS	NS	NS	NS	NS	*
LSD								0.24
	0	3.5	18	19	0.88	0.11	0.27	1.65
	1	3.6	19	29	0.90	0.13	0.27	1.59
	2	3.7	19	16	0.74	0.11	0.23	1.81
	3	3.5	18	15	0.49	0.04	0.27	1.76
	4	3.6	19	17	0.68	0.09	0.27	1.69
	5	3.8	20	15	0.73	0.07	0.18	1.87
	Mean	3.7	19	18	0.71	0.09	0.24	1.74
	Sign. biosolids rates	NS	NS	NS	**	NS	NS	NS
	LSD				0.22			
	N vs bio-solids	NS	NS	NS	NS	NS	NS	NS

[†] Identical biosolids applications were made in 1994, 1996, and 1998; therefore, the cumulative amount is 3 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.

Table 4. Effects of N fertilizer and biosolids rates on elemental concentrations of dryland winter wheat straw at North Bennett, 1998-99.

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		0.36	2.0	1.4	0.76	0.11	0.60	0.32
20		0.46	2.2	1.5	0.75	0.09	0.51	0.35
40		0.37	2.0	1.4	0.53	0.09	0.64	0.35
60		0.43	2.3	1.5	0.55	0.07	0.64	0.37
80		0.33	2.3	1.6	0.79	0.09	0.74	0.39
100		0.34	2.4	1.8	0.90	0.09	0.55	0.41
Mean[§]		0.38	2.2	1.6	0.70	0.08	0.62	0.38
Sign. N rates		*[¶]	NS	**	**	NS	*	*
LSD		0.12		0.3	0.31		0.20	0.06
	0	0.47	2.2	1.6	0.99	0.20	0.60	0.35
	1	0.47	2.2	1.6	0.59	0.11	0.55	0.36
	2	0.42	2.3	1.6	0.81	0.15	0.73	0.37
	3	0.42	2.3	1.6	0.67	0.11	0.73	0.40
	4	0.51	2.7	1.8	0.84	0.11	0.64	0.45
	5	0.64	2.8	1.9	0.76	0.13	0.64	0.49
	Mean	0.49	2.5	1.7	0.73	0.12	0.66	0.42
	Sign. bio-solids rates	*	**	NS	NS	NS	NS	*
	LSD	0.14	0.6					0.11
	N vs bio-solids	*	NS	NS	NS	NS	NS	NS

[†] Identical biosolids applications were made in 1994, 1996, and 1998; therefore, the cumulative amount is 3 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.

Figure 1. North Bennett Grain Yields 98-99.

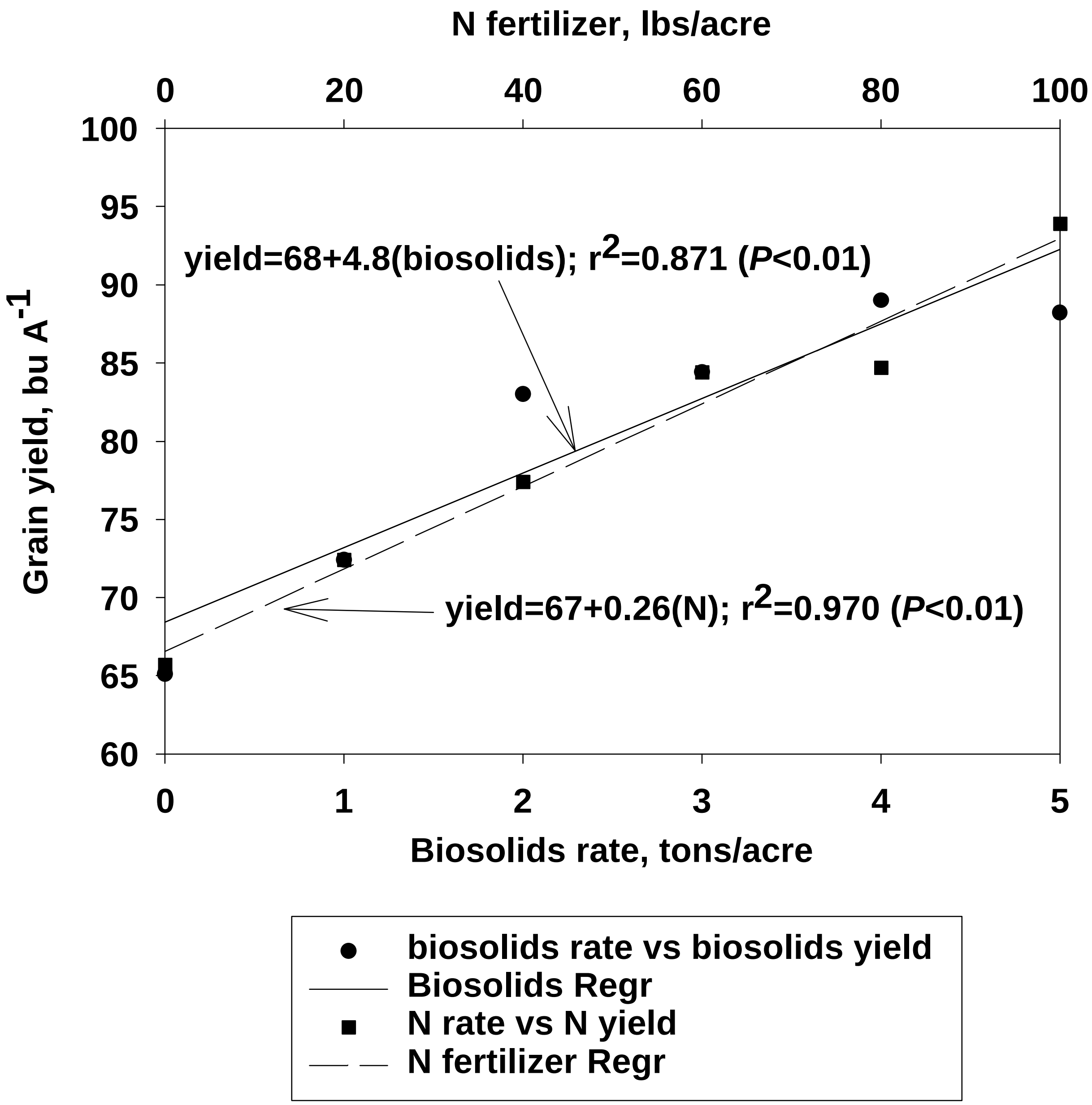
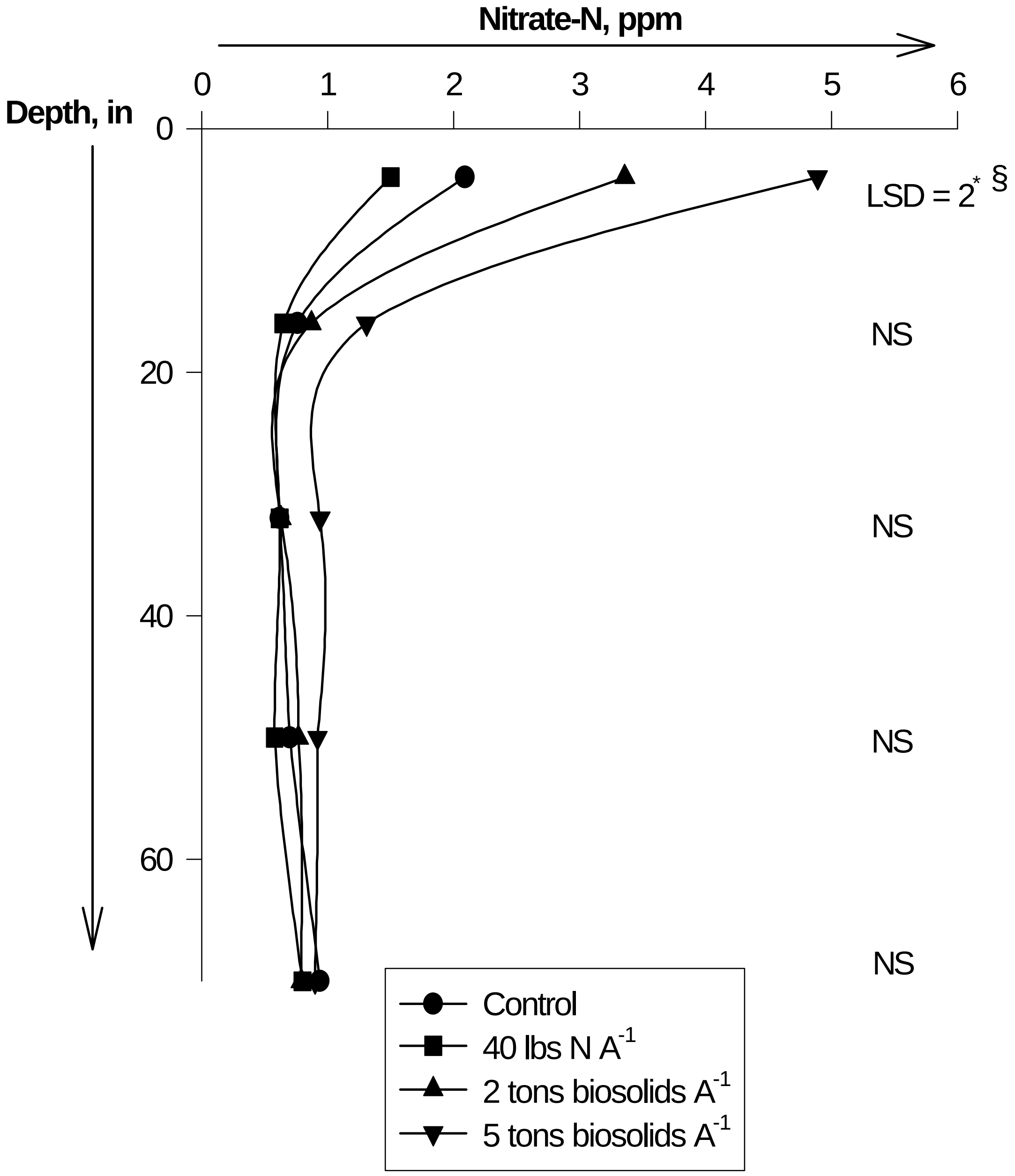


Figure 2. North Bennett Harvest Soil Nitrogen 98-99.



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