

## Appendix F

### Verifying biosolids N availability with grass N uptake research

Nitrogen uptake by a perennial grass crop provides an indirect estimate of the plant-available N supplied by biosolids. We have conducted research at a number of field sites to verify the performance of agronomic rate calculations. Perennial grasses are an ideal test crop for this research because :

- They are highly-efficient in taking up available N from the soil (low nitrate leaching losses)
- They are active in N uptake almost all year in western Oregon and Washington
- They exhibit consistent N uptake responses over a wide range of biosolids application rates (200 to 800 lb N/acre/yr).

**Field Research Method.** At each experimental location, we applied biosolids and measured the increase in above-ground N uptake (apparent N recovery) by the grass. At each site, grass N uptake was measured for the following treatments (3 to 4 replications per site):

- biosolids only (three application rates per site)
- N fertilizer only (urea or ammonium nitrate)
- no N fertilizer (unfertilized control)

**Calculation of N availability.** Biosolids N availability was estimated using grass N uptake data with the following equations:

Apparent N recovery for biosolids,  $ANR_{\text{biosolids}}$  (% of N applied) =

$$[(NUP_{\text{biosolids}} - NUP_{\text{nofert}})/NAPP_{\text{biosolids}}] * 100$$

where:

$NUP_{\text{biosolids}}$  = grass N uptake with biosolids, lb/acre

$NUP_{\text{nofert}}$  = grass N uptake without N fertilizer, lb/acre

$NAPP_{\text{biosolids}}$  = total N applied as biosolids, lb/acre

A similar equation was used for calculating apparent N recovery for fertilizer N:

Apparent N recovery for fertilizer N,  $ANR_{\text{fertilizer}}$  (% of N applied) =

$$[(NUP_{\text{fertilizer}} - NUP_{\text{nofert}})/NAPP_{\text{fertilizer}}] * 100$$

where:

$NUP_{\text{fertilizer}}$  = grass N uptake with N fertilizer, lb/acre

$NUP_{\text{nofert}}$  = grass N uptake without N fertilizer, lb/acre

$NAPP_{\text{fertilizer}}$  = total N applied as fertilizer, lb/acre

A “fertilizer N equivalent” for biosolids was then calculated, by assuming that the grass was equally efficient in utilizing plant-available N from biosolids or a fertilizer N source:

$$\text{Fertilizer N equivalent, FNE (\% of biosolids total N applied)} = (\text{ANR}_{\text{biosolids}}/\text{ANR}_{\text{fertilizer}}) * 100$$

where:

$\text{ANR}_{\text{biosolids}} =$  Apparent N recovery for biosolids, % of N applied

$\text{ANR}_{\text{fertilizer}} =$  Apparent N recovery for fertilizer N, % of N applied

Alternately, the relationship between biosolids N availability and fertilizer N availability can be expressed as a ratio:

$$\text{Fertilizer N Equivalent Ratio, FNER} = \text{ANR}_{\text{fertilizer}}/\text{ANR}_{\text{biosolids}}$$

where:

$\text{ANR}_{\text{fertilizer}} =$  Apparent N recovery for fertilizer N, % of N applied

$\text{ANR}_{\text{biosolids}} =$  Apparent N recovery for biosolids, % of N applied

### Example Calculation:

Fertilizer N was applied at a rate of 200 lb N/acre/yr. Biosolids applied at a rate of 400 lb total N/acre/yr. Measured grass N uptake was 200 lb/acre with biosolids, 220 lb/acre with fertilizer N, and 100 lb N/acre with no N fertilizer applied.

So, variables are:

$$\text{NAPP}_{\text{biosolids}} = 400$$

$$\text{NAPP}_{\text{fertilizer}} = 200$$

$$\text{NUP}_{\text{biosolids}} = 200$$

$$\text{NUP}_{\text{fertilizer}} = 220$$

$$\text{NUP}_{\text{nofert}} = 100$$

$$\text{ANR}_{\text{biosolids}} = [(200 - 100)/400] * 100 = 25\% \text{ of total N applied}$$

$$\text{ANR}_{\text{fertilizer}} = [(220-100)/200] * 100 = 60\% \text{ of total N applied}$$

$$\text{Fertilizer N equivalent (FNE)} = (24/60) * 100 = 41.6\%$$

$$\text{Fertilizer N equivalent ratio (FNER)} = 60/25 = 2.4 \text{ lb biosolids N per lb of fertilizer N}$$

**Results and Discussion.** Fertilizer N equivalent values from our research with dewatered and heat-dried biosolids are presented in Table A-1 (two locations in western Washington). Also listed is the N fertilizer equivalent for liquid biosolids at a location in Oregon’s Willamette Valley (Kiemnec et al., 1987).

Our research results (Table A-1) show that biosolids were a consistent source of plant-available N on different soils, for different biosolids processing methods (heat-dried, dewatered, and liquid) and for different grass species (tall fescue, perennial ryegrass, and prairiegrass). In the first year of application, biosolids total N was 29 % as effective as fertilizer N (3.7 lb biosolids total N was equivalent to 1 lb fertilizer N). In the second consecutive year of biosolids application, biosolids total N was 53 % as effective as fertilizer N (1.9 lb biosolids N was equivalent to 1 lb fertilizer N).

The difference between FNE for year 1 and year 2 of consecutive application ( $53-29 = 24$  % of biosolids total N) demonstrates the residual N availability from the first year application. This residual N is derived from:

- additional mineralization of biosolids applied during the first year
- recycling of first-year N stored in the unharvested stubble, roots, and crowns of a perennial grass crop

**Conclusion.** Biosolids provide slow-release N for perennial grass cropping systems. Biosolids application rates should be reduced substantially for the second consecutive year of application to perennial grasses. In the first year of application, biosolids total N was 29 % as effective as fertilizer N. In the second consecutive year of biosolids application, biosolids total N was 53 % as effective as fertilizer N.

## References

- Cogger, C.G., D.M. Sullivan, A.I. Bary and S.C. Fransen. [1999; In Press]. Nitrogen recovery from heat-dried and dewatered biosolids applied to forage grasses. *J. Envir. Qual.* (May/June issue)
- Cogger, C.G., A.I. Bary, S.C. Fransen, and D.M. Sullivan. 1998. Heat-dried and dewatered biosolids as fertilizers in intensive forage production. p. 499-505. In: 12<sup>th</sup> Annual Residuals and Biosolids Management Conference. July 12-15, 1998. Bellevue, WA. Water Environment Federation, Alexandria, VA. WEF Stock number CP3805.
- Kiemnec, G.L., T.L. Jackson, D.D. Hemphill and V.V. Volk. 1987. Relative effectiveness of sewage sludge as a nitrogen fertilizer for tall fescue. *J. Environ. Qual.* 16:353-356.
- Sullivan, D.M., S.C. Fransen, C.G. Cogger, and A.I. Bary. 1997. Biosolids and dairy manure as nitrogen sources for prairiegrass on poorly drained soil. *J. Prod. Agric.* 10:589-596.

Table A-1. Fertilizer N equivalent (FNE) and fertilizer N equivalent ratio (FNER) for anaerobically-digested biosolids applied to irrigated perennial grasses in western Washington and western Oregon.<sup>a</sup>

Years	Biosolids	Grass	FNE <sup>b</sup>	FNER <sup>c</sup>
Consecutive Processing				
Biosolids				
Application				
			% of N applied	
1	Dewatered	Per. ryegrass	17	5.9
		Prairiegrass	35	2.9
		Tall fescue	37	2.7
	Heat-dried	Per. ryegrass	23	4.3
		Per. ryegrass	27	3.7
		Tall fescue	40	2.5
	Liquid	Tall fescue	27	3.7
		all	29	3.7
	1, Avg.	all	8	1.1
1, Std dev.	all			
2	Dewatered	Per. ryegrass	60	1.7
		Prairiegrass	43	2.3
		Tall fescue	59	1.7
	Heat-dried	Per. ryegrass	57	1.7
		Per. ryegrass	61	1.7
		Tall fescue	49	2.0
	Liquid	Tall fescue	42	2.4
		all	53	1.9
	2, Avg.	all	8	0.3
2, Std. dev.	all			

<sup>a</sup> Data sources for dewatered and heat-dried biosolids: Sullivan et al. (1997), Cogger et al. (1998), Cogger et al. (1999). Data source for liquid biosolids: Kiemnec et al. (1987).

<sup>b</sup> FNE = Fertilizer N Equivalency for biosolids determined by grass N uptake:

$$\text{FNE} = \text{ANR}_{\text{biosolids}} / \text{ANR}_{\text{fertilizer}} * 100$$

A FNE of 50 means that 50% of biosolids total N was plant available.

<sup>c</sup> FNER = Fertilizer N Equivalency Ratio for biosolids determined by grass N uptake;

$$\text{FNER} = \text{ANR}_{\text{fertilizer}} / \text{ANR}_{\text{biosolids}}$$

A FNER of 2 means that 2 lb biosolids total N has the same available N as 1 lb of fertilizer N.