Long–term and Residual Biosolids Effects on Nutrient Management

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Objectives

- Determine long-term nitrogen recovery from surface-applied biosolids under intensive management.
- Determine the residual effect of biosolids on plant-available nitrogen after biosolids applications cease.

Methods

Site, Soil, and Crop

Site: Puyallup, Washington. 50 km south of Seattle.
Soil: Puyallup fine sandy loam (coarse-loamy over sandy, isotic, mixed, mesic Vitrandic Haploxerolls).
Climate: Mild (18°C), dry summers and cool (4°C), wet winters.
Crop: Tall Fescue (Festuca arundinacea Schreb). 'A.U. Triumph'.

Biosolids

- Thermophilically digested, dewatered cake.
- Mesophilically digested, heat-dried granules.

Treatments 1994-2002 (application period)

- Dewatered biosolids applied at 6.7, 13.4 and 20.2 Mg ha^{-1} yr^{-1} dry wt.
- Heat-dried biosolids applied at 6.7, 13.4 and 20.2 Mg ha^{-1} yr^{-1} dry wt.
- Mean biosolids N applications were 290, 580 and 870 kg ha^{-1} yr^{-1}.
- Inorganic N applied as ammonium nitrate (336 kg ha^{-1} yr^{-1} 1994-96; 403 kg ha^{-1} yr^{-1} 1997-2002).
- Zero-N check.

Treatments 2003-2006 (residual period)

- All treatments (including check) received half rate (202 kg ha^{-1} yr^{-1}) N as urea.

Design

- Randomized complete block with 4 replicates.
- Plot size 1.8 x 6 m.

Applications, Management, and Harvest

- Tall fescue harvested 6 times per year (monthly April–September).
- Biosolids split into three applications each year (after first three harvests).
- Inorganic N split into five (1994–96) or six (1997–2006) applications each year.
- All plots supplemented with K, Mg, and S annually.
- Plots were limed in 1997 and 2000.
- Other nutrient levels were adequate, based on annual soil tests.
- Experiment was irrigated each summer to avoid moisture stress.

Measurements and calculations

- Tall fescue dry matter yield, nitrogen concentration, N uptake.
- Apparent N recovery (ANR) calculated as difference between forage N uptake from treated and check plots.
- Fertilizer N equivalent calculated as ratio of ANR from biosolids treatments to ANR from inorganic N treatment.
- Soil nitrate-N was determined in the fall of each year. Samples were collected in 30 cm increments from 0 to 120 cm during 1994–2002 and from the 0 to 30 cm depth only during 2003–2006.
- Soil apparent N recovery calculated as difference between soil nitrate-N (0 to 120 cm depth) in treated plots and check plots.

Results and Discussion

Results were averaged over the two sources of biosolids, because yield, N uptake, and apparent N recovery were similar for the two materials.

Biosolids application period (1994-2002)

- Medium rate of biosolids (580 kg total N ha^{-1} yr^{1}) had similar long-term yield, forage N concentration and apparent N recovery as the inorganic N treatment. (***Figures 1-3***).
- Cumulative apparent N recovery was 43% averaged over all biosolids treatments, compared with 68% for the inorganic N. (***Table 1***).

Residual period (2003-2006)

- All treatments (including the check plots) received a half rate of inorganic N split over 6 applications per year during the residual period.

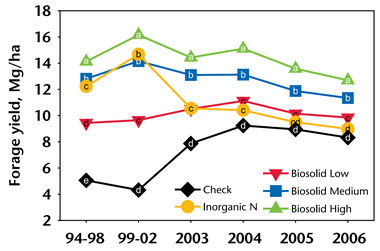

Figure 1. Tall fescue dry matter yield during biosolids application (1994-2002) and residual (2003-2006) periods.

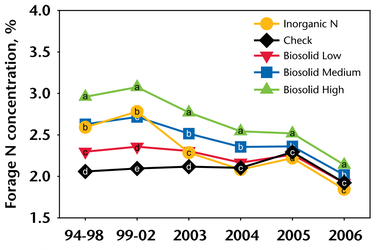

Figure 2. Tall fescue forage nitrogen concentration during biosolids application and residual periods.

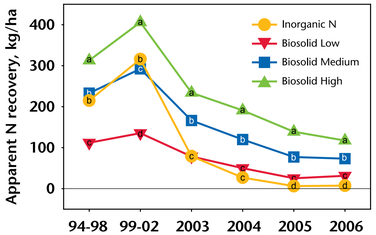

Figure 3. Apparent nitrogen recovery in tall fescue forage during biosolids application and residual periods.

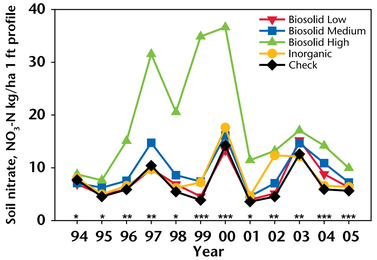

Figure 4. Soil nitrate-N concentration following final harvest, 0–30 cm depth, 1994-2005.

Table 1. Biosolids apparent nitrogen recovery percent in forage dry matter and biosolids fertilizer nitrogen equivalent during the application and residual periods.

Year	Apparent N Recovery Biosolids %	Apparent N Recovery Inorganic %	Fertilizer N Equivalent Biosolids %
94–98	38.2%	59.2%	64.5%
99–02	48.7%	78.4%	62.1%
2003	3.1%	2.3%	—
2004	2.2%	0.8%	—
2005	1.4%	0.2%	—
2006	1.4%	0.2%	—
Cumulative 94–02	42.8%	68.3%	62.7%
Cumulative 94–06	50.9%	71.8%	71.0%

Table 2. Cumulative apparent N recovery of nitrate-N in the soil profile (0 to 120 cm) during the application period (1994-2002).

Treatment	kg ha^{-1}	% of total N applied
Biosolids Low	6	0.2%
Biosolids Medium	38	0.7%
Biosolids High	225	2.9%
Inorganic N	38	1.1%

References

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Funding

Northwest Biosolids Management Association

The ***Northwest Biosolids Management Association*** provided funding to support this project throughout its duration.

- Yield, N concentration and ANR declined rapidly in the inorganic N treatment once the reduced application rate was imposed (***Figures 1-3***). The difference in yield compared with the check plots in 2003 and 2004 was probably the result of a more robust stand of grass going into the residual period.
- Yield at the medium and high biosolids rates declined slowly, while forage N concentration declined more rapidly.
- Mean apparent N recovery from the biosolids (based on cumulative previous biosolids applications) declined from 3.1% in 2003 to 1.4% in 2005 and 2006. (***Table 1***). This represents a substantial N contribution to the grass crop from the past biosolids applications, with the ANR averaging 166 kg N ha^{-1} yr^{1} for the medium biosolids rate in 2003 and 73 kg N ha^{-1} yr^{1} in 2006. (***Figure 3***).

Fertilizer Nitrogen Equivalent

- Previous research on biosolids applications to forage grasses showed plant available N (calculated as fertilizer N equivalent) of approximately 35% for the first year of biosolids application and 45%–50% for the second year of consecutive application (*Cogger et al., 2001; Cogger et al., 2004; Gilmour et al., 2003*).
- This research shows a long-term fertilizer N equivalent of > 60% of biosolids N applied during the period of continuous application (***Table 1***).
- Additional N mineralized during the 4-year residual period increased the fertilizer equivalent to 71% of total biosolids N applied (***Table 1***).

Fall Nitrate-N Residual

- Fall soil nitrate-N levels were highest in the high rate biosolids treatment during the application years, with only small differences observed among the other treatments. (Results for 0–30 cm depth are shown in ***Figure 4***).
- Differences declined rapidly after biosolids applications ceased, although they were still statistically significant.
- Cumulative apparent N recovery as nitrate-N in the soil profile during the application years was < 1% of the total N applied for the low and medium biosolids rates and 3% of the total N applied for the high rate (***Table 2***). This showed that the grass crop was very efficient at nitrogen capture across the range of application rates.