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Effects of Sucrose and Dried Alum Sludge on the Growth of Rudbeckia and Leaching of Nitrogen and Phosphorus from Potting Media Containing Biosolids Compost

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Sewage treatment biosolids are composted at 198 facilities in the United States (Goldstein 1998). Amending potting media, used in the commercial production of ornamental plants, with biosolids compost is considered a prime use (Bugbee 1996). Biosolids compost contains substantial amounts of the plant nutrients nitrogen (N) and phosphorus (P). If these nutrients leach from the potting media they can become a pollutant. Nitrate ($N0_3$-N) is the most common chemical contaminant in drinking water wells (USEPA 1990) and non-point sources of N may contribute to low oxygen levels in marine estuaries (Frink 1991). Phosphorus enrichment of freshwater ponds and lakes promotes the growth of nuisance algae (Frink and Norvell 1984). Strategies are needed to help prevent N and P in potting media containing biosolids from leaching to the environment.

Commercial nurseries may have hundreds of acres of plants growing in containers. Potting media has been shown to leach significant amounts of N regardless of whether or not it contains biosolids compost. State and federal environmental regulators intensely scrutinize the use of biosolids compost yet largely ignore conventional potting media. Rhododendron and Rudbeckia grown in media containing biosolids compost leached from 119 and 177 kg/ha/yr N (Bugbee and Elliott 1998, Bugbee 1996) while a variety of woody ornamentals grown in media containing no biosolids compost leached from 24 to 705 kg/ha/yr (Rathier and Frink 1991). Soluble N in biosolids compost is often in the ammonium (NH_4-N) form and NH_4-N can be the primary form of N in leachate (Bugbee and Elliott 1998, Bugbee 1996). Through the process of nitrification, NH_4-N is converted to $N0_3$-N by soil bacteria (Bunt 1976). Much of the N leached from container media amended with biosolids compost occurs within a few weeks of planting when water soluble N is greatest and plant utilization is least (Bugbee and Elliott 1998, Bugbee 1996). Although far less P than N leaches from potting media, much lower concentrations of P can deteriorate water. For instance, $N0_3$-N must exceed 10 mg/L to make water unfit to drink (USEPA 1990) while lakes become eutrophic when P

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levels surpass 0.03 mg/L (Frink and Norvell 1984). Potting media containing 50 %/vol biosolids compost can leach from 8 to 33 kg/ha P (Bugbee and Elliott 1998). Amendments that reduce leaching of N and P would reduce the adverse effects of biosolids composts on the environment and enhance the prospects for utilization of the compost by the nursery industry.

Microbial immobilization (Allison et. al. 1963) chemical binding and/or ionic adsorption (Bunt 1976) by potting media amendments could retain N and P for later use by plants. Sawdust, peat, bark, and calcined clay have proven ineffective at reducing leaching of N and only slightly effective at reducing P (Bugbee and Elliott 1998). The addition of a quickly available carbohydrate like sucrose, may immobilize N until it can be utilized by plants. Some evidence suggests carbohydrate additions can also improve plant growth. Keeling et. al. (1996) found over a 50% increase in dry matter yield in grass grown in compost amended soil treated with glucose. Leaching of P might be minimized with a potting media amendment containing reactive aluminum that immobilizes P as aluminum phosphate compounds (Lin et. al. 1996). Dried alum sludge (DAS) is a byproduct from the treatment of municipal drinking water. It's created when aluminum sulfate and polymer are added to water to remove color, turbidity and particulates. The resulting sludge is often placed in drying beds where it forms a material that resembles soil. Few beneficial uses for DAS are available and restrictions on disposal are a problem. DAS immobilizes P when added to potting media but may hinder plant growth by inducing P deficiency (Bugbee and Frink 1985). This study determines if amending a potting media containing biosolids compost with sucrose or DAS will prevent leaching N or P without adversely affecting plant growth.

MATERIALS AND METHODS

Biosolids compost from the Hartford, CT USA municipal "in-vessel" composting facility was obtained on June 16, 1997. The compost was made from biosolids and mixed softwood and hardwood chips (1:1.5 by volume). This mixture was composted for 21 days and cured outdoors in a windrow for six months. A potting medium was made by mixing the biosolids compost, Canadian sphagnum peat, shredded bark (mixture of hardwood and softwood) and coarse masonry sand in volume percentages of 50, 20, 20, and 10 respectively. Dolomitic limestone was added at a rate of 12 g/L and the fertilizer 5 N - 4 P- 8 K (5-l O-l 0) and 18 N - 3 P- 10 K (Osmocote 18-6-12, resin-coated), was added at a rate of 1 and 2 g/L respectively. This is referred to as the 0 Sucrose/DAS medium in this study. Experimental media were made by adding 0, 6, 12 and 24 g/L sucrose and 0, 2, 5 and 10 %/vol DAS to the 0 Sucrose/DAS medium.

Table 1. Chemical properties of individual potting media components[Y].

Potting Media Component	Organic Carbon (%/wt)	Total (%/wt)	C:N (wt/wt)	pH	Soluble Salts (ds/m)	Bulk Density[z] (g/cc)
DAS	11b	0.5d	22b	6.0c	0.3a	0.83c
Bark	41d	0.4c	102c	4.6b	0.2a	0.20b
Compost	32c	3.0a	11a	5.9c	2.9b	0.33d
Peat	42d	0.9b	47d	3.5a	0.2a	0.24b
Sand	Oa	0.0c	-	6.4d	0.1a	1.75a

‘Means within a column, for each type of compost, followed by the same letter are not significantly different (p=0.05) as measured by the Tukey multiple comparison test.

‘Oven dry

A medium containing 0 %/vol biosolids compost, 50 %/vol Canadian sphagnum peat, 40 %/vol shredded bark and 10 %/vol sand was included to compare the differences between media with and without the compost. This is referred to as the No Compost medium in this study. Fertilizer was added to the No Compost medium at the same rate as biosolids media but limestone was increased to 24 g/L to neutralize the acidity caused by the greater proportion of peat.

Chemical properties and plant available nutrients of individual media components were measured on three randomly obtained samples. Organic carbon was determined by loss on ignition, total nitrogen by the Kjeldahl method, pH by glass electrode and soluble salts by the electrical conductivity of a saturated extract. Plant available NO_s-N, NH_4-N, P, K, Ca and Mg were extracted with Morgan’s solution (Lunt et. al. 1950). $N0_3$-N and NH_4-N were determined by the Brucine and Nessler’s methods (Grewling and Peech 1965) using a Milton Roy Spectronic 20D spectrophotometer. Concentrations of P, K, Ca and Mg in extracts were determined using a Thermo Jarrell Ash AtomScan 16 inductively coupled plasma spectrometer.

On June 20, 1997, 2L (12 cm x 12 cm x 15 cm) plastic pots were filled with each medium. Rooted *Rudbeckia hirta* L. ‘Goldstrum’ (Black-Eyed Susan) divisions were transplanted into each pot. Each medium was replicated 5 times and pots’ were placed outdoors at Lockwood Farm, Hamden CT USA. Pots were arranged in a complete randomized block design. Overhead irrigation supplied 1.8 cm of water per day when rain

Table 2. Plant available nutrients in individual media components[y].

DAS	214b[z]	8a	8a	41a	646abc	36a
Bark	2a	3a	11a	199b	405ab	59a
Compost	273b	989b	127b	323c	1097c	203 bc
Peat	9a	55a	11a	41a	197a	211c
Sand	6a	11a	18a	88a	835bc	35a

‘Means within a column, for each type of compost, followed by the same letter are not significantly different (p=0.05) as measured by the Tukey multiple comparison test.

‘Expressed on a volume basis to give the best estimate of the amount of nutrient in each treatment. mg/kg = mg/L divided by the components bulk density in Table 2.

was judged insufficient. On August 12, 1997, 4 g of 10 N - 4 P - 8 K (10-10-10) water soluble granular fertilizer was applied to each pot.

Rudbeckia were grown until October 6, 1997, when aerial plant parts were harvested. Plant parts were dried at 75° C for one week and weighed to determine plant growth. Leaching of $N0_3$-N, NH_4-N and P was monitored on three replicates of each medium. Leachate collection devices were made by cutting 12 cm square openings in lids for 5L plastic buckets. Pots were glued in the lid opening and the pot plus lid was placed on the bucket. This allowed only the leachate passing through the media to be collected. Collection buckets and lids were painted silver on the outside to help moderate leachate temperatures and prevent light from causing algal growth. Pot size and culture of plants in the leachate collection treatments were identical to the plant growth experiment but the plants were not used for growth measurements. Two 100 ml leachate samples were obtained from each bucket, at 7 to 20 day intervals, when approximately 1 L of leachate had accumulated. Activated carbon was added to one sample from each bucket to remove color and the leachate was separated from the carbon by centrifuge. All samples were then refrigerated until being analyzed. The color free samples were tested for $N0_3$-N and NH_4-N using the Brucine and Nessler's methods (Grewling and Peach 1965) and for water soluble P using the ascorbic acid method (Eaton et. al 1995) on a Milton Roy Spectronic 20D spectrophotometer. Samples not receiving activated carbon were subjected to Kjeldahl digestion to determine N using USEPA (1983) method 351.2. Total P was determined on the same Kjeldahl digestate using the molybdate-

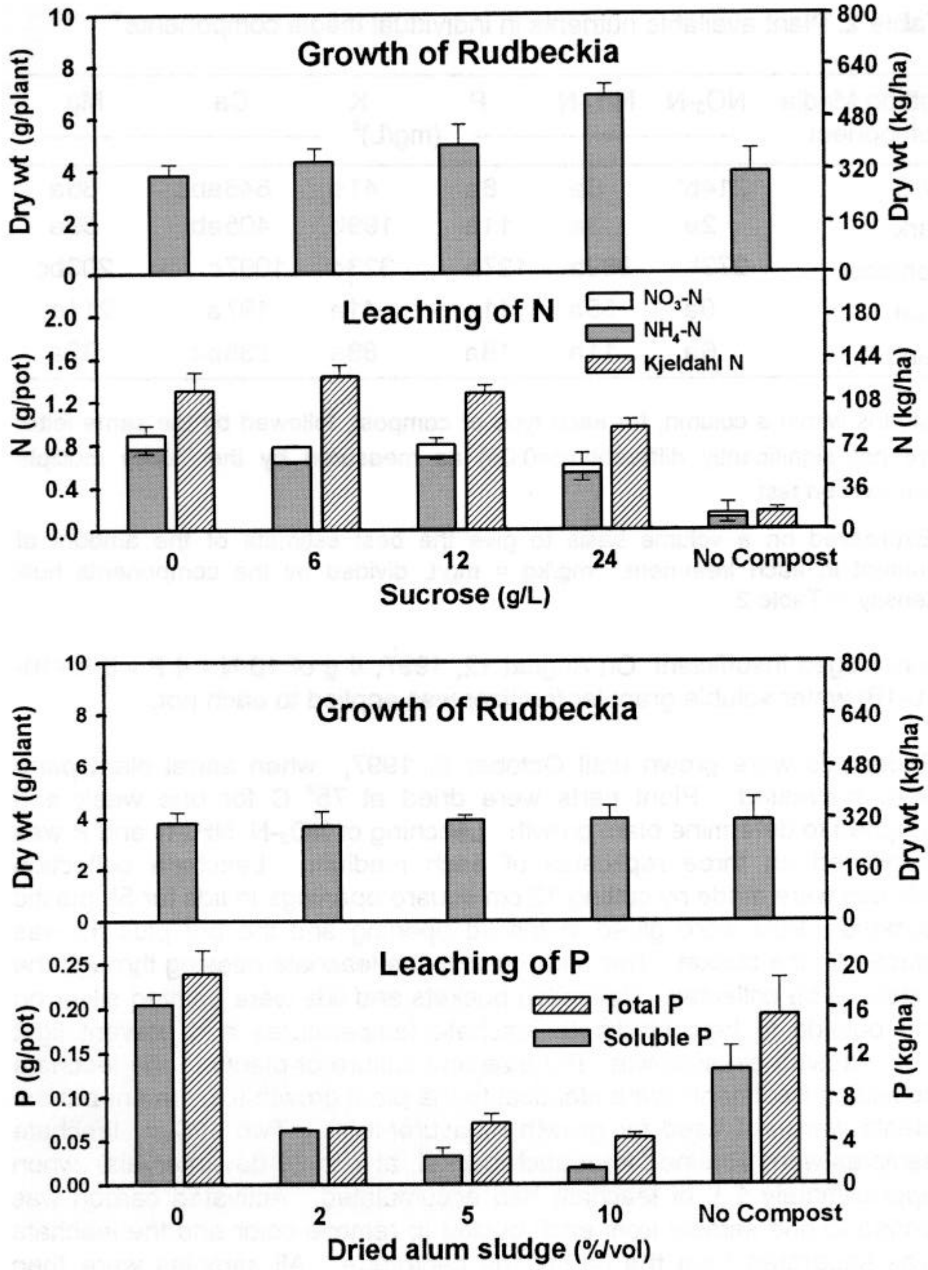

Figure 1. Growth of Rudbeckia and cumulative total leaching of N and P in media amended with sucrose, DAS and no compost. Error bars equal one standard error of the mean. 80,000 pots/ha is used to calculate kg/ha on right axis.

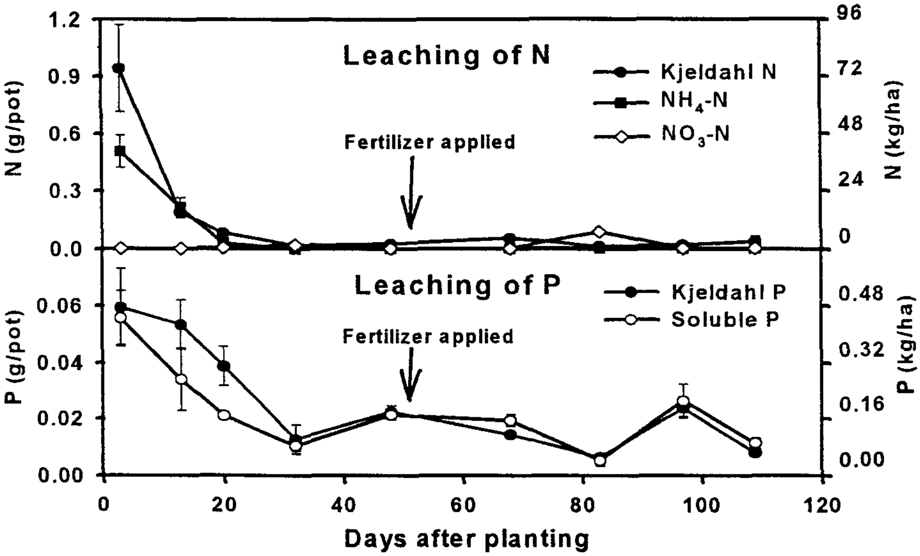

Figure 2. Leaching of N and P from the 0 Sucrose/DAS medium over time. Error bars equal one standard error of the mean. 80,000 pots/ha is used to calculate kg/ha on right axis.

ascorbate method (Murphy and Riley 1962). Concentrations of Kjeldahl N and total P were quantified on a Milton Roy Spectronic 1001 spectrophotometer.

RESULTS AND DISCUSSION

Bark, compost and peat contained large amounts of organic carbon (C) compared to DAS and sand (Table 1). Compost had the lowest C:N ratio, the most N and the highest soluble salts. The salts in the compost were below levels considered harmful to plants (Maynard and Hochmuth 1995). The pH of the components varied considerably, but with the addition of limestone, all media had a pH between 5.5 and 6.5. Sucrose or DAS had little effect on media pH. The biosolids compost contained higher levels N (NH_4-N+NO_s-N), P and K than the other components (Table 2). When DAS was added to the media dilution of the compost could account for a small reduction in N, P and K available to plants and leachate. Prior to the application of fertilizer on August 12, the biosolids compost and the preplant fertilizer represented the primary source of N and P. Most of the N in the compost was in the NH_4-N form. NH_4-N would be expected to be the principal form of nitrogen in leachate until nitrification converts it to NO_3-N.

Growth of Rudbeckia increased with additional sucrose and changed little with increasing amounts of DAS (Figure 1). A reduction in NH_4-N or benefits related to increased microbial activity might have caused thegrowth increase. Plant growth in the 0 Sucrose/DAS medium was the same as in the No Compost medium. Increasing sucrose from 0 to 24 g/L decreased leaching of NH_4-N from 882 to 599 g/pot, NO_3-N from 122 to 70 g/pot and Kjeldahl N from 1305 to 949 g/pot. Compared to the No Compost medium that leached 149 g/pot NH_4-N, 40 g/pot $N0_3$-N and 167 g/pot Kjeldahl N the reductions caused by Sucrose are modest. Sucrose had no significant affect on the leaching of P (p=0.05).

The addition of DAS had no adverse affects on growth of Rudbeckia but greatly reduced leaching of P. Leaching of water soluble P from the 0 Sucrose/DAS medium was 204 g/pot compared to 18 g/pot from media containing 10 %/vol DAS. The addition of only 2 %/vol DAS decreased the leaching of water soluble P by 70 percent. Concentrations of total P were higher than water soluble P suggesting that some P was in an organic form. DAS had no significant affect on the leaching of any form of N(p=0.05). Most N leached as NH_4-N in the first 20 days and most P leached during the first 40 days (Figure 2). Plant uptake of N and P and losses by previous leaching probably explains much of the reduction with time. Plant uptake also may explain why the application of fertilizer 52 days into the experiment failed to substantially increase concentrations of N and P in leachate.

This study suggests the addition of sucrose to potting media containing biosolids compost will not reduce N leaching to the extent needed to justify it's use. The growth improvement caused by the sucrose should be of interest to growers and deserves further study. Dried alum sludge is extremely effective at removing P from leachate when used at rates that do not adversely affect plant growth. It's utilization in potting media containing biosolids compost appears promising.

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REFERENCES

Allison FE, Murphy RM, Klien CJ (1963) Nitrogen requirements for the decomposition of various kinds of finely ground woods in soil. Soil Sci 96: 187-191

Bugbee GJ, Elliott GC (1998) Leaching of nitrogen and phosphorus from potting media containing biosolids compost as affected by organic and clay amendments. Bull Environ Contam Toxicol 60:716-723

Bugbee GJ (1996) Growth of Rhododendron, Rudbeckia, and Thujia and leaching of nitrates as affected by the pH of potting media amended with biosolids compost. Comp Sci Util 4:52-59

Bugbee GJ, Frink CR (1985) Alum sludge as a soil amendment: Effects on soil properties and plant growth. Conn Agr Exp Sta Bull 827

Bunt AC (1976) Modern potting composts. Pennsylvania State University Press, University Park and London

Eaton AD, Clesceri SC, Greenberg AE eds. (1995) Standard methods for the examination of water and wastewater. American Public Health Assoc p.4-113

Frink CR, Norvell WA (1984) Chemical and physical properties of Connecticut lakes. Conn Agr Exp Sta Bull 817

Frink CR (1991) Estimating nutrient exports to estuaries. J Environ Qual 20: 717-724

Goldstein N (1998) National Overview of biosolids management. Biocycle 39:64-68

Grewling T, Peech M (1965) Chemical soil tests. Cornell Agr Exp Sta Bull 960: 22- 25

Keeling AA, Cater GLF, Cook JA, Wilcox A (1996) Application of glucose at low concentrations to grass swards in waste-derived compost can significantly increase long-term yields. Plant and Soil 184(1):117-121

Lin YLP, Holcomb EJ, Lynch JP (1996) Marigold growth and phosphorus leaching in a soilless medium amended with phosphorus-charged alumina. Hort Sci 31(1):94-98

Lunt HA, Swanson CL, Jacobson HGM (1950) The Morgan soil testing system. Conn Agr Exp Sta Bull 541

Maynard DN, Hochmuth GJ (1997) Knott's handbook for vegetable growers. John Wiley & Sons, Inc. p. 145

Murphy J, Riley JP (1962) A modified single solution for the determination of phosphate in natural waters. Anal Chem Acta 27:31-36

Rathier TM, Frink CR (1989) Nitrate in runoff water from container grown juniper and Alberta spruce under different irrigation and fertilization regimes. J Environ Hort 7:32-35

USEPA (1990) National pesticide survey. Summary of results of EPA's national survey of pesticides in drinking water wells. USEPA Washington, DC

USEPA (1983) Methods for chemical analysis of water and wastes. Environ Mon Sup Lab, Cincinnati OH