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APPLICATION OF MUNICIPAL BIOSOLIDS TO BAHIAGRASS PASTURE: TRACE METALS IN HARVESTED FORAGE

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Abstract

Municipal biosolids (sewage sludge) are the by-products of wastewater treatment plants and their production, worldwide, has steadily increased over the past years. Florida is one of the fastest growing states in the USA. Biosolids are readily and increasingly available throughout the state. Pasture fertilization has been shown to increase biomass and quality of bahiagrass (*Paspalum notatum* Flugge) dramatically in Florida sandy soils. Nevertheless, with low cattle prices, ranchers are forced to reduce fertilizers inputs. Biosolids contain considerable amounts of nutrients, especially nitrogen (N), phosphorus (P), sulphur (S), calcium (Ca), and micronutrients, and are inexpensive when compared with commercial fertilizers. Nevertheless, the concern remains that metals contained in these residuals accumulate in the tissues, in levels that would result be harmful to animals consuming the forage. This study investigated effects of seven rates of municipal biosolids applied to bahiagrass pasture on trace metal concentration in the forage. Iron (Fe), copper (Cu), cadmium (Cd), lead (Pb), and nickel (Ni) concentrations were determined in the tissue sampled at various dates after initial biosolids application. Metal concentrations were increased with increasing rates of biosolids, especially with the highest rate, in the first harvest date, but decreased with successive harvests. By the fourth harvest, Cd, Pb and Ni were hardly detected in forage. The increases verified in plant metal contents were not substantial enough to yield concerns regarding animal consumption, even with the higher rates of biosolids.

Keywords: Sludge, bahiagrass, heavy metals, iron, lead, cadmium, nickel

Introduction

In Florida, there are more than 5 million hectares of pastures that require fertilization, and approximately 2 million of these are planted with bahiagrass. Yields and protein content of bahiagrass (*Paspalum notatum*) have been shown to increase drastically from additions of both N and S (Sveda et al., 1992). Iron deficiencies are commonly observed on pastures in the spring, especially following N fertilization. Biosolids contain considerable amounts N, P, Ca and Fe, and constitute a relatively inexpensive nutrient source, when compared with commercial fertilizers (Muchovej, 1997). Previous work has demonstrated that bahiagrass forage yields and quality are increased by biosolids (Muchovej and Rechcigl, 1998). In sorghum and barley, Fe deficiencies were corrected by biosolids (McCaslin and O’Connor, 1985; McCaslin et al., 1986).

Most of the state of Florida is characterized by sandy soils, Spososols, and abundant rainfall. For these reasons, biosolids may be a beneficial source of nutrients compared with inorganic fertilizers that tend to leach readily, especially when a heavy rain follows application (Muchovej and Rechcigl, 1995). Information is scarce on bahiagrass metal concentrations resulting from biosolids amendments. This study investigated the effects of municipal biosolids rates on trace metal concentration in bahiagrass forage, growing on a sandy soil in Florida.

Material and Methods

The study was conducted on an established bahiagrass pasture growing on a Myakka fine sand, pH 5.0, to test the effects of anaerobically digested dehydrated municipal biosolids on forage trace metal concentrations. Treatments consisted of 7 rates (0, 0.55, 1.1, 2.2, 4.4, 8.8, and 17.6 Mg ha^{-1}) of biosolids, which provided 0, 25, 50, 100, 200, 400, and 800 kg N ha^{-1} (organic plus inorganic). The biosolids had the following composition: 4.5, 0.91, 2.0, 0.6, and 2.0 percent of N, P, Ca, Mg, and Fe, and 800, 7.5, 230, and 45.9, mg kg^{-1} of Cu, Cd, Pb and Ni, respectively. Phosphorus and potassium were applied at the same rate to all plots, as Triple Superphosphate (40 kg ha^{-1}) and KCl (80 kg ha^{-1}), respectively. Treatments were surface-applied in the Spring on 6 m x 3 m plots, arranged in a randomized complete block design with 4 replications.

Bahiagrass samples were collected 71, 113, 148, 188, and 231 days after initial application. Sub-samples of plant tissue from each harvest were analyzed for selected trace metals by dry-ashing in a muffle furnace and dissolution in diluted HCl. Iron, Cu, Cd, Pb, and Ni concentrations were determined on extracts by ICAP, at the Analytical Research Laboratory from the University of Florida in Gainesville.

Results and Discussion

Iron concentration in the forage was increased by increasing biosolids rates, with marked increases obtained at the 8.8 Mg ha^{-1} rate and higher (Table 1). These increases were still verified for the last harvests, indicating that the micronutrient was maintained available for plant uptake throughout the growing season. Thus, biosolids appear to be a good source of the element in some chelated form. Similar results were verified for Cu and the maximum concentration was 8.50 mg kg^{-1}, obtained for the first harvest and with the highest biosolids rate (Table 1).

Increased Cd concentration was detected with 8.8 and 17.6 Mg biosolids ha^{-1} but the highest value was 0.30 mg kg^{-1} (Table 1). Similar results were verified for Pb, and Ni, and the maximum values for these metals were 4.93 and 1.5 mg kg^{-1}, respectively (Table 1). Hansen and Schaeffer (1995) reported maximum tolerated levels of important elements in foliage and compared those with the maximum levels chronically tolerated by domestic animals. For cattle, the authors indicated 1000, 100, 0.5, 30, and 50 mg kg^{-1} dry foliage or dry diet, for Fe, Cu, Cd, Pb, and Ni, respectively. The highest concentrations of these trace metals, obtained with application of 17.6 Mg/ha, are several magnitudes lower than those values considered toxic in forage for animal consumption.

There is concern about potential contamination of water by metals contained in biosolids. The total quantity of trace metals permitted for land application in the USA is regulated by guidelines from the USEPA (1993). Furthermore, metals present in biosolids are generally immobile and have low water solubility. Juste and Mench (1992) reviewed long-term application of biosolids on metal distribution in the soil profile, and bioavailability of metals and determined that biosolids-borne metals remained in the zone of incorporation (0-15 cm depth) and phytotoxicity of these metals was rarely observed on grain crops. Trace metal movement resulting from biosolids application is limited unless surface erosion is considerable, and is only likely to occur in sandy, acid, low organic matter soils receiving high applications, together with high rainfall or irrigation (Hue, 1995).

Biosolids applied to agricultural land can improve soil physical properties (e.g., water retention, infiltration, aggregate stability, aeration, drainage, and bulk density) as well as chemical characteristics (e.g., pH, cation exchange capacity and plant nutrient availability) (Hue, 1995); furthermore, they may contribute to disease suppression (Stratton et al., 1995) and promote a reduction of chemical fertilizer requirement. Muchovej and Rechcigl (1998) obtained significant linear increases in forage yield, and nitrogen accumulation from biosolids rates higher than 1.1 Mg ha^{-1}. In the present study, overall concentrations of the trace metals were low for all harvests (Table 1). Slight increases in these trace metals concentrations should not be of major consequences for forage utilization and consumption, even with rates of 17.6 Mg biosolids ha^{-1}.

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Table 1 - Iron, copper, cadmium, lead and nickel concentrations in bahiagrass forage amended with biosolids at the various harvest dates.

Biosolids	71	113	148	188	231	Ave.
Mg ha^{-1}	-----------------------Days after treatement------------------------					
			Fe (mg kg^{-1})			
Control	60.50	55.75	54.75	28.50	51.50	50.20
0.55	61.25	47.75	62.25	41.50	58.75	54.30
1.1	65.25	51.50	52.75	46.25	60.75	55.30
2.2	90.00	58.75	59.25	43.00	56.75	61.55
4.4	68.75	58.00	76.50	49.00	65.00	63.45
8.8	119.50	55.00	98.00	48.50	63.00	76.80
17.6	125.25	69.25	102.50	58.50	75.25	86.15
			Cu (mg kg^{-1})			
Control	3.50	3.50	2.75	2.00	2.25	2.80
0.55	3.75	4.50	2.75	2.00	2.50	3.10
1.1	3.75	4.25	2.75	2.75	2.50	3.20
2.2	6.00	4.50	2.00	2.50	2.75	3.55
4.4	3.25	5.00	3.75	2.75	4.75	3.90
8.8	6.25	4.25	5.25	4.25	5.75	5.15
17.6	8.50	5.75	5.25	5.50	6.50	6.30
			Cd (mg kg^{-1})			
Control	0.03	0.05	0.05	0.00	0.00	0.03
0.55	0.05	0.03	0.08	0.03	0.00	0.04
1.1	0.08	0.10	0.05	0.00	0.00	0.05
2.2	0.10	0.10	0.05	0.03	0.10	0.08
4.4	0.13	0.10	0.10	0.08	0.15	0.11
8.8	0.20	0.15	0.15	0.15	0.20	0.17
17.6	0.30	0.20	0.15	0.18	0.30	0.23
			Pb (mg kg^{-1})			
Control	2.25	3.50	2.40	0.00	0.05	1.64
0.55	2.90	2.55	2.58	0.20	0.18	1.68
1.1	2.98	3.20	2.48	0.03	0.10	1.76
2.2	3.35	3.68	1.98	0.05	0.10	1.83
4.4	2.50	2.93	1.90	0.00	0.15	1.50
8.8	4.93	3.95	1.93	0.23	0.15	2.24
17.6	3.17	4.43	1.78	0.05	0.15	1.92
			Ni (mg kg^{-1})			
Control	0.23	0.28	0.25	0.08	0.12	0.19
0.55	0.30	0.25	0.35	0.10	0.18	0.24
1.1	0.38	0.33	0.25	0.15	0.18	0.26
2.2	0.33	0.55	0.30	0.18	0.23	0.32
4.4	0.43	0.53	0.33	0.30	0.50	0.42
8.8	0.78	0.78	0.60	0.50	0.70	0.67
17.6	1.15	1.05	0.83	0.70	0.95	0.94