Nitrate Levels at Different Growth Stages of "Biofilter" Forages Irrigated with Dairy Effluent and Municipal Waste Water

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Abstract. *There is an increasing need to minimize the potential of nitrate contamination of groundwater from dairy effluent and municipal waste water. One such remediation technique is to grow nitrogen (N) scavenging crops, commonly referred to as "bio-filters", which also have the potential to be used as forages. In our previous studies Elephant grass (Pennisetum sp.) has been identified as a highly nutritious forage crop with the ability to readily take up N from soils subjected to high N rates. In this phase of our research, our objective was to evaluate optimal harvest time for Elephant grass and Sudan grass (Sorghum bicolor) irrigated with secondary treated municipal waste water (MW) and dairy effluent (DE). The grasses were grown in 5 gallon pots in greenhouse experiments set up as completely randomized designs (CRD) with three rates (0, 50 and 100 percent) of effluent, and replicated four times with three harvest times (8, 10 and 12 weeks). Findings from the first round of trials completed in Spring 2011 indicate that the average biomass for the grasses harvested at 8 and 10 weeks were generally higher for plants irrigated with the DE than those irrigated with the MW. By the 12th week, similar yields were obtained for each grass regardless of the water source. Generally, the highest crude protein (CP) content and total digestible nutrients (TDN) were detected in grasses harvested at eight weeks. The exception was the EG treated with MW, which had its greatest CP and TDN values at 12 weeks. Grasses irrigated with DE exhibited their greatest nitrate content earlier (at 8 weeks) than those receiving MW. More importantly, the grasses receiving MW accumulated as much as five times more nitrate than the grasses treated with DE.*

Keywords. Elephant grass, Sudan grass, biofilter, scavenging crop, dairy effluent, municipal wastewater, water reuse, secondary treated wastewater, nitrate contamination.

Introduction

In California, which is now the number one dairy producing State in the U.S. (CDFA 1999 & 2003), dairy manure is commonly handled as an effluent stream of liquid or slurry by means of a hydraulic flushing - lagoon storage - irrigation system. Dairy effluent with high nutrient contents can cause overloading of land with nutrients, especially nitrogen and phosphates, and thereby have the potential to contaminate surface and ground water resources. The Central San Joaquin Valley of California with its growth of Concentrated Animal Feeding Operations (CAFO) and sprawling urban development is a paramount example of the serious problems in the United States of accommodating population growth in prime agricultural land areas. An intensive study of shallow groundwater wells around diaries in this Valley indicates that within the diaries nitrate-N (nitrogen) levels were 64 mg/l compared to 24 mg/l immediately up-gradient of these dairies (Harter, 2001).

In addition to dairy products, land application of secondary treated municipal wastewater (MW) from wastewater treatment facilities allows for the beneficial reuse of nutrients, organic matter, and water. In this scenario, the soil profile is expected to "treat" the process water and prevent degradation of groundwater. However, some constituents may pass through the soil profile and detrimentally impact groundwater.

Excess nutrients from irrigation of crops with recycled wastewaters from municipal facilities can therefore be a major potential source of groundwater pollution. Hence, a major component of any Best Management Practice (BMP) should be the inclusion of either an agronomic crop or perennial forage capable of utilizing the nutrients applied in the wastewaters. "Promor A" perennial forage grass (*Pennisetum Sp.*), commonly called Elephant grass, was introduced into California in 1994. Elephant grasses are perennials and are grown throughout the tropical world and are one of the most widely used forages for large and small animals. Since the introduction of the Elephant grass into the U.S. via official quarantine channels it has been subjected to a series of trials to test its bio-filtering characteristics, forage qualities, agronomic qualities, water use efficiency and its tolerance to insect pests and diseases.

In a previous study (Goorahoo et al., 2004) a trial with Elephant grass was conducted at the Center for Irrigation Technology (CIT), in Fresno, California with the following objectives:

- Determination of the nitrogen and phosphorus filtering characteristics of the grass;
- Determination of water consumption of the grass; and,
- Estimation of any possible interactions between bio-filtration and water consumption.

In that study a "Nutrient Farm Balance" protocol was established to determine the biofiltration characteristics of the grass (Barry et al, 1993; Goss and Goorahoo, 1995). The irrigation protocol was based on the daily reference evapotranspiration index (ETo), and treatments consisted of water applications of 40%, 80%, 120%, and 160% of the daily ETo. General findings were that the Elephant grass appeared to have significant potential for scavenging excess soil nitrogen and phosphorus and can be very useful in a bio-filtration system aimed at managing irrigation or recycled water, such as dairy or food processing wastewaters. The stooling growth habit of this grass should provide a secondary benefit through reduction of water velocity and consequent sedimentation of water borne particles when the grass is used as barrier plantings or buffer strips.

In the current study, our overall goal was to continue to evaluate the potential of the Elephant grass as both a biofilter and as a forage grass. Specifically, the objective was to evaluate optimal harvest time for Elephant grass irrigated with secondary treated municipal waste water (MW) and dairy effluent (DE). For comparison a similar experiment was conducted on Sudan grass (Sorghum bicolor).

Materials and Methods

The study was conducted in one of the California State University- Fresno (Fresno State) greenhouses. The grasses were grown in five gallon pots filled with a sandy soil collected from a wastewater treatment facility (WWTF) and a sandy loam soil the campus fields, for experiments irrigated with secondary municipal wastewater (MW) from the WWTF and with dairy effluent (DE) from the Fresno state dairy, respectively. The pots were lined with plastic bag to maintain a closed system.

Two experiments were set up as completely randomized designs (CRD) with three rates (0, 50 and 100 percent) of effluent, and replicated four times (Figure 1). Hence each experiment consisted of 72 pots of which half were Elephant grass (EG) and the other half were Sudan grass (SG).

A starter fertilizer was applied for the onset of the plants and plants were irrigated on a regular basis based visual and "feel" observations of soil moisture during the first six weeks. Starting from the seventh week MW and DE were applied based on the soil moisture content in the pots.

The pots were labeled for the harvest time and at the end of the 8, 10 and 12 weeks whole plants were removed for analysis. The plant samples were analyzed for biomass, crude protein (CP), total digestible nutrients (TDN) and nitrate (NO_3). A representative soil sample was taken from each pot after plant harvest for determination of pH, Electrical Conductivity (EC), total nitrogen, ammonia and NO_3 at a later date, using the techniques outlined by Gavlak et al. (2003).

Data collected was subjected to analyses of variance using the univariate general linear model available for a completely randomized design using the SPSS® software (SPSS, 2010).

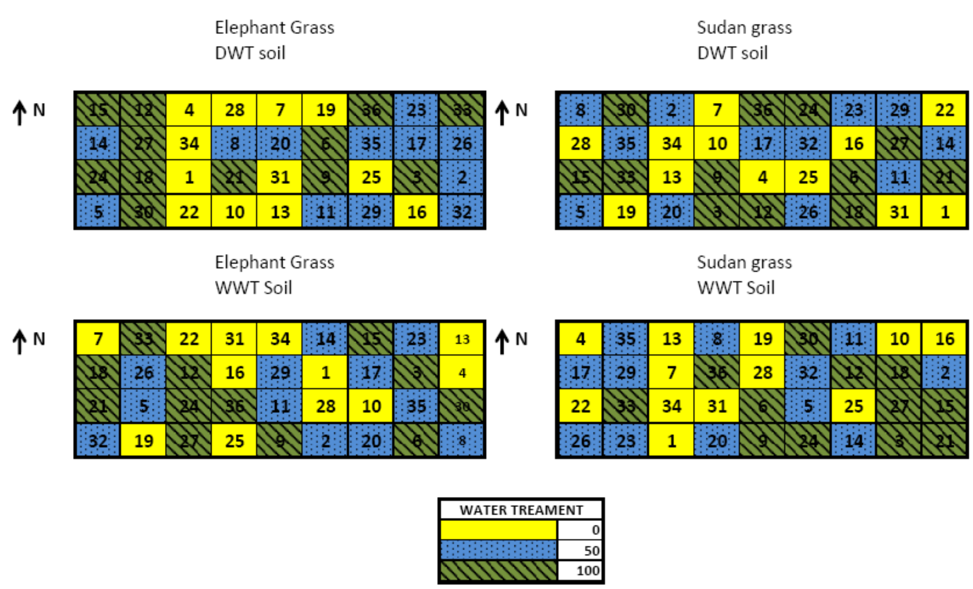

Figure 1. Greenhouse experimental layout and irrigation treatments

Results and Discussion

Figure 2 in an example of trends observed for average biomass of the grasses for plants grown in the sandy loam soil and irrigated with DE. Similar trends were observed for plants receiving MW. Generally, the average biomass for the grasses harvested at 8 and 10 weeks were generally higher for plants irrigated with the DE than those irrigated with the MW. By the 12th week (Harvest 3), similar yields were obtained for each grass regardless of the water source.

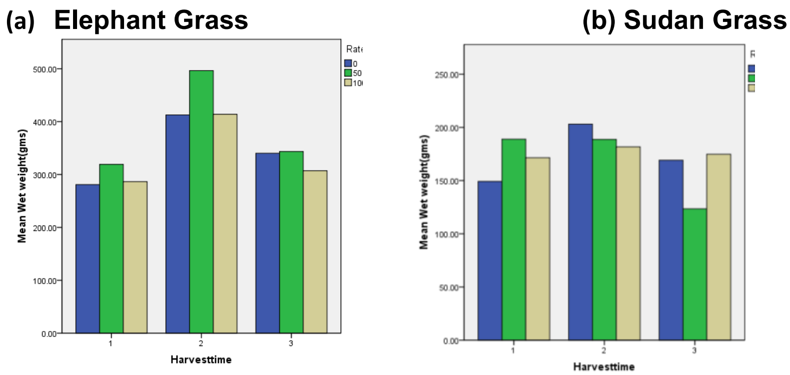

Figure 2. Average biomass values for grasses irrigated with dairy effluent (DE) at harvests 1, 2, and 3 which is equivalent 8, 10, and 12 weeks, respectively after planting.

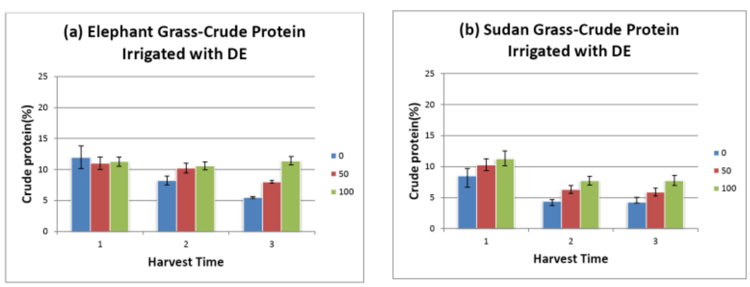

Figure 3. Crude protein (CP) content of grasses irrigated with dairy effluent (DE) at harvests 1, 2, and 3 which is equivalent 8, 10, and 12 weeks, respectively after planting.

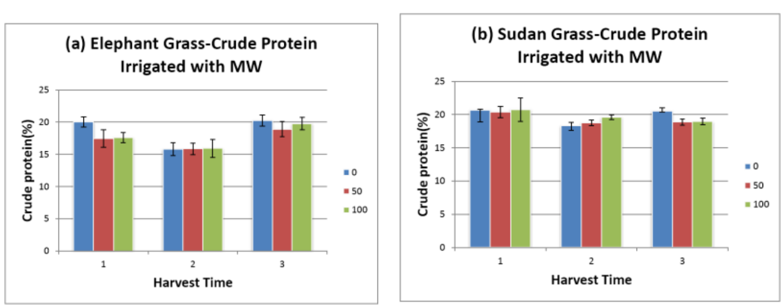

Figure 4. Crude protein (CP) content of grasses irrigated with municipal wastewater (MW) at harvests 1, 2, and 3 which is equivalent 8, 10, and 12 weeks, respectively after planting.

Figures 3 and 4 show trends in the crude protein contents determined for the two grasses subjected to the various irrigation waters. Generally, the highest crude protein (CP) content and total digestible nutrients (TDN) (Figures 5 and 6) were detected in grasses harvested at eight weeks. The exception was the EG treated with MW, which had its greatest CP and TDN values at 12 weeks. The CP and TDN values represent the total protein of the feed from all sources, and an estimate of the digestible protein, fiber, carbohydrates and fat, respectively, of the feed (SDK, 2011). Based on the laboratory interpretations provided by SDK (2011), it would appear that any given harvest time, the quality of both grasses were similar in term of protein content. This is an important finding for the EG as growers are constantly seeking out alternative forages to SG which can be used to feed animals and also have the potential to take up nitrates- i.e. be an effective biofilter.

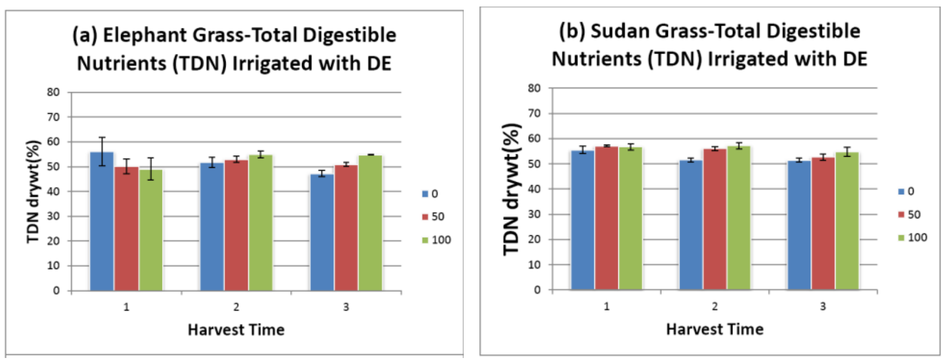

Figure 5. Total Digestible Nutrients (TDN) of grasses irrigated with dairy effluent (DE) at harvests 1, 2, and 3 which is equivalent 8, 10, and 12 weeks, respectively after planting.

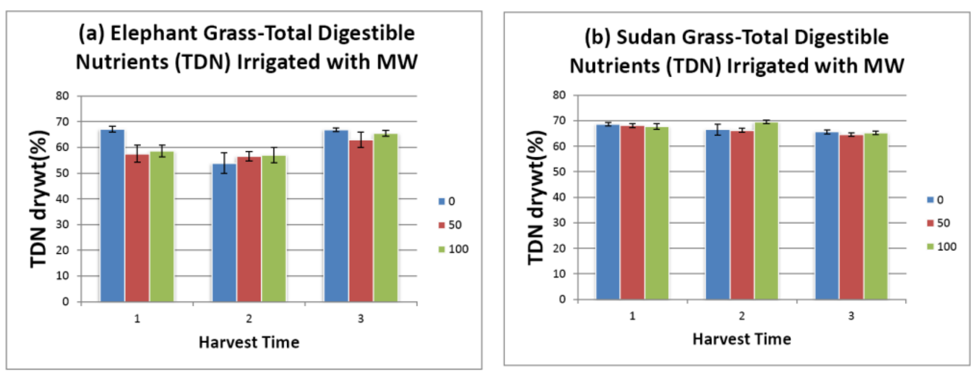

Figure 6. Total Digestible Nutrients (TDN) of grasses irrigated with municipal wastewater (MW) at harvests 1, 2, and 3 which is equivalent 8, 10, and 12 weeks, respectively after planting.

Figure 7 is an example of the nitrate trends detected in the grasses irrigated with the DE and harvested at 8, 10 and 12 weeks after planting. Generally, grasses irrigated with DE exhibited their greatest nitrate content earlier (at 8 weeks) than those receiving MW. More importantly, the grasses receiving MW accumulated as much as five times more nitrate than the grasses treated with DE. Furthermore, with the exception of the EG receiving 100% DE and harvested at eight weeks, the grasses should be safe for animal consumption. For example, forages with nitrate levels ranging from 0- 6,500 ppm can be safely fed to non- pregnant animals (SDK, 2011). In the case of forages with levels between 6,500 and 9,000 ppm nitrate, these can safely fed if limited to 50% of the total dry matter ration. The current findings concur with those from our previous studies (Goorahoo et al., 2004) in which Elephant grass was been identified as a highly nutritious forage crop with the ability to readily take up nitrate from soils subjected to high rates of N fertilization.

(a) Elephant Grass **(b) Sudan Grass**

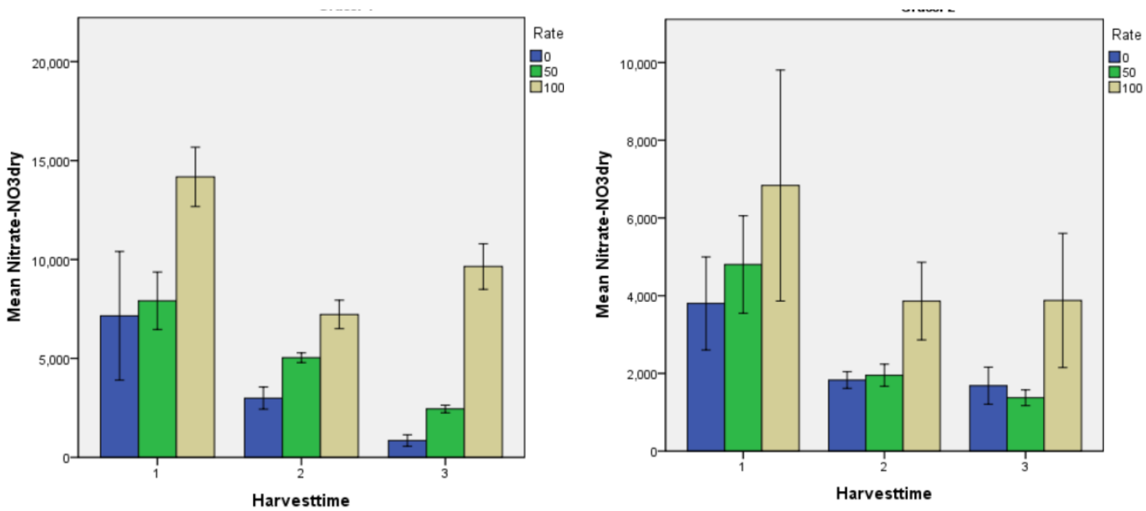

Figure 7. Average nitrate levels in grasses irrigated with dairy effluent (DE) at harvests 1, 2, and 3 which is equivalent 8, 10, and 12 weeks, respectively after planting.

Conclusion

The findings summarized below represent those obtained from the first rounds of our ongoing study to evaluate optimal harvest time for Elephant grass and Sudan grass irrigated with secondary treated municipal waste water (MW) and dairy effluent (DE). A second trial will be conducted during Spring 2012 and complete findings should be available by June 2012.

- The average biomass for the grasses harvested at 8 and 10 weeks were generally higher for plants irrigated with the DE than those irrigated with the MW.
- By the 12th week, similar yields were obtained for each grass regardless of the water source.
- Generally, the highest crude protein (CP) content and total digestible nutrients (TDN) were detected in grasses harvested at eight weeks. The exception was the EG treated with MW, which had its greatest CP and TDN values at 12 weeks.
- Grasses irrigated with DE exhibited their greatest nitrate content earlier (at 8 weeks) than those receiving MW.
- Grasses receiving MW accumulated as much as five times more nitrate than the grasses treated with DE.
- The findings from this current trial concur with those from our previous studies in which Elephant grass has been identified as a highly nutritious forage crop with the ability to readily take up N from soils subjected to high rates of N fertilization.

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