Potential use of a New Forage Grass (*Pennisetum Sp.)* in Best Management Practices Involving Irrigation with Food Processing and Dairy Wastewaters.

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Abstract

Excess nutrients from irrigation of crops with recycled wastewaters from food processing and dairy operations can be a major 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, and has now been planted in five locations in the State. In this paper we present a summary of research by the Center for Irrigation Technology (CIT) at California State University- Fresno, aimed at investigating the potential use of the Elephant grass to act as a scavenging crop for mitigating contamination of groundwater from fields irrigated with food processing wastewater and dairy effluent. Our findings to date indicate that the Elephant grass is a highly nutritious forage grass exhibiting efficient water use, and is a luxury feeder of nitrogen and phosphorus, thereby implying that the grass has good potential to absorb significant amounts of excess nutrients from dairy effluent and processing wastewater used for irrigation.

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. Major problems associated with the manure management are high solids and nutrient contents of the effluent stream. High solids content causes fast sludge buildup in storage lagoons, thus reducing the available storage volume, and also causes high solids loading to the soil when the wastewater is irrigated, hindering the crop seed germination and growth. High nutrient contents tend to cause overloading of land with nutrients, especially nitrogen and phosphates, causing contamination of 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, California also leads the nation in grape and wine production (CDFA, 2002). For example, in 2001 California accounted for 91 percent of the nation's grape receipts. Inherent in the production of wines is copious amounts of processing water commonly referred to as winery Stillage. Land application of the process winery stillage allows for the beneficial reuse of nutrients, organic matter, and water, while utilizing the soil profile 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 the wineries and dairy operations can be a major 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, and has now been planted in five locations in the State. 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. *Pennisetum* grows in clumps or stools having an upright growth habit (Figure 1). 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.

Summary of Research Conducted

In 1995, a three acre plot of the Elephant grass was established at the University of California, Fresno, Center for Irrigation Technology (CIT) in proximity to Fresno University dairy lagoon. The objectives of the trial were to gather initial information on: nutrient absorption and effect of dairy effluent on the growth and condition of the grass; grazing and acceptance of the grass by beef cattle; DM yields and nutritional evolution of the grass with age.

Irrigation water from wells was initially applied by furrow application during the germination period. Subsequent dairy pond waste irrigations were applied on a normal 8-day irrigation interval. Six fenced plots were established in the middle of the planting for sampling of nutrient absorption, yield and forage quality. Fifty mixed breed pregnant beef cows and calves adjusted to and grazed the Elephant grass for daily intervals during two 10-day periods. A second 10-day grazing period occurred after refoliation. A 60-day age of harvest was established to permit 3 harvests from May to October. This trade-off maximized nutrient absorption, and produced quality forage for animal feeding purposes.

In 2002 a grant was obtained through the Agricultural Research Initiative (ARI) California State University System. The Center for Irrigation Technology, Fresno State installed a fully replicated trial with Elephant grass with the following objectives:

- Determine the nitrogen and phosphorus filtering characteristics of the grass
- Determine water consumption of the grass
- Determine possible interactions between bio-filtration and water consumption

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 consisted of four treatments replicated four times. Water application was based on the daily evapotranspiration index. The treatments consisted of water applications of 40%, 80%, 120%, and 160% of the daily measured reference evapotranspiration. Water was precisely applied by drip irrigation tubing and an electronic controller timed the daily irrigation interval application.

The soil sampling protocol consisted of 12 sampling sites with one foot intervals to a depth of five feet. The soil was sampled before the experiment was installed, after the first season of harvest, and after the second season. 180 soil samples were taken and analyzed from the 16 plots from a total area of 8600 square feet.

The grass nutrient absorption and forage protocol consisted of harvesting a center section of each plot representing 31% of the area of the plot. The forage was chopped, mixed and two composite 2-kg sub-samples were taken. The chemical fertilization protocol consisted of an initial application in equal amounts to all of the plots of nitrogen, phosphorus and potassium. Subsequent chemical fertilizer applications (in equal amounts to all plots) were made based on the average amounts of N, P, and K absorbed by the grass from the nine separate harvest periods from 2002 to 2003.

Experimental Results

During the 1995 trials, the 60-day age of crop samples averaged the following:

- DM weights of six replicated 1 m^2 plot samples were 2.3 kg.
- Dry Matter (DM) - 17%
- Nitrogen (N) content - 2.0%
- Total N absorption of the crop - 460 kg per hectare
- Protein content ranged between 25.71% at three weeks of age and 15.03% at 10 weeks of age (Table 1)
- Phosphorus (P) content - 0.70%
- Total P absorption of the crop - 161 kg per hectare.

The implications of the data and observations are:

- The grass was highly palatable with no negative effects on the animals (Figure 2)
- Significant amounts of N and P were absorbed by the Elephant grass over the 60 days
- No "burning" or other negative effects on the grass were caused by the wastewater
- Total N accumulation increased from the youngest emerging leaf to the stalk
- Stalk total N accumulation was seven times more than the youngest leaves

- Increasing stalk to leaf mass by aging the grass would increase total N bio-filtration
- The waste application produced forage of significant quality and value for ruminants

For the 2002 experiment, conducted on a sandy loam soil, the average amount of total N extracted by the Elephant grass over the course of the experiment was 1162 kg per hectare compared to the 883 kg of fertilizer N applied per hectare (Tables 2 and 3). However, care must be taken in making any comparison as the total N value reported for the forage includes organic N sources such as proteins, where as the N fertilizer was inorganic nitrogen. Generally, soil nitrate levels within the top five feet of soil were maintained below 8 ppm throughout the duration of the experiment (Figure 3). The only exception was the 16 ppm value measured within the top foot of soil in spring 2003. Soil phosphate levels followed a similar trend as that observed for the soil nitrate (Figures 3 and 4). On average, the grass extracted 230 kg (in 2003) of P per hectare compared to an application rate of 368 kilos of P per hectare in 2002-2003 (Tables 2 and 3). Table 4 contains total dry matter production for years 2002-2003.

The implications of the data from the 2002 funded experiment are the following:

- The Elephant grass has bio-filtering characteristics for filter strip applications
- Treatment 1, the 40% level of water application produced significantly lower dry matter ($P < .01$) than the other treatments
- There was no significance of dry matter production between the 80%, 120%, and 160% treatments
- The evapotranspiration coefficient (water use) of the grass is between 80 and 100% of the referenced daily evapotranspiration
- There was a trend in total nitrogen and phosphorus absorption due to the higher dry matter production of the 80%, 120% and 160% treatments.
- There was no interaction of water level application and N and P absorption. However there seemed to be a trend for higher absorption for the highest water application

Conclusions and Future Research

The information derived from the current research is very important for the agriculture processing and dairy industries as increasingly more strict discharge regulations are being implemented by regulatory agencies. For example, the findings will be useful in providing important information on how different dairy effluent and wastewater discharge regimes affect the loading rates in the field at different growth stages of the elephant grass. Overall, from studies conducted to date, it can be concluded that the Elephant grass appears 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.

The California State Water Resources Control Board has awarded a grant to the Imperial Valley Conservation and Resource Center Committee (IVCRCC), Brawley, California to plant 28 acres of the Elephant grass for a buffer/filter application. The project entitled "Nutrient Control of Agricultural Runoff Water" will use agricultural drain water now running into the Salton Sea to irrigate the grass. The objective of this project is to reduce nitrogen, phosphorus, and sediments, which are causing eutrophication of the Salton Sea. The project will be installed, monitored, and audited by a team of scientists from the Center of irrigation Technology, California State University, Fresno and is scheduled to run for three years.

In another small scale study the use of elephant grass as a scavenging crop for nitrates and organic loading is being compared to Sudan grass on fields which have been subjected to winery Stillage disposal. Soil water quality in the vadose zone will be monitored using suction lysimeters installed at 2 and 4 feet. Vadose zone monitoring at those two depths will be valuable to assess solute movement through the soil profile and determine the role of Elephant grass in reducing water contamination below the root zone. This project is funded by the California State University –Agricultural Research Initiative (CSU-ARI) and is being conducted in collaboration with the City of Fresno Wastewater Treatment Facility.

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Table 1. Nutritional Evolution of the Elephant grass with Age , Irrigated with Dairy pond Liquid Waste (Rothberg, 1995 Internal Report CIT).

Age in weeks	Dry Basis	Protein (DB)	TDN	Acid Detergent Fiber	Neutral Detergent Fiber	Relative Feed Value
3		25.71%	65.20%	30.00%	48.99%	119.0
4		19.72%	62.22%	33.77%	48.99%	119.0
5		21.80%	64.03%	31.48%	49.38%	121.0
6		18.87%	62.67%	33.20%	51.58%	114.0
7		17.16%	61.30%	34.94%	52.68%	109.0
8		15.44%	59.93%	36.68%	53.77%	104.0
9		15.24%	59.94%	36.66%	54.21%	103.5
10		15.03%	59.95%	36.64%	54.64%	103.0
Average		**18.62%**	**61.91%**	**34.17%**	**51.78%**	**111.6**

DB – Dry Basis; TDN- Total Digestible Nutrients; ADF – Acid Detergent Fiber – residue of cellulose, lignin and silica after boiling in acid detergent; NDF – Neutral detergent fiber – remains of cellulose, hemicellulose, lignin, and ash after boiling in a neutral detergent solution; RFV – Relative Feed Value – a ranking index for digestability and intake potential.

Table 2. NITROGEN AND PHOSPHORUS FERTILIZATION

YEAR	N kg/ha	P kg/ha
01 & 02	542	185
2003	341	183
TOTAL	883	368

Table 3. TOTAL N AND P ABSORPTION BY THE GRASS 2001-2003

TREATMENT	N/kg/ha	P/kg/ha*
1	819	178
2	1210	258
3	1208	241
4	1412	241
Average	1162	230

*** P Absorption only in 2003**

Table 4. Total dry matter production in kg/ha 2002-2003

	PERCENT OF WATER APPLICATION/EVAPOTRANSPIRATION INDICE			
	T 1 – 40%	T2 – 80%	T3 - 120%	T4 -160%
DRY MATTER PRODUCTION	52,586	74,774	76,839	78,142

Figure 1: Elephant grasses (*Pennisetum sp)* grows in clumps or stools (Top) and have an upright growth habit as they attain heights of greater than six feet.

Figure 2: Cows grazing Elephant grass irrigated with dairy waste, California State University, Fresno, Center for Irrigation Technology

Figure 3

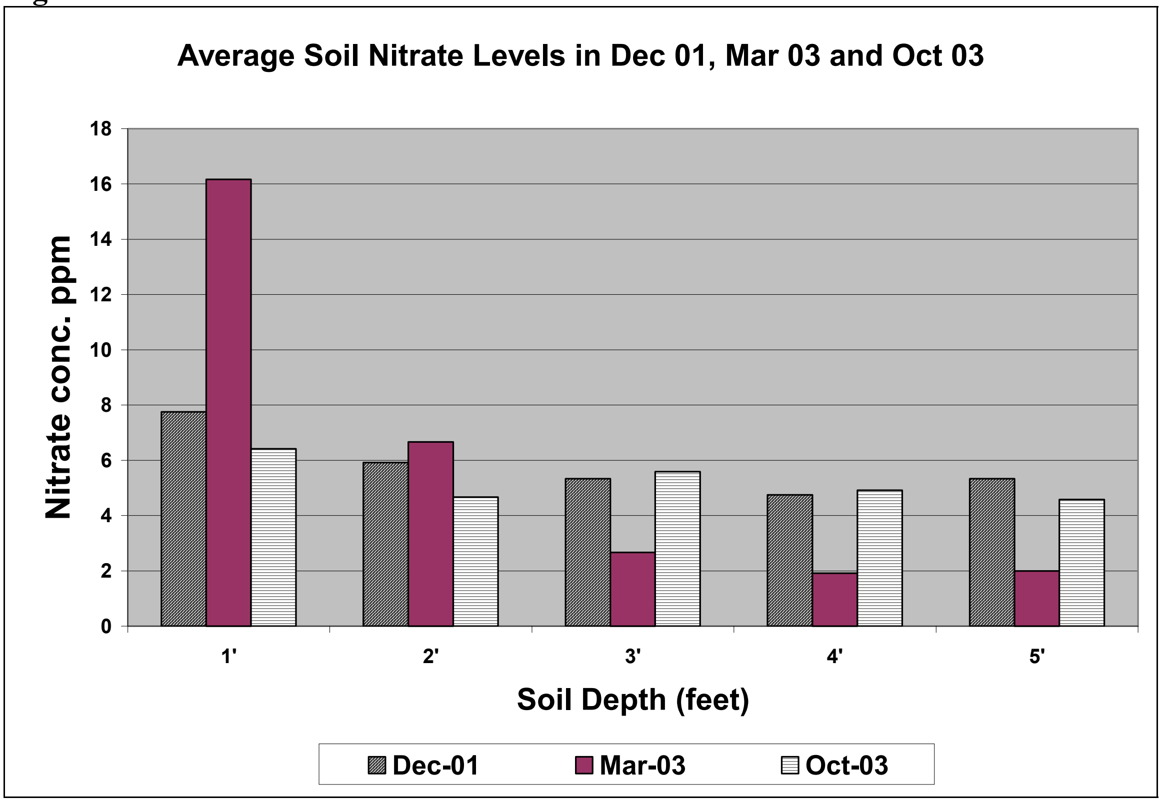

Figure 4