Vetiver System for Industrial Wastewater Treatment in Queensland, Australia

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Abstract: The disposal of industrial wastewater in Queensland is subjected to the strict environmental guidelines enforced by the Environmental Protection Authority. The most common method of treating industrial wastewater in Queensland is by land irrigation, which is presently based on tropical and subtropical pasture plants. However with limited land area available for irrigation, these plants are not efficient enough to sustainably dispose of all the effluent produced by the industries. Therefore to comply with the new standards, most industries are now under strong pressure to upgrade their treatment processes.

Over the past two years a series of research projects conducted at GELITA Australia gelatine factory in Beaudesert, Queensland and at Teys Bros. abattoir in Beenleigh to determine a viable means to achieve these goals. The Vetiver System has been identified as having the potential to meet all the criteria:

- Vetiver has the potential of producing up to 132t/ha/year of dry matter yield as compared to 23 and 20t/ha/year for Kikuyu and Rhodes grass respectively
- With this production vetiver planting has the potential of exporting up to 1920kg/ha/year of N and 198kg/ha/year of P as compared to 687 of N and 77kg/ha/year of P for Kikuyu and 399 of N and 26 of P for Rhodes grass respectively.
- Vetiver growth can respond positively to N supply up to 6 000kg/ha/year and to ensure this extraordinary growth and N uptake, P supply level should be at 250/ha/year.

Based on the above results the two companies have developed long term implementation plans for effluent and other solid waste product disposal.

Key words: Vetiver, effluent disposal, irrigation, nutrient, fodder

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1 INTRODUCTION

GELITA owns and operates a plant for the manufacture of gelatine from cattle skin at a site at Sunny Hills via Beaudesert in Queensland Australia. This plant is situated on a property of 170 hectares, approximately 75 kilometres from Brisbane. The GELITA operation is a medium sized enterprise employing 70 full time staff and producing 2200 tonnes of gelatine each year for an approximate annual turnover of AUD30 million per year. Raw materials are sourced from meatworks across the country and consist of face pieces and scraps of hide of little other commercial value. The manufacturing process is unique to this country and requires a high through put of water to be effective. GELITA generates approximately 1.3 ML a day of wastewater, which is characteristically high in nitrogen and total dissolved salts.

TEYS Bros Pty Ltd operates a beef abattoir in Beenleigh, Queensland. Effluent generated by the plant is passed through various primary treatment devices and to irrigate 65ha of Kikuyu grass pasture.

The Queensland government has applied strict regulations regarding the disposal of this wastewater. In order to meet these regulatory requirements and to fulfil expectations of ESD (Ecologically Sustainable Development), GELITA and Teys Bros. have undertaken a comprehensive research program to develop optimal disposal methodologies.

2 CURRENT CONSTRAINTS

The GELITA factory extracts gelatine from cattle hide using chemical processes involving strong acids, lime and hydroxides. The site consists of 170 hectares of land with 121 hectares licensed by the Environmental Protection Authority (EPA), for disposal of effluent generated in the production of gelatine. The effluent from the processing plant is highly saline (average 6 dS/m), alkaline and has a high organic matter content. This effluent is further processed in a typical series of anaerobic and aerobic digestive processes to lower the nitrate contents to approximately 300 mg/L of nitrogen and 2 mg/L of phosphorus.

The property has 13 distinct soil types, which range widely in their properties from Rudosol, Dermosol, Vertosol to Sodosol. Of these soil types only the Rudosol alluviums display acceptable characteristics to deal with the long-term application of effluent. Effluent applied to the Sodosol and Vertosol clay soils can result in a surface concentration of salts that affects the root zone and is not considered a long-term sustainable practice. Due to extreme climatic variations over the seven years of operation the planting of pasture and annual crops has not provided a viable operational methodology as concentrations of salts in soil increase proportionately to diminishing rainfall.

In order to ensure sustainability of the disposal process, an alternative method was sought that would allow for the “flushing” of salts through the soil profile whilst stripping the nitrogen from the solution. Such a process would meet the EPA requirements and eliminate a real environmental risk to the operation.

TEYS Bros abattoir in Beenleigh, Queensland, which processes in the order of 210 000 cattle per year for both domestic consumption and export. Effluent generated by the plant is passed through various primary treatment devices and a series of ponds prior to on-site irrigation of 65ha Kikuyu grass pasture. Previous investigation has concluded that the current effluent irrigation scheme is unsustainable in the long term. In response to this situation, the management is looking for means of disposing the effluent output more sustainably.

3 LICENSING LIMITS FOR NITROGEN AND PHOSPHORUS

Under Queensland law, the treatment of industrial wastewater is administered by the EPA, which has adopted a computer model - MEDLI (Model for Effluent Disposal using Land Irrigation), as a basic tool for industrial wastewater management. MEDLI is a Windows based computer model for designing and analysing effluent disposal systems, which use land irrigation, for a wide range of industries such as piggeries, feedlots, abattoirs, sewage treatment plants, and food processing factories (Truong *et al*., 2003; Vieritz *et al*, 2003)

For GELITA, the current licensing limits set out under the EPA permit the irrigation of 3.0ML/day of wastewater with a maximum Nitrogen level of 200mg/L, total Phosphate at 5mg/L and total dissolved salts of 12t/ha/annum.

4 CURRENT MANAGEMENT PRACTICES

To comply with EPA licensing conditions, the GELITA factory effluent output is currently distributed by spray irrigation from hard hose traveling irrigators across 121 hectares of grassland dominated by Rhodes grass. This is “a command and control mode” in which compliance is assessed by comparison with of sample data with fixed criterion. The license controls fail to adapt appropriately to extremes of climatic conditions and production variability. Under a strict licensing interpretation, the current practice is not adequate in providing a long-term sustainable treatment solution.

At Teys Bros a total area of 65ha is available for irrigation, but after allowing for buffer perimeter, currently only 42.3ha are can be used for irrigation. Currently effluent is either spray or surface irrigated onto Kikuyu pasture at various sites around the property. The pasture is not harvested and the application uniformity is quite poor. Current MEDLI modelling predicted that only 204ML/year could be disposed off if Kikuyu pastures were used. This would leave a surplus effluent volume of 347ML/year to be treated by other means.

5 SEARCHING FOR A MORE INNOVATIVE AND NATURAL SOLUTION:

For GELITA, alternative solutions such as chemical treatment plant and transportation to sewage treatment plant were considered but both of which are impractical and most importantly very costly to build and to operate. Therefore a more innovative and natural solution was needed.

Tree planting was one of the earlier options considered, it has been trialed for several years but has not provided an effective solution to the problems faced by the company. To date no data is available for comparison of the effectiveness of the two eucalypt species trialed for N uptake as opposed to that of traditional pasture regimes. Preliminary findings have established that an estimated 16.5 t/ha/year dry matter yield of pasture will result in a N export of 458kg/ha/year from between tree rows if an assumed N level of 2.9% occurs. No further results are expected from these trials for some time. This is not an outcome that meets the company objectives, as the EPA requires an updated farm management program to be submitted by the end of September 2003.

Due to the limit of the land area, TEYS Bros abattoir will pipe excess effluent output to the Logan Shire Council for treatment. The cost of treating this effluent is based on both quantity and quality of the effluent. Therefore any means, which can lower the volume and/or the nutrient loading of the effluent will reduce the costs of treatment to the company.

Application of the Vetiver System (VS) for wastewater treatment is a new and innovative phytoremedial technology developed by the Department of Natural Resources and Mines in Queensland, (Truong and Hart, 2001). VS was identified as having the potential to meet all the criteria of both factories.

The vetiver option using MEDLI as a model offers a practicable and cost effective solution. However, to date the application of MEDLI in tropical and subtropical Australia has been restricted to a number of tropical and subtropical crops and pasture grasses. These species have been specially calibrated for MEDLI use, to apply vetiver to MEDLI model it has to be calibrated first.

To obtain this vital information, GELITA Australia and Teys Bros abattoir, with support from the Queensland Department of Natural Resources and Mine, and a grant from the Wallace Genetic Foundation of the US (through The Vetiver Network), has undertaken a comprehensive research program to calibrate vetiver for MEDLI modelling (Veritz et al, 2003).

In addition both companies also conducted other trials with vetiver for erosion and sediment control, wetland establishment, cattle feed and composting. GELITA Australia has a goal of zero waste off site and the trial of vetiver as a bulking material and for odour reduction in the composting process is part of an ongoing research program designed to achieve this outcome.

6.0 RESEARCH AND DEVELOPMENT PROGRAM

The program consisted of two projects:

- Calibrating Vetiver grass for the MEDLI model (Truong and Smeal, 2003)
- Providing base line data to assist the development of a suitable strategy for implementation in both companies.

6.1 Calibration for MEDLI

Over the past two years a series of research projects conducted in glasshouse and on-site to provide critical parameters for the MEDLI model.

6.1.1 Pot experimentation

The aims of this series of experiments were to determine the ability and capacity of vetiver to withstand and to uptake very high level of N and P in the soil and their recovery rates (Wagner *et al.* 2003).

- ***Vetiver growth cycle and shoot dry matter yield***

Vetiver shoot yields after 10 weeks growth ranged from 12.8 to 105 g/pot or approximately 4 000 to 34 000 kg/ha/10weeks. Although pot yields are often higher than those shown in the field, it nevertheless demonstrates the enormous potential for vetiver to achieve high rates of biomass production.

It is also interesting to note that vetiver grew reasonably well on pure sand, relying only on the nutrients initially supplied by the propagating tissue (slip) (69mg/pot of N and 8.4mg/pot of P) and sand (2.4mg/pot of N and 4.8mg/pot of P).

- ***Effects of high N supply on vetiver growth***

Figure 1 shows that vetiver growth increased with the level of N supplied. However very little growth response occurred at rates higher than 6 000kg/ha/year although rates up to 10 000kg/ha of N did not adversely affect vetiver growth.

- ***Effects of high P supply on vetiver growth***

Figure 1 also shows that vetiver requirement for P was not as high as for N, and no growth response occurred at rates higher than 250kg/ha/year. However its growth was not adversely affected at P application rates up to 1 000kg/ha/year.

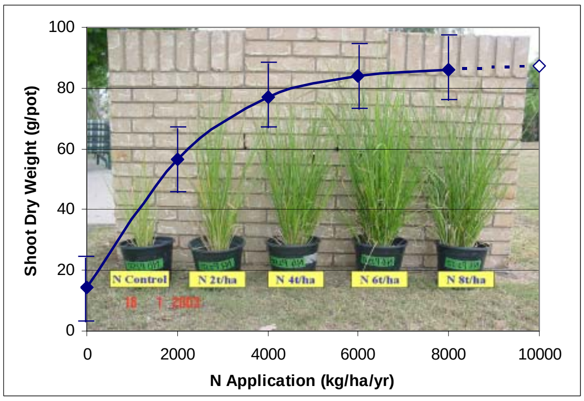
- ***Interaction of N and P effects on vetiver growth***

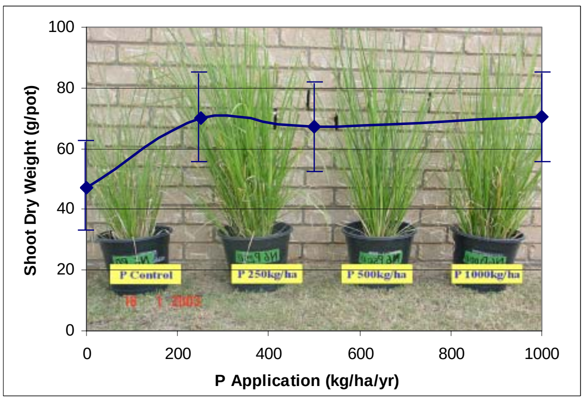
A significant interaction between the effects of N and P was also observed, with greater N response occurring in the presence of higher levels of P. This suggests that to ensure optimal growth and N uptake, vetiver needs adequate P supply; at least at 250kg/ha/year (Fig. 2).

- ***Recovery rates of N and P***

Vetiver has a very high recovery rate for N, about 70% recovered in the shoots for application rates up to 6 t N/ha/year and about 55% for 8t N/ha/year and 45% for 10t N/ha/year. This characteristic makes vetiver highly suitable for treating N in wastewater. However the P recovered in the shoots is only 30% at a supply level of 250kg P/ha/year, and lower at higher supply rates (Table 1).

Fig. 1. *Left,* Shoot dry matter yield under very high Nitrogen supply.
***Right,* Shoot dry matter yield under very high Phosphorus supply.**





- ***Results and Conclusion***

Results show that vetiver grass has a very high capacity of absorbing N at elevated levels of N supply. Vetiver growth will respond positively to N supplied at rates of up to 6 000kg/ha/year, with no adverse growth effects apparent up to 10 000kg N/ha/year. These features make vetiver highly suitable for treating wastewater and other waste materials high in N.

Vetiver requirement for P was lower than that for N, and no growth response was observed at rates exceeding 250kg/ha/year. Its growth was not adversely affected at P application rates up to

1 000kg/ha/year. However, in combination with a high growth rate and high yield, the total amount of P uptake by vetiver was found to exceed those of other tropical and subtropical grasses.

Fig. 2. Shoot dry matter yield interaction between the effects of N and P.

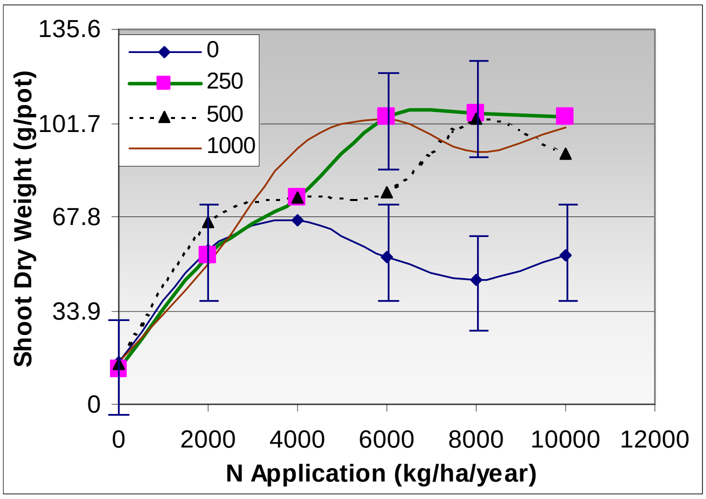


Table 1: Recovery rates of N and P by vetiver grass.

Treatment	%Recovery by Shoot	%Recovery by Root	% Recovered in Soil	Total
N2	76.3	20.4	0.3	97
N4	72.1	23.1	0.1	95
N6	67.3	21.2	0.4	89
N8	56.1	30.0	0.4	87
N10	46.7	17.0	0.1	64
P250	30.5	23.3	46.3	100
P500	20.5	14.6	48.7	84
P1000	16.5	14.2	40.8	72

6.1.2 Field experimentation

Field plot experimentation was conducted to determine vetiver growth cycle, dry mater yield, water use, potential N and P uptake, and export, potential irrigation area and to compare vetiver performance with the other two currently used grasses, Rhodes and Kikuyu (Truong and Smeal, 2003).

- ***Growth cycle***

Results from field trial showed that vetiver growth increased steadily until week 10 and the rate was slightly reduced thereafter until week 12, indicating that under the existing site conditions (soil type, fertility level and irrigation regime etc.), vetiver growth has peaked at week 12 (Fig.4). Therefore after 12-week growing period or 3-month, it is probably the best time to harvest vetiver to maximize yield and nutrient export from the field. At this stage vetiver plant is 1.7m tall with an Leaf Area Index higher than 14, and dry matter yield of 4 074g/m2.

- ***Dry matter yield***

Data collected over the experimental period of 12 weeks show that Vetiver out yielded Kikuyu by almost 6 times and Rhodes over 6 times (40.7, 7.0 and 6.1 t/ha respectively). Based on this data, if harvest were carried out every 12 weeks, the potential vetiver yield for the 6 and 9-month periods would be 88.3 and 132.4 t/ha respectively, and that for Kikuyu would be 15.2 and 22.71/ha and that for Rhodes 13.3 and 19.9t/ha (Fig.5). The 9-month yield was considered instead of 12-month growing period to allow for the much slower growth rate during the winter period.

Fig.4: Dry matter yield of vetiver over the 12-week period

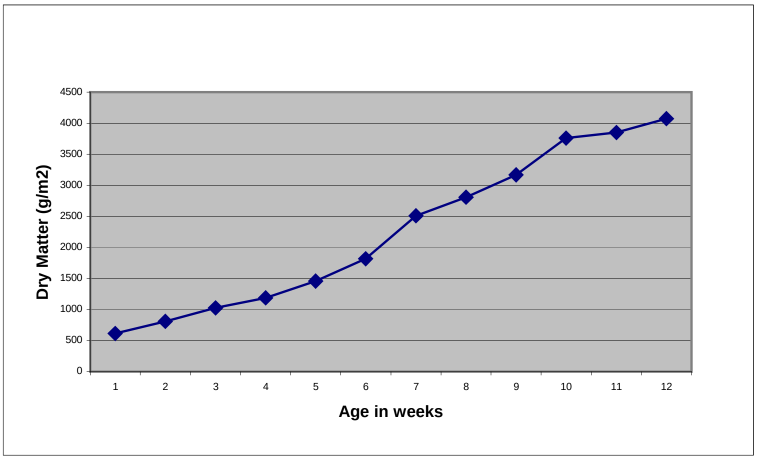


Fig.5: Potential DM yield of the three grasses over time

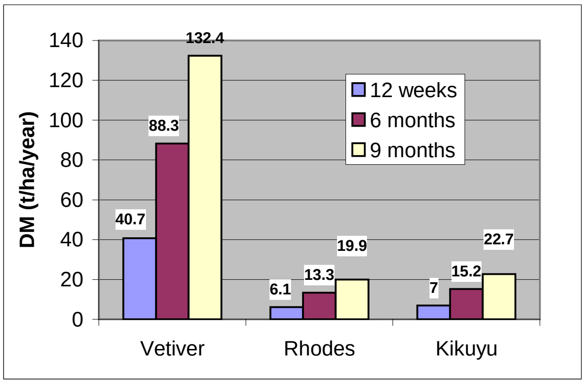
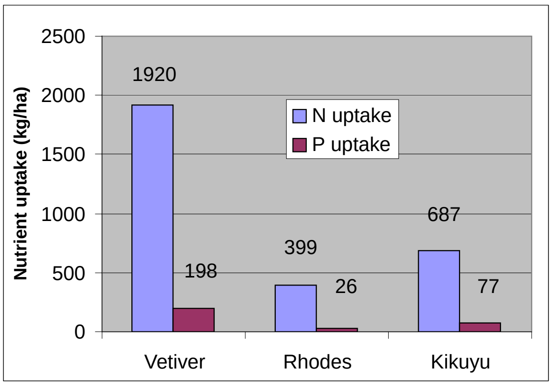


Fig.6: Potential N and P uptakes by the 3 grasses over 9-month period



- ***Potential N and P uptake***

The potential N and P uptakes of vetiver as compared with the other two grasses reflect the dry matter (DM) yield data shown in Fig.6, which over the 9-month period, N uptake was 1920, 687 and 399kg/ha for vetiver, Kikuyu and Rhodes grass respectively. Similarly the P uptake was 198, 77 and 26kg/ha respectively for the three grasses.

- ***Harvested production of the three grasses.***

The potential DM, N and P uptakes presented above were based on the whole shoot yield, which is the biomass cut to the ground level. This biomass consists of a harvested component plus the "residue" component, which is the portion, remains on the ground. In the case of vetiver, as an erect grass, the residue constitutes a substantial part of the potential yield, up to 25%, as compared with 10% of Rhodes and Kikuyu. Fig. 7 shows the difference between potential and actual yield of vetiver grass.

- ***N Export of the Three Grasses***

N export by vetiver is more than 2.2 times that of Kikuyu and 3.9 times that of Rhodes (1442 kg/ha, 642 kg/ha and 373 kg/ha respectively) (Fig.8). Similarly P export by vetiver is more than twice that of Kikuyu and 6.2 times that of Rhodes (149 kg/ha, 72 kg/ha and 24 kg/ha respectively) (Fig.9).

Fig 7: Harvested dry matter yield of the three grasses over time

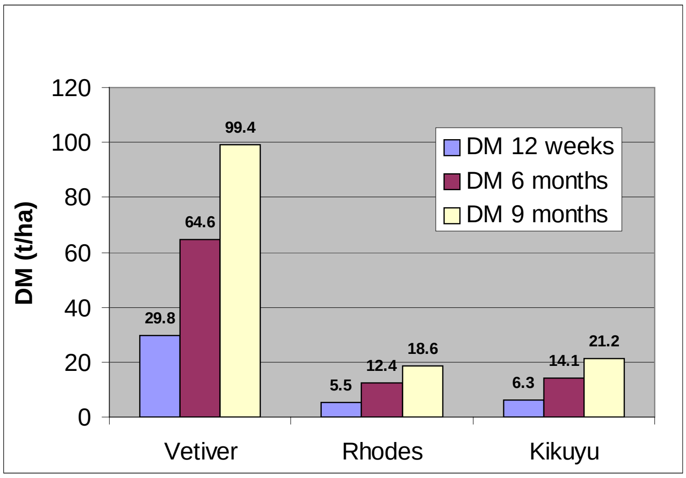


Fig 8: N export by the three grasses over time

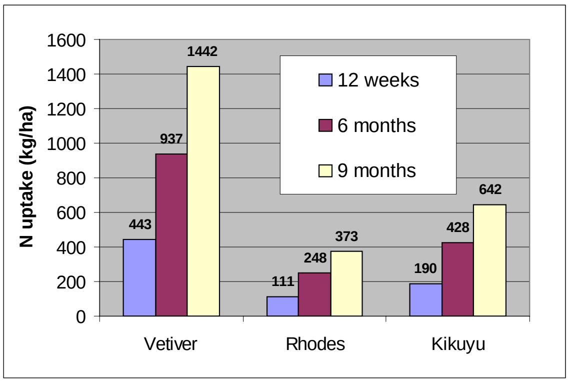
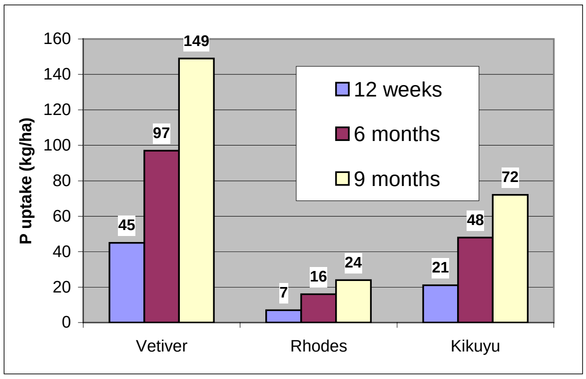


Fig 9: P export by the three grasses over time



- ***Water use***

Under wetland conditions, vetiver had the highest water use rate as compared with other wetland plants such as *Iris pseudacorus*, *Typha spp*, *Schoenoplectus validus*, *Phragmites australis*. At the average consumption rate of 600ml/day/pot over a period of 60 days, vetiver used 7.5 times more water than Typha (Cull *et al.* 2000).

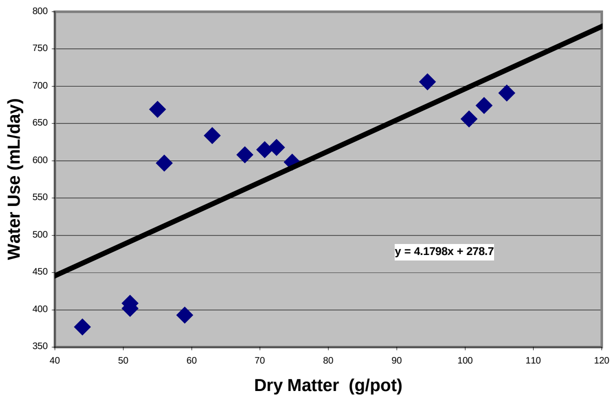
To quantify the water use rate of vetiver, a glasshouse trial showed a good correlation between water use (soil moisture at field capacity) and dry matter yield (Fig.10). From this correlation it was estimated that for 1kg of dry shoot biomass, vetiver would use 6.86L/day. If the DM yield of a 12-week-old vetiver were 40.7t/ha, at the peak of its growth cycle, a hectare of vetiver would potentially use 279KL/ha/day.

- ***Summary of results***

1) Vetiver planting at Sunny Hills has the potential of producing up to 132t/ha/year of dry matter yield as compared to 23 and 20t/ha/year for Kikuyu and Rhodes grass respectively

2) With this production vetiver planting has the potential of exporting up to 1920kg/ha/year of N and 198kg/ha/year of P as compared to 687 of N and 77kg/ha/year of P for Kikuyu and 399 of N and 26 of P for Rhodes grass respectively.
3) The harvested dry matter yield of vetiver grown at Sunny Hills was 100t/ha, exporting 1442kgN/ha and 149kgP/ha, as compared with 642 kgN/ha and 72 kgP/ha for Kikuyu; and 373 kgN/ha and 24 kgP/ha for Rhodes, respectively

Fig 10: Relationship between water use and dry matter (r = 0.7286)



6.2 Research and Development for baseline data

In conjunction with the MEDLI calibration program, a series of others trial was conducted at Sunny Hills to determine the effects of other adverse effects on vetiver growth such as soil salinity, high sulphate level, low P and water logging. The followings are summary of results:

1) Vetiver growth can respond positively to N supply up to 6 000kg/ha/year and to ensure this extraordinary growth and N uptake, P supply level should be at 250/ha/year.
2) Results from both field and pot trials, and anecdotal evidence indicate that endemic “adverse” factors in the soils that commonly affect plant growth such as high acidity, high salinity, high S, Na and Ca, do not adversely affect vetiver growth.
3) Data on growth and nitrogen content of mature plants indicate that the deep and extensive root system of vetiver could reduce or eliminate nitrate leaching.
4) Nutritional values in Table 2 show that vetiver is highly digestible and comparable with Rhodes grass and Kikuyu.

Table 2: Nutritional values of Vetiver, Rhodes and Kikuyu grasses grown at Sunny Hills and Beenleigh

Analytes	Units	Vetiver grass			Rhodes	Kikuyu
		Young	*Mature*	*Old*	*Mature*	*Mature*
Energy (Ruminant)	kCal/kg	522	706	969	563	391
Digestibility	%	51	50	-	44	47
Protein	%	13.1	7.93	6.66	9.89	17.9
Fat	%	3.05	1.30	1.40	1.11	2.56
Calcium	%	0.33	0.24	0.31	0.35	0.33
Magnesium	%	0.19	0.13	0.16	0.13	0.19
Sodium	%	0.12	0.16	0.14	0.16	0.11
Potassium	%	1.51	1.36	1.48	1.61	2.84

Phosphorus	%	0.12	0.06	0.10	0.11	0.43
Iron	mg/kg	186	99	81.40	110	109
Copper	mg/kg	16.5	4.0	10.90	7.23	4.51
Manganese	mg/kg	637	532	348	326	52.4
Zinc	mg/kg	26.5	17.5	27.80	40.3	34.1

5) Monitoring bores, up to 2m deep, were installed at various distances on a vetiver plot at Teys Bros to monitor the efficiency of the vetiver treatment. Table 3 shows total N in seepage was reduced from 170mg/L to 17.5mg/L after going through 20m of vetiver and to 10.6mg/L after 50m. Similarly total P was reduced from 32mg/L to 3.4mg/L and 1.5mg/L respectively.

Table 3: Effectiveness of vetiver planting on quality of effluent seepage

Analytes	**Nutrient levels**		
	Inlet	**Mean levels in monitoring bores**	
		20m down slope from inlet	**50m down slope from inlet**
pH	8.0	6.5	6.3
EC (uS/cm)	2200	1500	1600
Total Kjel. N (mg/L)	170	11.0	10.0
Total N (mg/L)	**170**	**17.5**	**10.6**
Total P(mg/L)	**32**	**3.4**	**1.5**

7 MEDLI SIMULATION

7.1 GELITA APA.

Table 4 shows the MEDLI output based on an assumed maximum annual effluent output of 584ML, N concentration of 300mg/L and 121ha available for irrigation, Amongst the three grasses, vetiver requires the least land for sustainable irrigation in both N and effluent volume.

Table 4: Land area required by the three grasses for irrigation and N disposal

Plants	**Land needed for irrigation (ha)**	**Land needed for N disposal (ha)**
Vetiver	***80***	***70***
Kikuyu	114	83
Rhodes	130	130

However, in theory, if this land area were used, there would be no runoff or leaching; to promote salt leaching either the land area is reduced or the irrigation volume increases. For example, MEDLI predicts that on the same irrigation regime, to provide 15-20% extra volume for leaching, only 49.5ha is required for irrigation. Some N will also move down the horizons with the extra volume, but vetiver would recover this N with its deep root system as shown above.

The potential for soil salinity, groundwater contamination and eutrophication of the adjacent Logan River has established rigorous parameters for the research program. A means for the transportation of soluble salts through the soil profile via adequate leaching of effluent is required.

A reduction from 121 hectares to 50 hectares for the application of the effluent is expected to result in significant cost savings for the operation. The program will however, require the implementation of a rigorous monitoring regime to protect natural assets including soil and ground water.

7.2 Teys Bros

MEDLI simulations predict that:

- When Vetiver grass was used, approximately ***1.24 ML/day*** of effluent can be sustainably irrigated on the available land
- When Kikuyu grass pasture only approximately ***0.8ML/day*** effluent can be sustainably irrigated on the same site.
- The above results indicate that, vetiver planting would provide ***an improvement of 55% over Kikuyu.***

8 FUTURE PLAN

8.1 GELITA APA.

8.1.1 Management consideration

Preliminary work has demonstrated that during the winter period vetiver nitrogen and water uptake is diminished. This is attributed to lower temperature and limited hours of sunlight. Winter at Sunny Hills is typically a dry period. The movement of soluble salts through the soil profile is therefore dependant largely on irrigation water. To prevent any concentration of salts occurring at the surface adequate volumes of effluent must be applied. In order to ensure that the nitrogen does not leach through to groundwater in levels exceeding the guidelines during this period, a complementary winter pasture, annual rye grass, will be planted between the vetiver rows to maximise the nitrogen uptake potential for the site.

Subject to acceptance of the proposal by the EPA, an amendment of the current license will be negotiated to allow for an outcome based irrigation program. Rather than irrigate to set limits based on effluent characteristic. The considered approach is to irrigate according to the soil condition and health, and climatic conditions, that is, outcome based. This approach is consistent with Ecologically Sustainable Development as per the EP acts and IPA.

The biomass generated will also form part of the compost trials to establish the odour control potential. The compost material will be used to improve the skeletal and stony soils on other areas of the property. The outcomes of that project may form the basis of a future presentation to this forum.

Establishment of vetiver wetlands in drainage lines is also being considered to polish excess irrigation and runoff water.

8.1.2 Commercial consideration

Vetiver will be harvested to maximize N removal and the totals calculated using a mass balance equation based on irrigation water quality data to ensure removal matches application. Trials have established that vetiver can be mown and baled for a palatable stock feed with high

Digestible Energy levels (Table 2). A potential market exists for such fodder when prevailing weather conditions are appropriate.

A strong local demand is currently building for vetiver slips for use in erosion control projects and mine rehabilitation. Supplies in this region are limited to small projects. Recognition of this growing demand ensures that the commercial opportunity to harvest slips for sale will be factored into the program.

8.2 Teys Bros

The following measures are being considered for implementation.

8.2.1 Floating pontoons treatment.

Any measures that reduce the volume or nutrient loading of the effluent will lower the treatment cost at the Logan sewage treatment plant for the company. Effluent in irrigation storage ponds will be first treated with a series of floating pontoons. This will substantially reduce the nutrient load of the effluent (Photo 1).

8.2.2 Tail drains planting.

Implementation of the current Irrigation Management Plan developed by FSA Environmental for the abattoir will be carried out. This plan includes extensive vetiver planting as indicated in Fig.11.

Photo1: Vetiver pontoons on an effluent pond

Fig.11: Dark areas indicate vetiver Planting

10 ACKNOWLEDGMENT

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11 REFERENCES

Cull, R.H., Hunter, H., Hunter, M. and Truong, P.N. (2 000). Application of Vetiver Grass Technology in off-site pollution control. II. Tolerance of vetiver grass towards high levels of herbicides under wetland conditions. Proc. Second Intern. Vetiver Conf. Thailand, January 2000

Truong P, and Hart B, 2001. Vetiver System for Wastewater Treatment. Technical Bulletin no. 2001/21. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong P, and Smeal C. 2003. Research, Development and Implementation of Vetiver System for industrial wastewater treatment, GELITA APA. Technical Bulletin no. 2003/3. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong, P., Truong, S. and Smeal, C (2003). Application of the vetiver system in computer modelling for industrial wastewater disposal**.** Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.

Vieritz A, Truong P, Gardner T and Smeal C. 2003. Modelling Monto vetiver growth and nutrient uptake for effluent irrigation schemes. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.

Wagner S, Truong P, Vieritz A and Smeal C. 2003. Response of Vetiver Grass to Extreme Nitrogen and Phosphorus Supply. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.

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