Response of Vetiver Grass to Extreme Nitrogen and Phosphorus Supply

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Abstract: Due to its unique morphological and physiological characteristics, vetiver grass is tolerant to many adverse climatic and edaphic conditions, and recently it has been found to show a large capacity for recovering N and P from wastewater and polluted water.

As a part of a project conducted to calibrate vetiver for use in a computer model - MEDLI (Model for Effluent Disposal Using Land Irrigation), a pot experiment was carried out to determine the maximum capacity of vetiver for N and P uptake in soil supplied with N and P at rates of 10,000 kg/ha/year and 1000 kg/ha/year respectively.

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 6000 kg/ha/year, with no adverse growth effects apparent up to 10,000 kg 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 250 kg/ha/year. Its growth was not adversely affected at P application rates up to 1000 kg/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.

Key words: Vetiver grass, wastewater, landfill, leachate, pollution, nitrogen, and phosphorus

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1 INTRODUCTION

The World Bank has promoted the Vetiver System (VS) since the 1980s for various applications such as soil erosion and sediment control, water conservation, landslip and riverbank stabilisation and recently for pollution control. It proved to be one of the most effective and low cost natural methods of environmental protection (Greenfield, 2002).

Due to its unique morphological and physiological features, such as a long, thick root system, tough and rigid stems and high tolerance to a wide range of soil conditions and heavy metal toxicities, this suggested a new application for the VS; the rehabilitation of contaminated lands and wastewater treatment (Truong and Baker, 1998; Truong, 1999).

2 LITERATURE REVIEW

Application of vetiver for wastewater treatment started in Australia in 1995 and in China in 1997. In Australia, vetiver was used to absorb leachate and effluent from landfill (Truong and Stone, 1996). In China, vetiver was used successfully to purify polluted river water (Anon., 1997; Zheng *et al.*, 1997).

Landfills are usually highly polluted with heavy metals, which are toxic to human, other mammals and plants. Research has shown that vetiver is highly tolerant to agrochemicals, heavy metals (Truong, 2000). Xia *et al*. (2002) in a trial conducted to compare the effectiveness and tolerance to toxicity of four plants in treating landfill leachates, concluded that the overall ranking of the four species is: vetiver > alligator weed (*Alternanthera philoxeroides*) > bahia grass (*Potatum notatum*) > common water hyacinth (*Eichhornia crassipes*).

Research has also shown that vetiver has a high capacity for absorbing nutrients such as N and P in polluted water (Truong, 2000). For polluted river water, vetiver was shown to remove 98% for total P after 4 weeks and 74% for total N after 5 weeks (Anon., 1997; Zheng *et al*., 1997). Recently in a hydroponic system using sewage effluent, Vetiver was not only able to remove both N and P over 90% from the effluent; it reduced also algae growth and faecal coliforms. One vetiver plant used an average of 1.1 L water daily (Truong and Hart, 2001).

3 VETIVER AND MEDLI

MEDLI (Model for Effluent Disposal Using Land Irrigation) is a Windows based computer program developed by Queensland Department of Natural Resources and Mines, Queensland Department of Primary Industries, and the CRC for Waste Management and Pollution Control, Australia. MEDLI models and analyses wastewater irrigation schemes for sewage treatment plants, intensive rural industries, and agri-industrial processors such as abattoirs (Gardner *et al.*, 1996). 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, such as Kikuyu grass (*Pennisetum clandestinum*), Rhodes grass (*Chloris gayana* Kunth) and Rye grass (*Lolium perenne*), which have been calibrated for MEDLI use.

Because vetiver grass holds great potential for use in wastewater irrigation schemes, the Queensland Department of Natural Resources and Mines, with grants from the Wallace Genetic Foundation of the US and Davis Gelatine initiated a research program to calibrate vetiver for the MEDLI model. The full calibration program is described in detail in Vieritz *et al.* (2003).

As a part of the calibration program, this trial sought to determine the maximum capacity of vetiver for taking up N and P from the soil and to calculate their recoveries. This paper describes the methodology used in growing vetiver under very high N and P supply, and presents results on yield, plant nutrient concentration and nutrient recovery percentage.

4 MATERIALS AND METHODS

The pot trial was conducted in open space on the property of Davis Gelatine, Beaudesert. The pots were placed on a level concrete platform, which was not shaded throughout the day to ensure good shoot growth. All pots received the same amount of sunlight and heat during the trial.

4.1 Containers

The experiment consisted of 63 plastic pots with a diameter of 20cm, which were placed in turn into 63 larger plastic pots with a 25 cm diameter. The bigger pots had no drainage holes. This prevented loss of any nutrients due to drainage or leachate from the smaller pots. Dry washed river sand was used as the growing medium and it contained negligible amounts of N (less than 0.01 mg/kg) and P (5 mg/kg). To prevent the sand from escaping through the drainage holes, the bases of the smaller pots were lined with thin paper towel before filling with 4000g of sand. The paper towel did not impede root growth.

4.2 Planting Material and Watering

Three-week-old vetiver slips of roughly the same size were used. They were removed from the propagating pots and the roots were cleaned carefully to remove any adhering soil. The shoots were cut back to approximately 10 cm height to reduce transpiration. Then one vetiver slip was planted in each small pot.

The water used throughout the experiment was de-ionised water containing 0.59 mg N/L and 0.068 mg P/L. The plants were watered on demand.

4.3 Experimental Design and Chemicals Used

A factorial design was used with five rates of N, four rates of P, and three replicates. The treatments were chosen so that vetiver was exposed to an extreme range of N and P supply rates: N at 0, 2000, 4000, 6000, 8000 kg/ha and P at 0, 250, 500 and 1000kg/ha.

The chemicals used for the main and basal treatments are: Ammonium Nitrate (NH_4NO_3), Potassium Orthophosphate (KH_2PO_4), Potassium Sulphate (K_2SO_4). Calcium chloride ($CaCl_2$), Magnesium sulphate ($MgSO_4$), Iron sulphate ($FeSO_4$), Manganese sulphate ($MnSO_4$), Zinc sulphate ($ZnSO_4$), Copper sulphate ($CuSO_4$), Sodium Molybdate (Na_2MoO_4) and Borax ($Na_2B_4O_7$).

In addition to the main experiment, vetiver was grown in three extra pots containing (1) pure sand (no added nutrients), (2) sand with basal treatment only, or (3) sand with 10,000 kg N/ha/year of N and 1000 kg P/ha/year, and basal treatment.

4.4 Harvest and Data collection

Plants were harvested 10 weeks after planting. The shoot biomass from each pot (and root biomass from one replicate only) was dried at 90^{o}C, weight and analysed for total N and total P concentrations using the Dumas combustion method for N and ICP for P. Shoot material from each replicate were bulked before chemical analysis.

Recovery percentages were calculated for each treatment as follows:

$$\text{Recovery \%} = \frac{\text{Final Shoot nutrient content (g/pot)} - \text{Final Shoot nutrient content of Control}}{\text{Nutrient application (g/pot)}} \_ \ 100$$

5 RESULTS AND DISCUSSION

5.1 Shoot Dry Matter Yield

Vetiver shoot yields after 10 weeks growth ranged from 12.8 to 105 g/pot or approximately 4000 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.

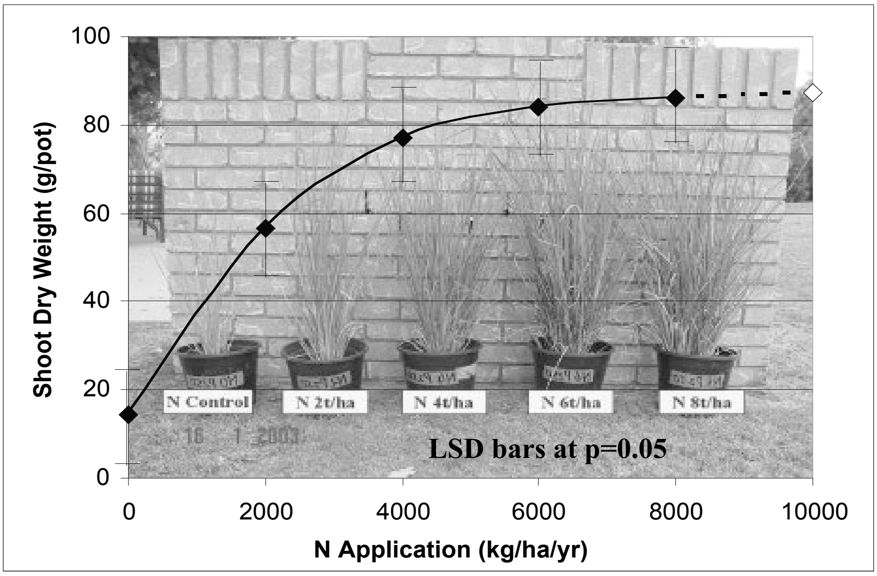
Statistical analysis found that both N and P supplies increased vetiver growth significantly (<1% level) with N providing the largest response.

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) (69 mg/pot of N and 8.4 mg/pot of P) and sand (2.4 mg/pot of N and 4.8 mg/pot of P).

5.1.1 Effect of N

Fig. 1 shows that vetiver growth increased with the level of N supplied. However very little growth response occurred at rates higher than 6000 kg/ha/year although rates up to 10,000 kg/ha of N did not adversely affect vetiver growth.

Fig. 1 Shoot dry matter yield under very high Nitrogen supply

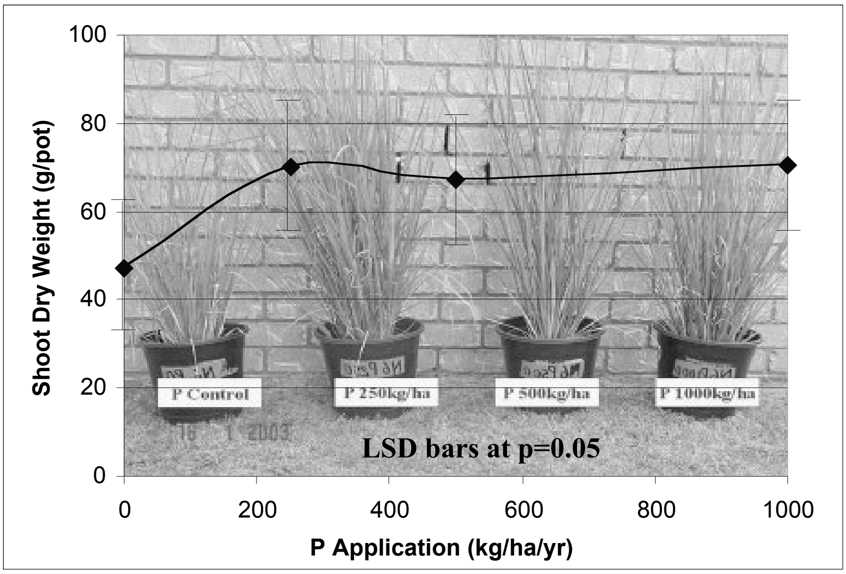


The 10,000 kg N/ha/yr treatment is shown using a dotted line since this treatment was not replicated and the data point is not an average of three replicates, as for the other data points

5.1.2 Effect of P

Fig. 2 shows that vetiver requirement for P was not as high as for N, and no growth response occurred at rates higher than 250 kg/ha/year. However its growth was not adversely affected at P application rates up to 1000 kg/ha/year.

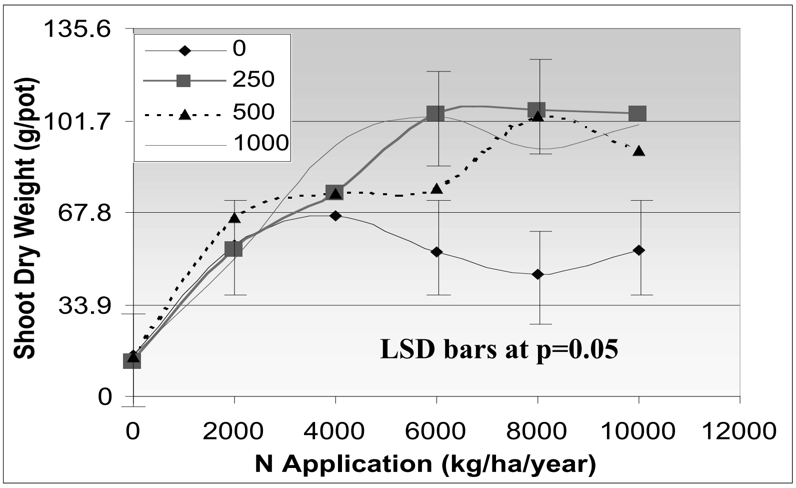
Fig. 2 Shoot dry matter yield under very high Phosphorus supply



5.1.3 Interaction of N and P effects

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 250 kg/ha/year (Fig. 3).

Fig. 3 Shoot dry matter yield showing the interaction between the effects of N and P



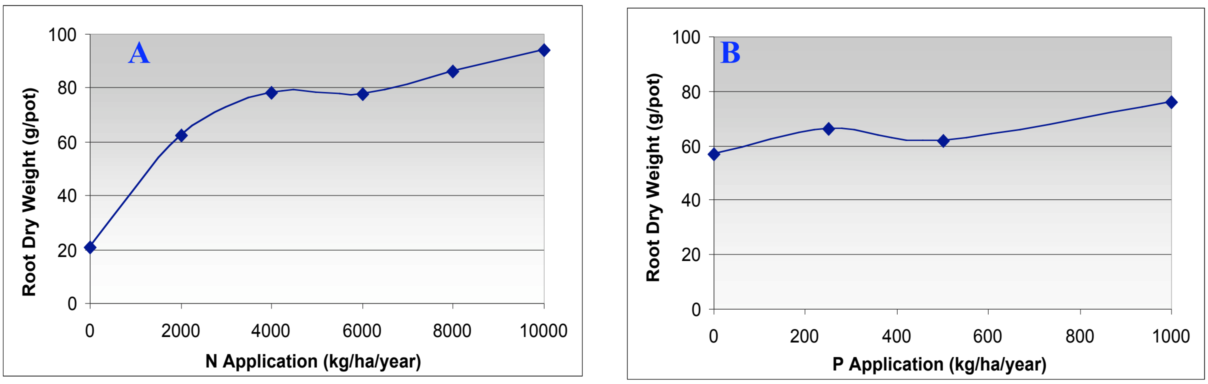
At least 250 kg/ha/year of P must be supplied before any further growth response to N application rates above 4000 kg/ha/year can be observed

5.2 Root Dry Matter Yield

Root growth response reflected the shoot growth response and showed increased root dry matter yield with increasing N supply up to 6000 kg/ha/year (Fig. 4A). At higher rates of N, no further root growth response occurred, and no adverse effect on growth was apparent at N application rates of up to 10,000 kg/ha/year.

Similarly Figure 4B shows that no further root growth response occurs at P level higher than 250 kg/ha/year and vetiver root growth was not adversely affected at the P application level of 1000 kg/ha/year.

Fig. 4 Root dry matter yield under (A) very high Nitrogen supply and (B) very high Phosphorus supply



Since one replicate only was analysed, data points represent single values

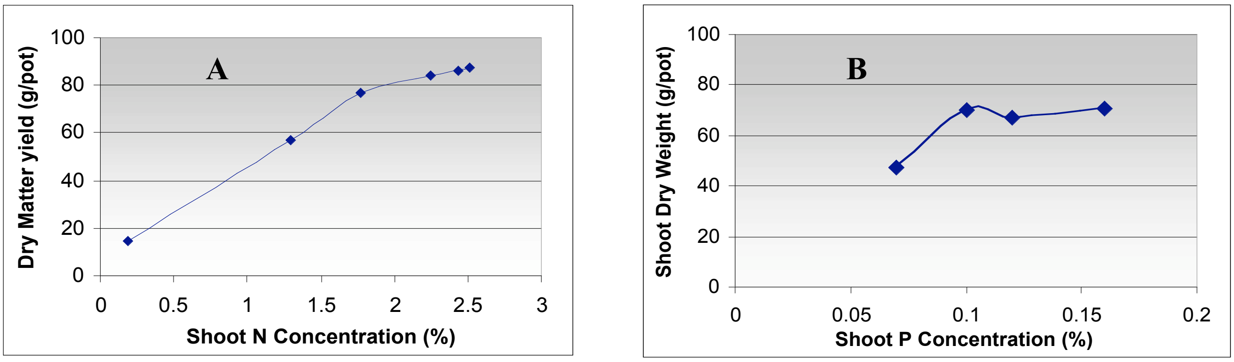
5.3 Shoot N Concentration

As expected, N shoot concentrations increased with increasing N application rate, reaching a concentration of 2.5% when 10,000kg/ha/year of N was supplied (Fig. 5A). However since neither shoot yield or shoot N concentration increased beyond the 6000kg/ha/year level, this suggests that lower N recoveries occurred at these high N application rates.

5.4 Shoot P Concentration

Vetiver has very little requirement for P as compared with temperate grasses. At the optimal P supply level of 250 kg/ha/year, vetiver has only 0.1% of P in the shoot as compared with value of 0.15% found in the mature vetiver plants grown in the field experiment. This value is comparable with Rhodes grass but much lower than 0.35% found in Kukuyu grass (Fig. 5B).

Fig. 5 (A) N concentration of vetiver shoot dry matter under very high N supply and (B) P concentration of vetiver shoot dry matter under very high P supply



Data points represent single bulked values

5.5 N and P Recovery Rates

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 8 t N/ha/year and 45% for 10 t 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 250 kg P/ha/year, and lower at higher supply rates (Table 1).

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

* Estimated from one replicate only

6 CONCLUSIONS

Due to its unique morphological and physiological characteristics, vetiver grass has a very high capacity for N uptake at elevated levels of N supply. It also can tolerate extremely high level of N in the soil. These features make vetiver highly suitable for treating wastewater and other waste materials high in N.

Because of its relatively low demand for P, Vetiver has only moderate capacity for treating high P effluent. However because of its fast growth and high yield, the total amount of P uptake by vetiver still far exceeds those of other tropical and subtropical grasses.

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A Brief Introduction to the First Author

Stefanie Wagner is a final year student at the Faculty of Geosciences, University of Hamburg, Germany. Geography is her major subject and Soil Science and Environmental Studies are her minor subjects. She has a keen interest in geomorphology, especially in soil erosion processes and erosion control techniques. She came to Australia for 5 months to gain experience on the use of Vetiver grass for both soil erosion control and environmental protection.

Appendix

Photo gallery showing vetiver growth response to various levels of nutrient supply

Phosphorus Nil,
Nitrogen from 0 – 8000 kg/ha/year

Nitrogen Nil,
Phosphorus from 0 – 1000 kg/ha/year

Phosphorus 250 kg/ha/year
Nitrogen from 0 – 8000 kg/ha/year

Phosphorus 1000 kg/ha/year,
Nitrogen from 0 – 8000 kg/ha/year

Nitrogen 6000 kg/ha/year
Phosphorus 0 – 1000 kg/ha/year

Nitrogen 8000 kg/ha/year
Phosphorus 0 – 1000 kg/ha/year

Above: Vetiver growing on pure sand in right pot and left pot had basal dressing of cations and micronutrients
Left: The highest yield treatment and the lowest yield treatment

Left: Vetiver growing vigorously, with no toxic effect at 10,000 kg/ha/yea of Nitrogen and 1000 kg/ha/year of Phosphorus
Below: Left pot shows more young shoots under 10,000 kg/ha/yea of Nitrogen than the right pot, received 6000 kg/ha/yea of Nitrogen