

VETIVER GRASS FOR SALINE LAND REHABILITATION UNDER TROPICAL AND MEDITERRANEAN CLIMATE

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1. INTRODUCTION

Vetiver grass (*Vetiveria zizanioides* L. Nash) is the base of the Vetiver System (VS), which was first developed by the World Bank for soil and water conservation in India in the 1980s. In addition to this very important application in agricultural lands, scientific research conducted in the last 14 years has clearly demonstrated that VS has much wider applications. This is due to its unique morphological, physiological and ecological characteristics that permit it to adapt to a wide range of climatic and soil conditions (Truong, 2002), including salt affected land (Truong, 1994).

Current applications include steep slope stabilisation, mine, contaminated and saline lands rehabilitation (Truong, 1999; Truong, 2000) and recently wastewater treatment (Truong and Hart, 2001). As a result VS is now increasingly being used in over 120 countries for these purposes.

Because of its remarkable characteristics that permit it to survive where others cannot, vetiver grass often acts as a pioneer plant establishing itself in hostile conditions and creating micro-climatic circumstances that permit a variety of other indigenous plants to prosper.

2. SOME SPECIAL CHARACTERISTICS OF VETIVER GRASS

2.1 Morphological Characteristics

- Vetiver grass does not produce above or underground runners. The plant is distinguished by its strong and massive root system, which is vertical in nature descending 2-3 meters in the first year, ultimately reaching some five meters under tropical conditions. This massive, thick and immensely strong root system, with a tensile strength of one sixth that of mild steel, is very difficult to dislodge but can nevertheless be removed easily by man if required. The depth of root structure provides the plant with great tolerance to drought, permits excellent infiltration of soil moisture and penetrates through compacted soil layers (hard pans). Under dry land salinity conditions, once established this deep root system can exploit the less saline subsoil moisture
- Above ground, the shoots can grow to two meters and when planted close together it forms a solid vegetative barrier that retards water flow and filters and traps sediment in runoff water. Growth occurs from the crown, which rises relative to soil build-up. It is also highly resistant to pests, diseases, fire and heavy grazing pressure (Truong, 2000).

2.2 Physiological Characteristics

- Tolerance to extreme climatic variations such as prolonged drought, flood, submergence and temperature levels ranging from -20°C to 55°C.
- Vetiver has been shown to thrive under levels of precipitation ranging from 300 mm to 6000 mm per annum.
- Ability to regrow rapidly after being affected by drought, frost, fire, saline and other adverse conditions when the adverse effects are removed.
- Adaptability to a wide range of soil types (pH 3.0 to 10.5) (Truong and Baker, 1998).
- Highly tolerant to growing media that are high in acidity, alkalinity, salinity, sodicity and magnesium (Truong, 1994) (Truong and Baker, 1996).
- Highly tolerant to Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soil (Truong and Baker, 1998).

2.3 Ecological Characteristics

- Although vetiver is tolerant to extreme soil and climatic conditions, it is intolerant to heavy shade. Shading will reduce growth and, in extreme cases, may result in plant failure. Vetiver thrives on warm temperatures and open sunlight and in colder climates commences growth when soil temperatures reach 12-14°C.
- The adaptability of vetiver to such a wide range of soil and climatic factors, and its tolerance to a hostile environment in soils and toxicity result in it being of great value as a pioneer plant. If the planted or invading indigenous species of trees and shrubs eventually form into a heavy canopy above the vetiver, it will reduce its growth and, if desired, it will die out under prolonged shading. Thus, vetiver is a valuable pioneer agent for land rehabilitation and the re-establishment of native plants or in the context of forestry establishment on steeply sloping lands.
- Whilst vetiver originates as a tropical grass its adaptability permits it to thrive in climatic circumstances outside the tropical and sub-tropical zones. Vetiver has been shown to grow well at latitudes of 40°N in China and Southern Europe where it thrives in the Mediterranean countries, particularly in the hot and dry climate of southern Spain and Sicily (Pease and Truong, 2000).
- In Australia Monto vetiver has been successfully established in Victoria and south west of Western Australia

2.4 Potential for Invasiveness

- Most of the cultivars of *Vetiveria zizanioides* that are now distributed globally have closely similar DNA characteristics and only a few have been shown to produce viable seeds or to become invasive (Truong and Creighton, 1994; Adams and Dafforn 1997).
- In Queensland a sterile cultivar was selected and rigorously monitored and tested over the eight-year period commencing in 1989, this cultivar produced no caryopses when grown under glasshouse and field conditions and in dryland, irrigated and wetland habitats. This cultivar is registered as Monto vetiver in Queensland.
- There are a number of seeded cultivars in Australia including a number from the Kimberley and New South Wales.

3. TOLERANCE TO HIGH SOIL SALINITY

The saline threshold of Monto vetiver is $EC_{se} = 8 \text{ dSm}^{-1}$ (Fig.1) and soil EC_{se} values of 10 and 20 dSm^{-1} would reduce yield by 10% and 50% respectively (Fig. 2 and Photo 1). These results indicate vetiver grass compares favourably with some of the most salt tolerant crop and pasture species grown in Australia (Table 1).

Figure 1: Saline threshold level of vetiver grass

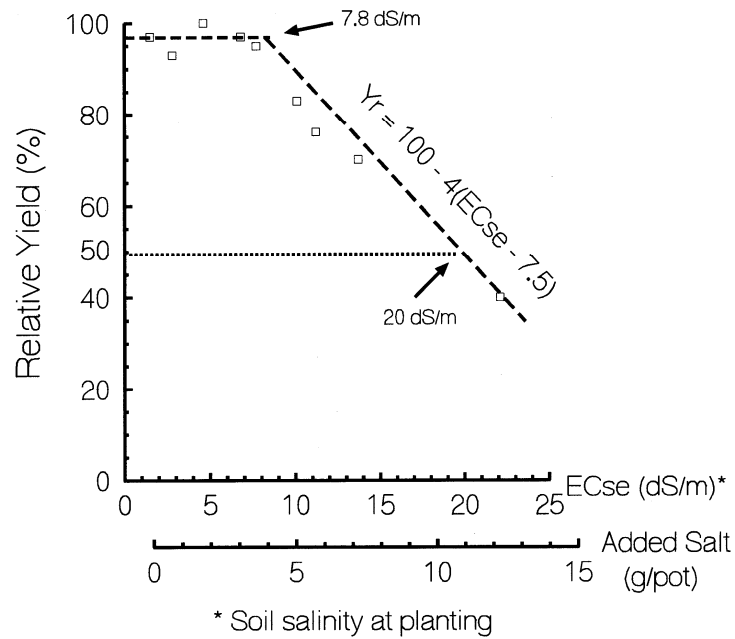


Figure 2: Saline threshold level of vetiver grass, Rhodes grass (*Chloris guyana*) and paspalum (*Paspalum dilatatum*)

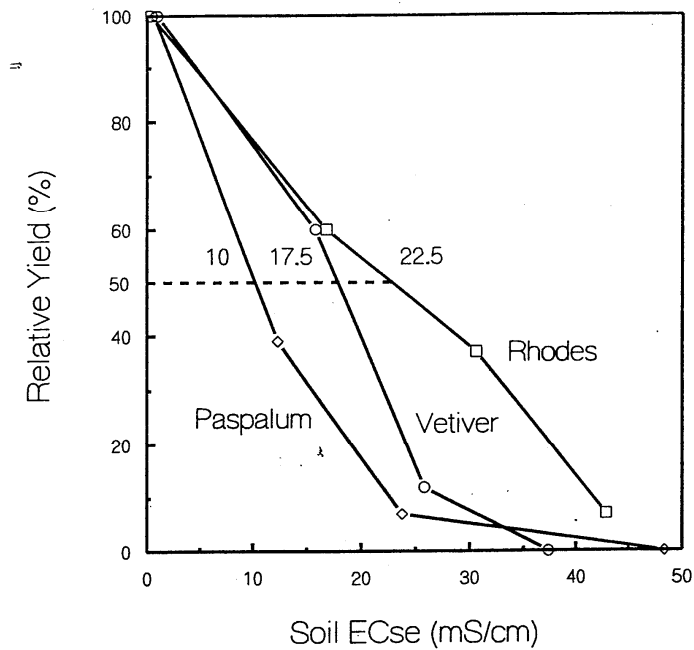


Photo 1: Response to varying levels of soil salinity

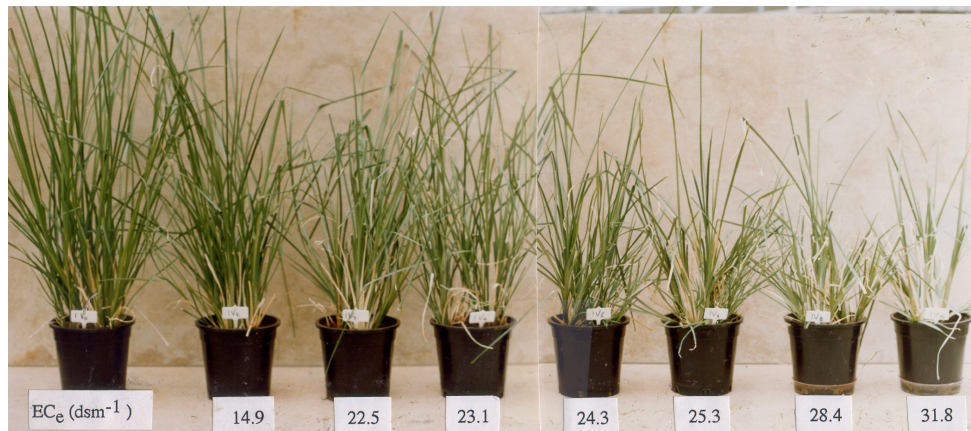


Table 1: Salt tolerance level of vetiver grass as compared with some crop and pasture species grown in Australia. (Shaw *et al.* 1987)

Species	Soil EC _{se} (dSm ⁻¹)		Yield
	Saline Threshold	50% Reduction	
Bermuda Grass (<i>Cynodon dactylon</i>)	6.9	14.7	
Rhodes Grass (C.V. Pioneer) (<i>Chloris guyana</i>)	7.0	22.5	
Tall Wheat Grass (<i>Thynopyron elongatum</i>)	7.5	19.4	
Cotton (<i>Gossypium hirsutum</i>)	7.7	17.3	
Barley (<i>Hordeum vulgare</i>)	8.0	18.0	
Vetiver (<i>Vetiveria zizanioides</i>)	8.0	20.0	

In Warril View Queensland, in an attempt to revegetate a highly saline area (caused by shallow saline groundwater) a number of salt tolerant grasses: vetiver, Rhodes (*Chloris guyana*) and saltwater couch (*Paspalum vaginatum*) were planted. Negligible rain fell after planting so vetiver establishment and growth were extremely poor under the extremely saline conditions. Following heavy rain during summer (nine months later), vigorous growth of all species was observed in the less saline areas. Among the three species tested, vetiver was able to survive and resume growth under the higher saline conditions (Table 3 and Photo 2), reaching a height of 60cm in eight weeks (Truong, 1996).

Table 3: Soil salinity levels corresponding to different species establishment.

Species	Profile Soil EC _{se} (dSm ⁻¹)	
	0-5cm	10-20cm
<i>Chloris guyana</i>	4.83	9.59
<i>Paspalum vaginatum</i>	9.73	11.51
<i>Vetiveria zizanioides</i>	18.27	18.06
Bare ground	49.98	23.94

These results are supported by observations in Fiji where vetiver has been grown in highly saline tidal flats next to mangrove.

Under saline conditions, while gypsum had no effect on the growth of vetiver, nitrogen and phosphorus fertilisers greatly increased its yield. DAP (Di-ammonium phosphate) application alone at 100 kg ha^{-1} increased vetiver dry matter yield nine times.

Photo 2: Among the three species tested, vetiver was able to survive and resume growth under the highest saline conditions at Warril View



4. TOLERANCE TO HIGH ALKALINITY AND HIGH SODICITY

In addition to its high salt tolerance, vetiver grass can flourish under high sodicity and alkalinity conditions. Soil with ESP (Exchangeable Sodium Percentage) higher than 15 is considered to be strongly sodic (Northcote and Skene, 1972). Vetiver established and grew vigorously on Bentonite tailings with ESP of at least 48%. Similarly, Table 4 shows a typical highly alkaline (pH=9.6) and sodic (ESP=33%) composition of a coalmine overburden. Moreover, the sodicity of this overburden is further exacerbated by the very high level of magnesium (2400 mgK g^{-1}) compared to calcium (1200 mgK g^{-1}).

Table 4: Chemical analyses of a coal mine overburden.

Soil pH (1:5)	9.6	Calcium	(mgK g^{-1})	1200
EC dSm $^{-1}$	0.36	Magnesium	(mgK g^{-1})	2400
Chloride	mgkg $^{-1}$ 256	Sodium	(mgK g^{-1})	2760
Nitrate	mgkg $^{-1}$ 1.3	Potassium	(mgK g^{-1})	168
Phosphate	mgkg $^{-1}$ 13	ESP*	(%)	33
Sulphate	mgkg $^{-1}$ 6.1			

* ESP = Na % of total cations

5. USE OF VETIVER GRASS IN SALINE LAND REHABILITATION

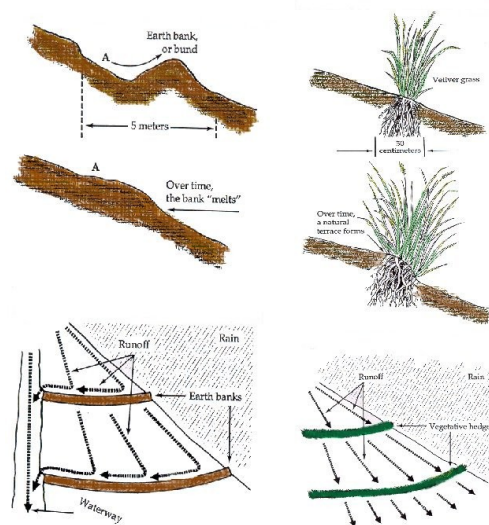
5.1 Soil and water conservation in agricultural lands in Queensland

Vetiver grass has been used for soil and water conservation in orchards, cropping and grazing lands instead of contour banks in Queensland. Due to its high level of salinity tolerance vetiver is particularly effective in gully erosion control in sodic and salt affected soils. When planted on contour lines vetiver hedge acts as a porous barrier, spreading and slowing down runoff water, trapping sediment and increasing water infiltration thus conserving soil moisture on sloping land (Fig.3).

5.2 Saline mine tailings in Queensland

A trial was set up to select the most suitable species for the rehabilitation of a 23ha coal tailings dam. The substrate was saline, highly sodic and extremely low in nitrogen and phosphorus. The substrate contained high levels of soluble sulfur, magnesium and calcium. Plant available copper, zinc, magnesium and iron were also high. Five salt tolerant species were used: vetiver, marine couch (*Sporobolus virginicus*), common reed grass (*Phragmites australis*), cumbungi (*Typha domingensis*) and *Sarcocornia spp.* Complete mortality was recorded after 210 days for all species except vetiver and marine couch. Mulching significantly increased vetiver survival but fertiliser application by itself had no effect. Mulching and fertilisers together increased growth of vetiver by 2 tha^{-1} , which was almost 10 times higher than that of marine couch (Radloff *et al.*, 1995; Truong, 1999).

Fig.3: Contrast between conventional contour bank and vetiver hedge in soil and water conservation



5.3 Sodic mine tailings in Queensland

Bentonite mine tailings (reject) is extremely erodible as they are highly sodic with Exchangeable Sodium Percentage (ESP) values ranging from 35% to 48%, high in sulphate and extremely low in plant nutrients. Revegetation on these tailings has been very difficult with other plant species but with adequate supply of N and P fertilisers vetiver established readily on these tailings (Bevan and Truong, 2000).

5.4 Tidal creek bank stabilisation in Queensland

Vetiver has been used successfully for stream bank stabilisation of tidal creeks and canals in southern Queensland. At a site on the Gold Coast, two years after vetiver was planted to stabilise a tidal creek bank, mangrove seedlings were found growing among vetiver rows. Similar occurrences were also observed on the west coast of Fiji.

5.5 Essential oil production in the Kimberley, Western Australia

More than 16 vetiver cultivars were introduced to the Ord River scheme in the 1960s as a crop for essential oil production. Although some of these produce viable seeds (2-3%) they have not spread beyond the boundary of the experimental plot at the research station in Kununurra.

However, because these cultivars are seeded, their use is not recommended outside the Kimberley region.

5.6 Monto vetiver as a grazing species in Katanning, Western Australia

Monto vetiver was first introduced to WA following the PURSL conference in Albany in 1996 by Tess Casson who was then working with Brian Warren, WA Agriculture in Katanning. The team was looking for:

- A salt tolerant and summer growing fodder plant to provide supplementary feed to stock during summer and autumn.
- A salt tolerant, deep-rooted plant that can lower the water table, particularly soil moisture built up in the summer months.

When Tess Casson left Katanning, the trial site was temporarily 'lost' until it was 'rediscovered' by Fred Armstrong in 2001. According to the grazier, Russel Thomson, vetiver established and grew well in the last 6 years on its own, without fertilizer and other maintenance despite extremely heavy and continuous grazing by sheep during drought periods (Photo 3). Based on the size of the plant growing in Fred Armstrong's garden at Katanning and the size of the crowns of plants in the paddock, this planting would produce vetiver at least 1.2m tall every summer (Photo 4)

In 2000, Jeremy Shepherdson introduced Monto vetiver for mine and saline lands rehabilitation in Kalgoorlie. Initial results from the demonstration trial at Gribble Creek were very encouraging, Monto vetiver established well with initial irrigation under extremely saline conditions (Soil EC = 10.43 - 46.00 dSm⁻¹ and pH: = 7.13 - 7.76). (Photo 5). However due to vandalism the trial was stopped after a few months, had it been continued until its root system reached the less saline subsoil moisture, vetiver would continue to grow. This is the outcome of plantings under similar conditions in Queensland and Victoria.

Currently Paul Truong is working with ATA Environmental South West using Monto vetiver for treatment of wastewater from wineries in the Margaret River region

Photo 3: Six year old vetiver planting at the Thomson's property, Katanning, it has survived under extremely heavy and continuous grazing by sheep during drought periods.



Photo 4: A Monto vetiver plant growing in Fred Armstrong's backyard in Katanning.



5.7 Monto vetiver in Victoria

The Victorian Department of Agriculture introduced vetiver to Swan Hill early in the 1990s to control saline seepage from sloping orchard land in the region. After initial irrigation in the first summer to encourage root growth, vetiver continued to thrive once its roots reached the less saline subsoil moisture. It was noted that under the wet Victorian winter, vetiver was not badly frosted and continued to grow slowly, reaching a height of 2m after 2 years. With this growth, when appropriately laid out vetiver planting would be very effective in reducing saline seepage on sloping land (Photo 6).

Recently Monto vetiver has also been used very effectively in providing a windbreak on an orchard in western Victoria.

Photo 5: Demonstration trial at Gribble Creek, Kalgoorlie.
Note the white salt on the surface near the vetiver plant.



Photo 6: A two-year-old vetiver row at Swan Hill planted to control saline seepage from sloping orchard plot.



6. OVERSEAS APPLICATIONS

Vetiver has been widely used to stabilise dykes on prawn farms in Thailand, China, Vietnam and the Philippines. Salinity level of these ponds fluctuates but it is often the same as seawater. In Indonesia and the Philippines vetiver has also been used successfully for beach erosion control and estuary protection against tidal surge.

7. NUTRITIONAL VALUES AND PALATABILITY

Concurrent to the field planting at Katanning, Tess Casson also tested the digestibility of vetiver shoots under both *in vivo* and *in vitro* conditions. Results indicate that vetiver is highly digestible, and at least equal to or better than most tropical grasses.

Vetiver has been used for centuries as a fodder crop in India, the Philippines, China and Thailand, its nutritional values and palatability are listed in Table 5.

Table 5: Nutritional values and palatability of Monto vetiver grass

Nutrients	Concentrations (%)
Nitrogen	1.51
Phosphorus	0.29
Potassium	1.75
Calcium	0.52
Magnesium	0.33
Sodium	0.08
Sulphur	0.21
Crude fat	0.4
Crude fibre	7.1
Palatability	Horse, dairy cows, cattle, buffalo, rabbits, goat, sheep, wallaby and kangaroo

8. PLANTING MATERIALS

Vetiver has to be established vegetatively by crown subdivision into slips of 3-4 tillers. Planting materials are available as:

- Bare root slips, fresh subdivision from clumps that can be planted direct. This method is inexpensive but plants take longer to establish and there is a greater likelihood of failures.
- Bare root plantlets, 2-3 weeks-old slips, which have been raised in sand bed and supplied fresh for planting within a week. This method reduces potential failures.
- Tube stock, slips raised in a nursery for 6-7 weeks in summer. This method is relatively expensive but produces good quality plants with minimal failures.

9. CONCLUSION

Monto Vetiver grass has demonstrated its ability to establish and thrive under highly saline conditions in general. But it has been shown to be particularly effective where saline high water table is the causal effect.

In the Woolbelt of WA, due to its fast growth in warmer months, vetiver can be used as a 'green pick' during the summer where it has been planted in hedgerows for soil and water conservation on high points in the landscape.

In the Wheatbelt of WA it can also be used for soil and water conservation, and sediment control particularly where gully and streambank erosion is a problem.

In orchards vetiver can be used to reduce saline seepage and windbreaks.

On sloping land it can be used as a pioneer species to stabilise erodible sites first and then rehabilitate with native or plantation species later.

Due to their seediness, albeit very low, the use of vetiver cultivars from Kununurra is not recommended outside the Kimberley region.

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