Vetiver Grass Technology
A Tool Against Environmental Degradation in Southern Europe

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Mr. Michael Pease
Coordinator European and Mediterranean Vetiver Network

Dr. Paul Truong
Leader, Erosion Control and Slope Stabilisation
Resources Sciences Centre, DNR, Brisbane, Australia

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ABSTRACT
A novel approach to the control of erosion, retention of water run-off and control of loss in plant nutrients is discussed. A tool, vetiver grass, is described; Vetiver Grass Technology (VGT) is defined and establishment and maintenance practices detailed. Existing applications of the technology within Europe are recorded. The strength of both research and field application results elsewhere in the world, linked to the established parameters that limit the effective use of the technology, point clearly to the justification for expanding research and field application in Southern European countries. VGT has application in controlling erosion in agriculture, forestry or areas of urban development. It improves precipitation usage and storage and reduces loss of plant nutrients. VGT is able to trap agrochemicals and stabilise soils in a bioengineering context, whether in roads and railways, dams, cliff tops or for dune stabilization. It can control leachate in municipal and industrial waste dumps, reduce the silting up of rivers and dams and is used for soils amelioration in agricultural lands and in rehabilitating mining wastes. The paper points to the need to determine more precisely how best to adapt the technology to Southern European conditions and thence to expand its use for overall environmental protection.

INTRODUCTION
In many tropical and sub-tropical countries Vetiver Grass Technology (VGT) has become an established tool in providing a permanent, low cost and effective means of controlling soil erosion, retaining water and minimising loss of plant nutrients. Field applications carried out on the technology in Spain, Portugal, Italy and Albania over the past five years indicate that it has considerable application in much of Southern Europe. Recently, the technology has been introduced to Cyprus and Turkey and there is historical evidence of the plant in Israel and Egypt.

The technology employs the use of *Vetiveria zizanioides* L. (vetiver grass) which, when planted correctly on the contour, rapidly develops into a deep-rooted vegetative barrier which slows and spreads runoff water, traps eroded materials and conserve soil moisture. The trapped sediment will build up to natural terraces if not removed and the increased soil moisture will be available for plants and eventually for ground

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water recharge. Organic and inorganic plant nutrients are retained where required, for plant growth.

Vetiver grass has unique morphological, physiological and ecological characteristics that permit it to adapt to a wide range of climatic and pedological conditions and to tolerate heavy metal or saline toxicities at levels well above most other plants (11). Furthermore, on the evidence of decades of use internationally, vetiver grass does not present any hazard in respect of invasiveness or disease spread (18).

BACKGROUND

Vetiveria zizanioides L. originates from swamplands in Northern India. Centuries ago, man took the plant to Southern India where it was used for the essential, aromatic and medicinal oils extracted from its roots. In time the plant lost its capability to reproduce from seed. In more recent centuries the plant was carried to various tropical countries and an industry developed for its oil. It was not until the 1980's that the plant was fully recognised for its potential in soil and water conservation and sediment control. Initially, it was used in an agricultural context for the protection of generally small-scale farmers' fields from erosion, control of water run-off and loss of plant nutrients. Subsequently, an application technology developed and its uses diversified into such fields as bioengineering (6, 7), forestry, control of toxic leachate in waste dumps (15,21), mine rehabilitation (1, 9, 13) and stabilization of disturbed lands under a wide range of climatic and pedological circumstances.

In agricultural lands, when correctly planted and maintained, vetiver hedges can reduce soil loss by 80-90% and water run-off by 50-70%. Crop yields can increase by as much as 40%. (19) A vetiver hedge is a cost-effective means of addressing these and other major environmental problems.(8)

As a tool of bioengineering, VGT has been shown to be a cost-effective alternative to engineered stabilization methods. This is exemplified in such circumstances as cuttings and embankments on roads, highways and railways; protection of bridges and culverts; and stabilization of dam walls, spillways, surrounds and inside of walls against lap and wind erosion. For example, it has been shown that the protection of infrastructure using VGT can be one tenth of the cost of engineered structures in country with low labour cost like China (22) and 40% in country with high labour costs as Australia (2).

Vetiver Grass Technology can play an important role in stabilising soils and reducing the soil and water run-off that leads to the silting up of rivers and dams, both important contributors to issues of desertification. This particularly applies to steep slopes used for forestry and agriculture.

In the context of general agriculture VGT can play a valuable role in soils amelioration. Top-soil, moisture and plant nutrients are retained, mulch from the vetiver can be used for soil betterment and native species of plants and grasses provided with circumstances favourable to their growth.

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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.

SOME SPECIAL CHARACTERISTICS OF VETIVER GRASS

Morphological Characteristics

Vetiver grass does not produce rhizomes and its stolons grow back into the plant and are generally only a few millimetres in length. 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. This massive, thick and immensely strong root system with a tensile strength of one sixth that of mild steel is very difficult to be dislodged 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 pan). Above ground, the culms can reach more than two meters and when planted close together it forms a solid vegetative barrier that retards water flow, filters and traps contaminated sediment in runoff water (4,10). Growth occurs from the crown, which rises relative to soil build-up.(16). It is also highly resistance to pests, diseases, fire and heavy grazing pressure (3, 20).

Physiological Characteristics

∑ Tolerance to extreme climatic variations such as prolonged drought, flood, submergence and temperature levels ranging from -10ºC to 50ºC.
∑ 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) (14).

- Highly tolerant to growing medium high in acidity, alkalinity, salinity, sodicity and magnesium (12, 17).
- Highly tolerant to Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soils (9).
- High level of tolerance to herbicides and pesticides (5).
- Highly efficient in absorbing dissolved N, P, Hg, Cd and Pb in polluted water (23).

Table 1 summarises the above points.

Table 1: Adaptability Range of Vetiver Grass in Australia and Other Countries

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	Australia	Other Countries
Adverse Soil Conditions		
Acidity	pH 3.3	pH 4.2 (with high level soluble aluminium)
Aluminium level (Al Sat. %)	Between 68% - 87%	80%-87%
Manganese level	> 578 $mgkg^{-1}$	
Alkalinity (highly sodic)	pH 9.5	pH 12.5
Salinity (50% yield reduction)	17.5 $mScm^{-1}$	
Salinity (survived)	47.5 $mScm^{-1}$	
Sodicity	33% (exchange Na)	
Magnesicity	2 400 $mgkg^{-1}$ (Mg)	
Heavy Metals		
Arsenic	100 - 250 $mgkg^{-1}$	
Cadmium	20 $mgkg^{-1}$	
Copper	35 - 50 $mgkg^{-1}$	
Chromium	200 - 600 $mgkg^{-1}$	
Nickel	50 - 100 $mgkg^{-1}$	
Mercury	> 6 $mgkg^{-1}$	
Lead	> 1 500 $mgkg^{-1}$	
Selenium	> 74 $mgkg^{-1}$	
Zinc.	>750 $mgkg^{-1}$	
Location	15^0S - 37^0S	41^0N - 38^0S
Climate		
Annual Rainfall (mm)	450 - 4 000	250 - 5 000
Frost (ground temp.)	-11^0C	-14^0C
Heat wave	45^0C	60^0C (China)
Drought (without effective rain)	15 months	
Fertiliser		
Vetiver can be established on very infertile soil due to its strong association with mycorrhiza	N and P (300 kg/ha DAP)	N and P, farm manure
Palatability	Dairy cows, cattle, horse, rabbits, sheep, kangaroo	Cows, cattle, goats, sheep, pigs, carp
Nutritional Value	N = 1.1 % P = 0.17% K = 2.2%	Crude protein 3.3% Crude fat 0.4% Crude fibre 7.1%

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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 12-14ºC.

- The adaptability of vetiver to such a wide range of soil and climatic factors and its tolerance to hostile circumstances of soils or 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. 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 sloped 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 40ºN in China and Europe. In the light of its adaptability to climatic and pedologic extremes it therefore appears to have considerable potential in much of Southern Europe.

Potential for Invasiveness

- It is critical that any plant used for environmental protection is not invasive and will not become a weed. The South Indian form of vetiver is not considered a weed in the dozens of places where it has been planted (U.S. National Academy of Sciences, 1993, 18). The accessions of Vetiveria zizanioides that are now widely distributed globally have closely similar DNA characteristics. None have been shown to produce viable seeds or to become invasive. In Australia under rigorous, monitored testing over the ten year period commencing 1989 the cultivar used (Monto) produced no caryopses when grown under glasshouse and field conditions and in dryland, irrigated and wetland habitats.

ESTABLISHMENT

Although vetiver grass is tough and resilient when established it responds well to, and needs, good management in the establishment stage. This is of particular importance in Southern Europe when active growing conditions are more restricted.

Planting Materials

Vetiver has to be established vegetatitively by root subdivision into slips of 3-4 tillers. It cannot be grown from seed. Four planting practices have been established, all of which require regular watering, weeding and general plant care. In all cases, however, bare root plants benefit from being held in 'cow-tea' for 7-10 days prior to planting. Cow tea is formed by the liquid arising from mixing any manure with water held in suitable containers so that plants can be kept with their roots immersed in the solution.

- Bare root slips from freshly divided clumps can be planted direct. This method is inexpensive but plants take longer to establish and there is a greater likelihood of failures. Gaps in a vetiver hedge pose serious problems where erosion can occur

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and the technology defeated. Consequently, bare root direct planting is primarily applicable for flatter lands or where other methods cannot be followed.

- Bare root 4-5 weeks-old plantlets are raised in sand beds and supplied fresh for planting within a week. This method reduces potential failures and is inexpensive to practice.
- Slips planted in polythene pots or tubes are raised in a nursery for 6-7 weeks in summer. This method is relatively expensive but produces good quality plants with minimal failures. It results in higher transportation costs to the field, but strong plant growth because the plant is growing in a rich potting medium in its early growth. This method is suitable where the high transportation costs can be justified by the need to establish a hedge rapidly with minimal failures, e.g. steep embankments such as occur in roads and railway cuttings and embankments or dam walls.
- Strip or band plants are raised in specially designed but simple containers of about 1 meter length for 2-3 months. These are ideal for extreme slopes where an instant hedge is required.

Planting Procedures

In general, for slope stabilisation, vetiver is planted in rows on the contour so that soils build up behind the hedge and water run-off is trapped and allowed to filter either into the soil or through each succeeding hedge on its down-slope progression. VGT is therefore quite different to the classical approach to soil conservation where earth bunds are created mechanically that channel run-off into waterways. This bunding methodology is expensive, breaks down over time and results in much land being removed from production. Hedgerow spacing varies between 1 and 2 meters vertical interval, depending upon slope gradient, soil type, slope length and climatic circumstances. It is critical to the effectiveness of the technology to establish a solid vegetative barrier without gaps and, if they do occur, to fill these in as rapidly as possible. On steeper slopes, typically those occurring in engineered structures such as dams, roads, railways etc. the standard spacing between plants should be not more than 10 cm. The width of a clenched fist is a good guide. For less severe slopes, often on agricultural land, spacing of 15 cm can be effective.

Watering

Vetiver needs water in the early stages of its growth. Ideally, therefore, it should be planted into moist soil. To obtain optimal results and early establishment new plants should be watered daily for the first week and every 2-3 days for the next 2 weeks dependent upon the weather. Once good leaf growth, reflecting active root growth is visible watering can be steadily reduced. Periodic, once weekly watering should continue during dry seasons for the next two years until the plants are solidly established. Thereafter, roots will have descended deeply, the plants will be well established and they can be left to fend for themselves, though responses can certainly be expected to watering in extreme conditions of drought.

Manures, Fertiliser and Maintenance

Vetiver responds well to farmyard manure, especially chicken manure and this should be provided, at least in the nursery stage, ideally in field planting as well. It is always

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wise to determine inorganic fertiliser requirements by conducting a soils analysis. However, a standard fertiliser application rate is 50g/m of Di-Ammonium Phosphate which should be applied at planting with a top dressing 5-6 weeks later. Vetiver has been shown to respond well to annual maintenance applications which should be applied twice in the growth months of summer.

Weed Control

As vetiver is particularly intolerant to shading, especially during the establishment phase weeding may be required during the first year, especially if tall or climbing weeds are present. Subsequently, the size and strength of the vetiver will dominate against all but the most severe weed ingression.

Trimming

Trimming of leaf growth to about 40 cm in height stimulates root growth and is desirable particularly in the first two years of growth. Thereafter, the practice should be followed if possible but if labour constraints do not permit will not result in retarded growth. Valuable by-products of trimming are: mulch, bedding, and livestock fodder.

Herbicides

Vetiver, a graminae, is extremely sensitive to Roundup weedicide (glyphosphate) to which it should not be exposed. However, other herbicides, pre-emergent or post-emergent chemicals, such as Atrazine or 2,4D based, can be used for broad leaf weed control.

QUALITY CONTROL

It is important to recognise that vetiver grass is no more than the essential tool in an overall technology. If incorrectly applied the technology cannot be expected to succeed. The most important factors that determine the success or failure of the application of VGT in a bio-engineering context are as follows:

∑ Good quality planting materials to ensure early and effective establishment.
∑ Plants produced for field planting using whichever technique is most appropriate to the circumstances.
∑ Correct spacings between plants, relative to slope, soil and climatic circumstances.
∑ Appropriate design layout down the slope relative to hedgerow spacings and any interaction, if necessary, with engineered structures such as concrete drains, gabions etc.
∑ Adequate watering during the establishment phase.
∑ Early action to fill any gaps that form.
∑ Chemical analysis of both base material and topsoil to determine fertiliser requirements and possible soils amendments prior to planting.
∑ Trimming, fertiliser applications and weeding when required.

APPLICATION OF VETIVER GRASS TECHNOLOGY TO SOUTHERN EUROPEAN CONDITIONS

VGT has a proven record of effectiveness in combating erosion and addressing a number of other environmental issues in many countries of the world. Its limitations

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in colder more northerly climates are as yet undefined. However, based on the known parameters under which vetiver grass will thrive, much of Southern Europe should prove suitable for application of the technology. In 1994 an EC-funded project sought to determine the application of vetiver under Mediterranean conditions. The selected site was a steep slope of some 60% on an access road leading to a reservoir near Lorca in Murcia Region of Spain. The area has a harsh climate with precipitation of only some 300 mm per annum and poor soils. Vetiver hedgerows were established at distances of approximately 1 meter vertical interval in two blocks of land with control blocks either side. Drip irrigation was provided for all plants during the first two years of establishment. Thereafter, within each block, three sections were defined receiving a) continued irrigation; b) reduced irrigation; and c) no irrigation. Since 1998, i.e. for the past two years, no maintenance or irrigation has been provided whatsoever. Nevertheless, the plants have survived well and the hedges are proving effective not only in controlling erosion but in providing a micro climate under which native species of plants have become established. Control blocks on either side show severe erosion with deep gullying and rilling.

This excellent result is in sharp contrast to an EU funded project on a batter of a highway leading to Murcia, where *Atriplex alimus* was used to stabilise a very steep batter. Although supported with extensive drip irrigation in the first year after planting, *Atriplex* failed completely to established at some sections and only a very small number just survived in others. As a result of establishment failure some severe erosion was most obvious at this site. This project was established at the cost of 148 millions Pesitas

In Portugal, vetiver was first introduced some 4 years ago onto a private property at 39º 14' North, in Ribatejo region where the soil is light and easily erodable. VGT has been used to protect dam walls and to stabilise the banks of a river that flows down a large cultivated valley. Results have been good and the vetiver has only received short term ? temporary set-backs from frost conditions. Subsequent importations have been made from Zimbabwe in 1998 and 1999. These plants have gone to The University of the Açores, Department of Agriculture, Local Authorities, a non-government organisation and a number of private growers, mainly in The Algarve region but some located in Alentejo region to the North. Other than where management has been faulty, general growth conditions have been excellent. On the Açores VGT is being used to stabilise volcanic pumice slopes which become unstable when sodden. Vetiver has performed well on volcanic pumice in such countries as The Philippines, Indoensia and the Carribean. One private fruit tree grower has used his vetiver hedges most effectively aginst wind-blow apart from their use as soil erosion barriers. Hedges planted in March and receiving fertigation in common with the fruit trees rapidly reached a hight in excess of two meters and formed a solid barrier.

In Italy research work has been conducted on biomass production and salt tolerance in Sicily. In 1998 a privately owned nursery located near Milano (45º, 25'N) established a large holding of vetiver plants originating from the EC-funded project in Spain. The

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winter cold is not conducive to good vetiver growth and the nursery has now been relocated further to the South.

In 1998 the internationally financed Albanian Private Forestry Development Project imported plants produced by tissue culture from Florida. There is no question that vetiver will survive in parts of Albania but locations have to be selected with care to avoid excessively cold winters. Field practices are now being modified to ensure that the correct technology is applied for future planting. These are likely to be mainly to control erosion on small-scale farms but also for the stabilisation of soils in a bio-engineering context.

CONCLUSION

The strength of both research and field application results elsewhere in the world, linked to the established parameters that limit the effective use of VGT, point clearly to the justification for expanding research and field application in Southern European countries. VGT has application in: controlling erosion in agriculture, forestry or areas of urban development. It can improve precipitation usage and storage and reduce loss of plant nutrients. VGT has important application in stabilising soils in a bio-engineering context, whether in roads and railways, dams, cliff tops or dune stabilisation and in controlling leachate in municipal and industrial waste dumps. It can reduce the silting up of rivers and dams; for soils amelioration in agricultural lands and is also used in rehabilitating disturbed lands. There is need to determine more precisely how best to adapt the technology to Southern European conditions and thence to expand its use for overall environmental protection. It is likely that under Southern European conditions the primary focus should be in the use of VGT in its bio-engineering context. However, protection of farmland and forested areas should not be ignored though this may be less dominant than in the case of many developing countries.

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