

Vetiver system ecotechnology for water quality improvement and environmental enhancement

Vetiver, *Vetiveria zizanioides* L. Nash, a native grass of India has traditionally been in use in India for contour protection and essential-oil production. Taking clues from its traditional usage in environmental protection, The World Bank initiated several projects in India in 1980s for systematic development of Vetiver Grass Technology (VGT), now popularly known as Vetiver System (VS). Large-scale developments have since taken place in the advancement of VS in environmental protection¹; new avenues have opened up over the past 15 years². The VS is emerging as a panacea to a host of environmental problems. It is a low cost, extremely effective system that offers proven solutions for soil and water conservation, wastewater treatment, embankment stabilization, flood control, disaster and pollution mitigation, agroforestry management, and many other environment-friendly applications being used in over 100 countries³. The VS for wastewater treatment is a new and innovative phyto-remedial eco-technology, which has the potential to meet all the right criteria necessary for environmental enhancement. It is a natural, green, simple, practicable and cost-effective solution, and its by-products offer a range of uses in handicrafts, animal feed, fuel and construction applications. Morphological and physiological attributes of vetiver grass, its strong, deep penetrating (Figure 1 a), aerenchymatous (Figure 1 b) root system, unusual ability to absorb and tolerate extreme levels of nutrients, agrochemicals and heavy metals make it an ideal system for environmental enhancement through appropriate interventions in the treatment regime.

The 3rd International Conference on Vetiver and Exhibition (ICV-3), was organized in Guangzhou, China during 6–9 October 2003 by the Guangdong Academy of Agricultural Sciences, in association with South China Institute of Botany (Chinese Academy of Sciences), South China Agricultural University and Guangdong Association of Grass Industry and Environment. The theme of the conference 'Vetiver and water' was truly embodied in the conference deliberations,

highlighting that vetiver (i) is native to hygro-environment such as wetland, lagoon and bog, (ii) is extremely tolerant to drought as well as waterlogged/submergence conditions, (iii) is effective for soil and water conservation, and (iv) is endowed with excellent biological features to ameliorate wastewater and pollution mitigation. The conference was inaugurated by the Patron of The Vetiver Network, HRH Princess Maha Chakri Sirindhorn of Thailand, and was attended by over 230 delegates representing 28 countries. There were 13 plenary presentations covering eight sub-themes, and 46 oral presentations, including four King of Thailand Vetiver Award presentations⁴. Also, an exhibition on VS-based ecotechnologies and products in the form of posters and demonstration stalls was arranged at the conference site by various scientific agencies and entrepreneurs. Further, the organizers had also arranged a one-day study tour for an on-site live demonstration of VS projects ranging from applications of vetiver in garbage landfill site management, land slope stabilization and slope afforestation, and water and vegetation rehabilitation at an ecological park.

Sumit Tantivejkul, Secretary General, Chaipattana Foundation, Bangkok in his keynote address on Thailand's experience with respect to vetiver and water, underpinned the significance of vetiver grass for its deep penetrating root system that forms an underground wall barrier and helps to filter silt and maintain topsoil. He stressed that exhaustive experimentation on vetiver system covering over 30 initiatives by the Royal Development Study Centres has since been implemented all over Thailand by the Governmental agencies for realization of benefits of vetiver system in soil and water conservation, forest rehabilitation and restoration of degraded soil, as well as environmental protection of water bodies from effluent contamination and garbage decomposition. John Greenfield (New Zealand) giving a historical perspective of 'Advance of scientific research on vetiver system' traced the rediscovery of the versatile VS, from realization of

vetiver hedges to mark out farm boundaries in Karnataka (India), to the World Bank-supported follow-up studies on grass biodiversity *vis-à-vis* its multifarious applications in phyto-remediation, reclamation of mine dumps, and its ability to filter toxins before they enter the water-table.

In his opening lecture 'Vetiver grass – a world technology and its impact on water' Richard G. Grimshaw (USA) described how vetiver has developed as a world technology over four phases of application: soil and water conservation in poor rural areas; infrastructure stabilization; rehabilitation of difficult and often polluted sites; and water quality enhancement and site rehabilitation in relation to industry and intensive agriculture. He admitted that introduction of VS-based new technology was slow, but it has since made steady progress.

Paul Truong (Australia) in his talk on 'Vetiver system for water quality improvement', dwelt upon the significance of the VS in addressing the imminent global crisis of water shortage. Pinpointing the ability of vetiver grass to withstand highly adverse climatic and edaphic conditions, including elevated levels of salt, acidity, alkalinity, sodicity as well as a whole range of heavy metals, and also its ability to absorb and tolerate extreme levels of nutrients, he advocated that vetiver is ideally suited for treating contaminated and polluted wastewater from industries as well as domestic discharge. Highlighting morphological and physiological attributes of vetiver supported with empirical observations, he emphasized that the VS can help manage wastewater quantity through seepage control, and its quality by trapping sediments and particles, tolerating and absorbing pollutants, heavy metals, and detoxification and breakdown of industrial, mining and agrochemical residues, during land irrigation and under wetland conditions. Through another presentation he pointed out that vetiver, on account of its trapping/absorption capacity of nutrients, sediments and agrochemicals, can help stabilize otherwise fragile drain banks made up of acid sulphate



Figure 1. Eco-technological applications of the vetiver system. *a*, A 3.4 m long fibrous root system after 275 days of growth, from China, *b*, Transverse section of mature root showing schizogenous aerenchymatous cortex suitable for waterlogged condition and well-developed phloem for essential oil. *c*, Garbage landfill site in China covered with thick rubber sheet on top and earthen slope planted with vetiver for slope stabilization and leachate absorption. *d*, Slide-slope protection by vetiver along the railway line in Madagascar – proper drainage and suitable agroforestry for sustainable utilization of the vetiver system. *e*, Tea bushes grown between vetiver hedge rows in China to advance tea growth and tea quality. *f* and *g*, Restoration of water channel in the ecological park – contaminated wastewater channel (*f*) and ecologically restored water channel after vetiver plantation (*g*). *h*, Natural water ponds near Lucknow. (Below) With eutrophicated water having algal bloom. (Top) With vetiver purified water supported with green vegetation. *i*, Vetiver floating pontoons for wastewater treatment in a sewerage pond in Australia.

soils highly loaded with heavy metals, iron, aluminum and other metal concentrations, thus facilitating control of channel bank erosion. Cameron Smeal (Australia) pointed out that treating effluents with vetiver in industrial wastewater is actually a 'recycling process' and not a treatment process per se, as in the process of 'treatment', the vetiver plant absorbs essential plant nutrients such as N, P and cations, and stores them for other uses. In Australia, with large-scale planning this recycling plant is anticipated to provide high nutrient material for animal feed, mulch for gardens, manure for organic farming and organic source for composting.

Ralph Ash (Australia) presented an innovative example for development of a VS prototype for sewerage treatment schemes in Australia. He suggested that as phyto-remedial technology for effective removal of nutrient loads in sewerage disposal ponds, vetiver when planted as floating pontoons (Figure 1 *i*) as well as on contours, helps reduce nutrient load to a great extent making the sewerage water suitable for subsequent irrigation purposes^{3,5}. Barbara Hart (Australia) suggested that septic-tank effluent hydroponic vetiver treatment helps remove nitrate contamination thus mitigating ground water pollution by septic-tank effluents. Ian Percy (Australia) showed that landfill leachate run-off, low in heavy metals but high in salt and nutrients, could be recycled through irrigation of garbage mounds with vetiver grown thereof, thus saving the adjoining areas from being contaminated with landfill-leachate discharges. Alison Vieritz (Australia) showed that vetiver implicit a high nutrient uptake that makes it ideal for wastewater purification in the effluent irrigation schemes.

Henping Xia (China) based on his findings on constructed vertical flow wetlands, depicted that vetiver is highly efficient in purification and refinement of wastewater produced from the oil refineries. He, however, emphasized that efficiency of vetiver in water refinement was high with the fresh plantation, but gradually decreased with the passage of time. Thares Srisatit (Bangkok) presented findings on chromium removal efficiency of vetiver from tannery-wastewater constructed wetlands, and arsenic removal from experimental pots. Studying the root growth pattern elucidated through radioactive labeling uptake, Jitti-

wan Mahisarakul (Bangkok) showed that the vetiver root could grow luxuriantly and tolerate contamination of agricultural residues, including endosulphan in the garbage-fill site. Xuhui Kong (China) showed that vetiver-bamboo floats efficiently absorb heavy metals such as Zn, Cu, Pb, Hg as well as nitrates from the wastewater, thus helping the purification of eutrophicated water accumulated on pig farms. Based on wetland microcosm test Xuerui Lin and Wensheng Shu (China), from their two independent studies, suggested that vetiver grass-constructed wetlands have a great potential in the treatment of nitrate-concentrated landfill leachate and acid mine drainage from lead/zinc mine tailings. Stefanie Wagner (Germany) showed that vetiver has tremendous capacity for recovering N and P from wastewater and polluted water loaded with excessive N and P supply, and can withstand N and P at rates of 10,000 kg/ha/yr and 1000 kg/ha/yr respectively, suggesting that vetiver is suitable for treating wastewater and other polluted materials having high N.

Based on analysis of hydraulic retardance, sedimentation trap and plant submergence characteristics of vetiver hedge planting, Oscar Metcalfe (Australia) suggested that vetiver hedges significantly reduce the effective flow area of a channel; dense planting of vetiver in deep un-submerging flows show high hydraulic resistance, and rows of vetiver are more suited to steep slopes/highly erosive flows where sedimentation is unlikely.

Giving an overview of the VS in slope stabilization, Diti Hengchaovanich (Bangkok) opined that ever since the benchmark experiments on vetiver root strength conducted in 1996, the VS has evolved to become an important bioengineering tool having global acceptance. As a follow-up of hard experimental background, vetiver has made headway in cost-effective stabilization of karst stony slopes in high-altitude region, as well as in re-vegetation of barren quarried face in China; river bank stabilization in fresh- and brackish-water environment in Vietnam and China; beach protection in Senegal; coastal polders stabilization in Bangladesh, and in providing channel and flood control measures in Australia. Chengchun Ke (China) provided an experimental account of engineering design samples for appropriate application of eco-engineering technology for steep slope and river-bank stabilization, sug-

gesting that in addition to mechanical characteristics, the root growth curve, three-dimensional root net, capacity to re-vegetate on slope are the important contributing factors in vetiver eco-engineering anti-scour and anti-slide applications. Ping Zhang and Bo Huang (China), through their independent studies, provided successful examples of quarry/karst stony slopes re-vegetation using complex vetiver eco-engineering technique, where vetiver plantations could be established in mechanically designed planting traps on quarry slopes. Surapol Sanguankao (Bangkok) provided an account of successful application of the VS in slope stabilization along the mountain roads in the northern, northeastern and southern regions of Thailand.

Le Viet Dung (Vietnam) showed that establishment of vetiver hedge rows has provided effective soil-erosion control measure and bank stability in Mekong river delta against current and wave erosion caused by motorized boats in freshwater, brackish water, rivers and canals, on alluvial as well as highly acid sulphate soil. Tran tan Van (Vietnam), through his vetiver trial and demonstration project, showed that both local farmers and engineers have adopted the VS as their preferred option for coastal dune and road-batter stabilization, stream-bank erosion and fish-pond stabilization. M. Nazrul Islam (Bangladesh) provided a case example of successful introduction of vetiver in coastal polders over a 87 km long stretch in Bangladesh, as a cost-effective measure to maintain the coastal embankment system. O. Bababola (Nigeria) showed that planting of vetiver strips almost completely checked soil and runoff water loss in the eroded soils and consistently enriched the protected soil with nutrients. Liyu Xu (China) furnished case examples where the VS has been found to be effective in agricultural utilization of red soil, soil and water conservation in orchards, and in advancing tea growth and tea quality (Figure 1 *e*).

In addition to the above-mentioned specific eco-technological applications, other aspects discussed at the conference included the VS for wasteland reclamation, agriculture production and agroforestry; adaptability of vetiver to flooding, medicinal vetiver, pesticidal vetiver, nutrient contents and digestibility of vetiver grass, the VS entrepreneurship, and other uses of vetiver in cottage industry/handicrafts and utilization of

vetiver grass raw material in industrial applications. U. C. Lavania (India) presented an overall account of vetiver oil, embracing its processing, composition, economics and perfumery applications. Seshu Lavania (India) dwelt upon the morpho-anatomical and topographic characteristics of vetiver root-system to identify root ideotype suitable for need-specific applications. Y. Vimala (India) presented physico-chemical potential of vetiver in wetland soil reclamation.

One of the important presentations made at the conference was by Diti Hengchaovanich (Thailand) about 'Vetiver victorious: the systematic use of vetiver to save Madagascar's FCE railway'. Vetiver plantation could help restore the 163 km train route in Madagascar, severely hit by over 280 landslides caused by two cyclones in 2000 (refs 3 and 6). An innovative 'vetiver-for-vetiver loan/reimbursement' plan and a 'modular cropping system' that facilitated dissemination and implementation with farmers over a three-year period has helped establish reduction of erosion damage, strengthening of slopes and infrastructure along the line. Success achieved by vetiver intervention not only helped in restoration of the railway line but also improved soil fertility of the stabilized slopes for afforestation with fruit trees (Figure 1 d). Another successful example witnessed by the delegates during the conference on the study tour was the management of 20 ha garbage landfill project site, Datanshan Garbage landfill, located in Huangpu district, 20 km east of Guangzhou town. Vetiver plantations along the slopes of the landfill site have not only stabilized the slopes, but controlled leachate outflow by on-site absorption by vetiver (Figure 1 c). Another demonstration about the potential of the VS in wastewater purification was in the water streams of Yingzhou ecological park located in Xiaozhou village, Xinjio town, Haizhu District Guangzhou. Water streams in this ecological park become severely polluted by tidewater from the Pearl river. Vetiver plantation in the water channels of the park has helped rehabilitation and purification of the otherwise contaminated channel water, making it suitable for growth of natural flora (Figure 1 f and g). A corollary to such a situation has been

observed by the present authors in a natural ecosystem. A field observation of natural flora of two adjoining ponds with and without vetiver plantations, shows that the stagnant water in the former is clean, supporting growth of aquatic plants and in the latter it is eutrophicated, supporting algal bloom (Figure 1 h).

Although there were no specific recommendations, it was duly emphasized that the VS has come to an age as a low-cost eco-technology measure for a host of environmental problems. However, in view of high absorption potential of vetiver not only for nutrients but also for toxic residues, including agrochemicals, heavy metals and industrial effluents reaching the upper ground parts, the question remains as to where to dispose/make best use of raw material containing toxic substances. The present authors are of the opinion that as a part of integrated post-management of the VS eco-technology, it may be appropriate to utilize the vetiver biomass containing toxic chemicals/substances through its fixed applications in an eco-friendly manner. The two possible solutions could be through utilization of such vetiver grass biomass for vetiver ceramic pots and use of vetiver grass ash as cement-replacement material that meets all environmental and engineering pre-requisites. Supporting evidences towards such a utilization were presented separately by Varunee Thiramongkol and Pichai Nimityongskul (Thailand).

Vetiver is native to India, its environmental applications for soil and water conservation are in traditional practice since ancient times. Also, systematic efforts to develop vetiver grass technology for mitigation of soil erosion and water conservation were first initiated in India, but we missed the due initiative. Several countries on the other hand, taking cues from the Indian initiative, extensively implemented environmental applications of this grass. In particular, Thailand, Australia and China have since made significant strides in applications and advancement of the VS eco-technology. India is the centre of origin of vetiver, where this species is enriched with tremendous genetic diversity in reproductive behaviour, physiological and morphological characteristics. Also, natural seed setting in vetiver is known to

be occurring only in India. With concerted efforts exercised, it is possible to identify/develop designer plant/root types of vetiver suiting specific applications, ranging from vetiver for its essential oil to vetiver for soil/water conservation and detoxification. Therefore, it is time that India rejuvenates its initiative and embarks upon optimum utilization of this low-cost environment-friendly natural technology.

In general, the ICV-3 was well organized. The first two conferences ICV-1 (1996) at Chiang Rai⁷ and ICV-2 (2000) at Cha-am¹, both in Thailand were an eye-opener that portrayed bioengineering potential of vetiver grass. The third one provided the means and ways for environmental enhancement, more particularly water quality improvement and mitigation of pollution. In fitness to the progress made, newer avenues opened for social and economic implications of the VS in future and it was suggested that ICV-4 be organized on the focal theme 'Vetiver and people'.

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