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REVIEW

Environmental perspectives of *Vetiveria zizanioides* (L.) Nash

**Jatin Srivastava · Shilpa Kayastha ·
Sarah Jamil · Vandana Srivastava**

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Abstract The twentieth century witnessed indiscriminate usage of natural resources for energy generation and xenobiotic chemical compounds for sustainability in agriculture and infrastructural development. Heavy metal and non-degradable chemical contamination of soil and water is one of the major environmental threats. In recent years, worldwide researchers are concentrating on the exploration of various sustainable methods to mitigate such environmental contamination. Vetiver (*Vetiveria zizanioides* (L.) Nash), a grass, is a proven source to mitigate such pollution, and in present days is one of the most recent thrust areas for the purpose of environmental mitigation. Unique morphology, physiology and symbiotic association render vetiver capable of tolerating environmental extremities. In addition, vetiver is also helpful in degradation of most of the recalcitrant compounds such as *benzo[a]pyrene*. The present review reflects the environmental perspectives of vetiver grass, a potential field which led the World Bank to initiate vetiver grass technology (VGT), which is now known as vetiver system (VS), in India and most of the other Asian countries to restore the natural environmental conditions.

Keywords Vetiver grass · Xenobiotics · Heavy metals · Symbiotic association · Environmental extremities

Introduction

Vetiver (*Vetiveria zizanioides* (L.) Nash) is a fast growing, perennial, tussock grass belonging to the family Poaceae and a native of southeast Asia with a particular cultivar in the Indian subcontinent. The genus *Vetiver* has recently been reclassified and is combined with Chrysopogon (Adams et al. 1998; Veldkamp 1999), which is now called as *Chrysopogon zizanioides* (L.) Roberty; however, in the present review the former classification is used throughout the article. It is being grown since centuries for roof thatching, perfumery, and cosmetic industries. Vetiver was among the first recognized grasses used for soil conservation purposes in Fiji in the early 1950s. Thereafter, it was promoted by The World Bank for soil and water conservation in India since the 1980s. The use of vetiver has been a tradition in India for contour protection and essential oil production (Peyron 1989; Lavania 2004) from its odorous roots. The World Bank has initiated several projects in India for systematic development of vetiver grass technology (VGT), now popularly known as vetiver system (VS).

Vetiver is a high-biomass plant having high C4 photosynthetic efficiency (Mucciarelli et al. 1998), with a long (3–4 m), massive, aerenchymatous and complex root system, which can easily penetrate into the deeper layers of

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J. Srivastava (✉)
Department of Environmental Sciences,
Chhatrapati Shahu Ji Maharaj University,
Kanpur 208024, UP, India
e-mail: jks_345@rediffmail.com

S. Kayastha
Department of Microbiology and Bioinformatics,
Chhatrapati Shahu Ji Maharaj University,
Kanpur 208024, UP, India

S. Jamil
Eco-auditing Division, National Botanical Research Institute,
Lucknow 226001, UP, India

V. Srivastava
Department of Plant Sciences, University of Lucknow,
Lucknow 226007, UP, India

soil and stabilize the soil (Dalton et al. 1996; Truong 2000). Vetiver is capable of withstanding extremely harsh environmental conditions, varying temperature from −20 to 60°C (Truong 2000; Lavania et al. 2004), and is highly tolerant to acidic, alkaline, and saline growth medium (Truong 1999, 2000). In addition, vetiver has an outstanding ability to survive in various types of soils and flooded/waterlogged conditions. The effectiveness of this grass in soil and sediment erosion control is due to its morphological and physiological distinctiveness (Greenfield 1995).

The emerging vetiver system is a universal remedy and a proven solution for many other environmental problems such as soil and water conservation, wastewater treatment, embankment stabilization, flood control, pollution mitigation, and agroforestry management (Xu et al. 2003; Lavania et al. 2004). Based on the eligibility of this grass for the sustainable mitigation of pollution from the environment, it proves as the best material that nature has provided to the earth to restore the quality of the environment.

Environmental contamination and vetiver

Metal removal from soil

Phytoremediation techniques are receiving more attention for pollution mitigation strategies and vetiver has the ability to extract metals from the soil and water. However, the available literatures also suggest that vetiver grass can effectively remove toxic metals (Pinthong et al. 1998; Paquin et al. 2002; Chiu et al. 2006; Markis et al. 2007). Vetiver has a special affinity to toxic heavy metals such as Pb, Cu, and Zn (Khan et al. 2000; Lai and Chen 2004; Chiu et al. 2006; Rotkittikhun et al. 2007). Vetiver is well known for its high tolerance for metals such as Al, Mn and heavy metals like Cd, Cr, Ni, Pb, Hg, Se, Zn, and metalloids such as arsenic (As) present in the soils (Truong 2000; Chen et al. 2004; Chiu et al. 2005). Lai and Chen (2004) and Chiu et al. (2005) recommended the use of chelators such as EDTA for the enhancement of uptake of heavy metals through vetiver grass. The tolerance to the heavy metals by vetiver grass is often attributed to its capability to accumulate metals in above-ground tissues that do not affect the roots and shoot growth (Roongtanakiat and Chairoj 2002), and to the mycorrhizal association within its roots that makes it sturdy enough to withstand high toxic metal concentration in soil (Chantachon et al. 2002; Chen et al. 2005). Recent studies carried out by the Department of Environmental Sciences (CSJM University, Kanpur, India) on vetiver grass showed negative effect on the plant growth and in the mycorrhization (unpublished data) after exposure to higher concentrations of As (III) under flooded conditions. However, some reports suggest enhanced uptake of As (V) from the soil in the presence of chelating agents (Chiu et al. 2005). A specific root system provides tolerance to vetiver for a wide range of adverse climatic and edaphic conditions including heavy metal pollution.

Water treatment

The important factors that contaminate the water quality are the agricultural waste, industrial waste, pesticides, biological pollutants such as pathogens and enrichment with inorganic nutrient ions. Cations such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, and anions such as PO_4^{3-}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-} represent the principal chemical constituents of surface water (Tchobanoglous and Schroeder 1985). Vetiver has tremendous capacity for recovering N and P from wastewater and polluted water loaded with excessive N and P, and can withstand against N and P at rates of 10,000 kg ha^{-1} $year^{-1}$ and 1,000 kg ha^{-1} $year^{-1}$, respectively (Lavania et al. 2004). Vetiver has been successfully demonstrated for the removal of phosphorous and nitrogen by 86–90% from surface water (Srivastava et al. 2007). These data suggest that vetiver is suitable for treating wastewater and other polluted media (soil and water) having high N content. In a study carried by our group at the National Botanical Research Institute, Lucknow, India, vetiver in combination with *Phragmites* spp. was found to mitigate the excessive nutrient levels from surface water (Singh and Srivastava 2007). Singh et al. (2008) provided comprehensive information on the removal of radionuclides from wastewater by vetiver grass. Vetiver plantlets can also remove ^{90}Sr up to 90% and ^{137}Cs up to 60% from the water within 7 h (Singh et al. 2008). Some other important usages of vetiver include the protective barricading as shown in Fig. 1, whereby the pontoons prepared with this grass float on the surface of the water and reduce the pollution level. Vegetated buffer strips of vetiver are widely used to reduce fluxes of eroding soil and associated chemicals from hill slopes into waterways (Babalola et al. 2007; Hussein et al. 2007).

Removal of xenobiotics

The twentieth century witnessed indiscriminate usage of xenobiotic chemicals such as pesticides, explosives, and dioxins, which are absent in nature and are hazardous to life. Researchers worldwide are exploring sustainable methods to clean such contaminants. In this context, vetiver has been proven to be well suited for soils contaminated with such hazardous chemicals as suggested by the reports of Paquin et al. (2002) who demonstrated the removal of *polyaromatic*

Fig. 1 Floating pontoons of vetiver grass

hydrocarbons (PAH) by the vetiver grass. Li et al. (2006) suggested the biodegradation of *benzo[a]pyrene*-like chemicals prompted by *V. zizanioides*. It also has promising potential to remove explosives from contaminated sites (McCutcheon et al. 2003). Significant work has been carried out on this aspect by Markis et al. (2007) who reported higher uptake of TNT by vetiver grass in aqueous conditions. In the presence of chaotropic agents, vetiver enhances the uptake of hydrophobic compounds like TNT from water (Markis et al. 2007). Chaotropic agents disrupt water structure, increasing solubilization of hydrophobic compounds that enhances the plant uptake. The use of vetiver grass in relation to petroleum-contaminated soils is promising for amelioration of slightly polluted sites. A greenhouse study conducted to determine the tolerance of *V. zizanioides* to heavy crude oil in soil, showed no effect on the total oil and grease content of the contaminated soil; however, vetiver grass was found to tolerate 5% (w/w) petroleum concentration in the soil (Brandt et al. 2006). Vetiver can efficiently remove the toxic metals from the contaminated soils with the oil (Xia 2004).

Vetiver grass and pathogen removal from water

Studies have shown that the treatment of wastewater in a constructed wetland by vetiver grass reduces the total bacterial count (Singh and Srivastava 2007). The mycorrhizal associations with the roots of vetiver grass cause chemical changes in the essential oil composition (Adams et al. 2004) and achieve killing effect on certain pathogenic members of family Enterobacteriaceae (Srivastava et al. 2007). Vetiver oil quality differs depending upon the infection with mycorrhizal fungi (Adams et al. 2004). Vetiver has been extensively investigated for its essential oil for various purposes (Hanayama et al. 1973; Kartusch and Kartusch 1978; Lembarg and Hale 1978; Peyron 1989; Viano et al. 1991; Adams et al. 2004; Srivastava et al. 2007).

Why vetiver is tolerant to various environmental extremes

Vetiver is a high-biomass plant with a high C4 photosynthetic efficiency (Mucciarelli et al. 1998) that renders it tolerant against various environmental conditions. Uptake of elements depends on environmental factors such as nutrient supply and the pH of the surroundings. Xia (2004) noticed that the application of nitrogenous fertilizers and herbicides reduces the ability to accumulate metals by the grasses but vetiver was found effective in such conditions for metal uptake because of the increased biomass (Xia 2004; Wilde et al. 2005). Profuse growth of the vetiver roots has been observed in mesocosm, especially in water (Fig. 2). The subsurface plant tissues grow vertically in soil and water, creating an extensive matrix with a large surface area for the uptake of metal as well as nutrient ions. In addition, vetiver accumulates toxic metals mainly in roots and the least in shoots (Yang et al. 2003). The restriction of metal translocation from root to shoot in *V. zizanioides* might be one of its metal tolerance strategies (Shu et al. 2002). Pang et al. (2003) suggested that the high proportion of toxic metals such as Pb and Zn greatly inhibit the leaf growth, dry matter accumulation, and photosynthesis, while on the other hand, vetiver also accumulates proline, abscisic acid (ABA) and enhances activity of super-oxide dismutase, peroxidase, and catalase, implying the existence of a mechanism to quench the active oxygen species. In addition, vetiver also has detoxifying mechanisms such as conjugation to glutathione with the non-degradable xenobiotics to convert them into less toxic substances that are further accumulated by the plant (Marcacci et al. 2006). Vetiver is also reported to have mycorrhizal associations (Wong 2003) that facilitate the uptake and transport of less mobile soil nutrients (Thingstrup et al. 2000; Jakobsen et al. 2001). Mycorrhizal association also reduces the pathogenic infections in the vetiver plants (Abdalla and Abdel-Fattah 2000; Srivastava et al. 2007).

Further studies

Plant immune response is still an open field as far as vetiver grass is concerned. The mycorrhizal association with the plants undoubtedly renders some sort of immunity to the

Fig. 2 Roots of vetiver growing in water

plants to tolerate environmental extremities. This aspect can be explored further for the different responses of the plants for various pollutants present in the environment. The biochemical changes in vetiver plant tissues can be used as biomarkers for defining the totality of the environmental degradation and its effect on the local vegetation. Several aspects of studies on the vetiver grass are still remaining to exploit its potential for the removal of various xenobiotics and non-degradable substances.

Conclusion

Phytoremediation is a sustainable way to mitigate pollution from the environment. Vetiver grass has successfully shown its potential towards phytoremediation since the last 2 decades. The grass has evolved the self-mechanism to tolerate various environmental extremities such as temperature, salinity, alkalinity, floods, heavy metal contamination, and the presence of xenobiotics. Researchers all over the world are coming up with a new face of vetiver grass with respect to checking the environmental hazards.

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