Vetiver [*Chrysopogon zizanioides* (L.) Roberty]: An aromatic root crop for soil and water conservation

ABSTRACT

Khus grass or vetiver (*Chrysopogon zizanioides* (L.) Roberty) is a hardy perennial aromatic grass with long enormous tufted fibrous root system. Commercially, dry roots are used for extraction of essential oil that acts as a fixative in perfumery industry worldwide. Besides, vetiver roots are used in medicinal and pharmaceutical industries to treat rheumatism, arthritis, gouty joints, paralysis and indigestion. Roots and root oil have strong anti-oxidant, stimulant, carminative and cooling properties and used in Ayurvedic medicines. Traditionally, vetiver plants are being used to cultivate across hill slopes, waterways and wastelands to reduce runoff and soil conservation. During 1990's World bank was promoting use of vetiver grass as contour vegetative barrier in upland farming systems of Asian and African countries. Further, recent studies report the use of vetiver in phytoremediation, reclamation of mined lands and soil and water detoxification in addition to carbon sequestration. Due to introduction of modern cultivation practices, traditional soil conservation practices are being vanished gradually over a period of time. In this regard, an attempt has been made to review the scientific evidence for use of vetiver grass as a soil and water conservation measure along with phytoremediation.

Keywords: Chrysopogon zizanioides; phytoremediation; soil conservation; water purification, carbon sequestration

1. INTRODUCTION

Vetiver (*Chrysopogon zizanioides* (L.) Roberty) or khus grass is a hardy perennial aromatic grass belonging to the family Poaceae. It is a densely tufted aromatic grass produce long roots growing about 3m depth having 1-1.5m radius around the plant. The roots are exceptionally tolerant to drought as well as flood conditions and highly suitable for poor and marginal lands under arid and water-logged conditions [1,2]. Even though it originated in India, Indonesia, Haiti, China, Vietnam, Thailand, Java, Japan, and Brazil are the major cultivators of vetiver, producing about 250 t of essential oil every year. Haiti and Indonesia are the largest producers of vetiver oil (180t/ year), contributing a significant share of the global market [2,3]. There is a huge demand for vetiver essential oil in the USA, Europe, Japan, and India as a major raw material for perfumery and pharmaceutical industries [4,5,6]. In India, it was found as a wild species in Northern and eastern parts, Rajasthan, Uttar Pradesh, Assam, and Meghalaya and cultivated in Kerala, Karnataka, Parts of Andhra Pradesh, Tamilnadu, Madhya Pradesh, Orissa, and Haryana states [7]. In South India, improved varieties of vetiver were commercially cultivated due to the high demand for essential oil in the perfumery industry, even though the quality of north Indian wild-type vetiver root oil was found to be better [8,9,10]. Other than that, fragrant roots are used in folklore medicines, water purification and soil conservation. Medicinally, roots have cooling properties used in aromatherapy, release stress, and treatment of rheumatism, paralysis, arthritis, and gouty joints [9,11-12]. Roots stimulate digestion, act as carminative and strong anti-oxidants, and are used in fabric conditioners, air and water cooling, and room fresheners [4]. Various handicrafts are made from vetiver roots, leaves, and inflorescence, such as doormats, curtains, baskets, hats, hand fans, brooms, and leaves have fodder value, used for thatching, bedding, mulching and as fuel [1,11-12].

Above all these, the vetiver plant has wide recognition as a soil conservator since the extensive rooting system preserves the soil from erosion. The grass is used on the border of coffee, tea, and rubber estates to plant against sloppy terrains to reduce soil erosion [2]. Vetiver is selected to grow extensively in arid and semi-arid regions, even in waste and barren lands, to conserve soil and reduce runoff [13,14,15]. Hence, an effort has been made to compile and review scientific evidence supporting the traditional use of vetiver grass as a natural soil and water conservation measure.

2. USE OF VETIVER IN SOIL AND WATER CONSERVATION

India has a long history of using vetiver grass as a soil conservator and hedge crop under hill slopes in arid, semi-arid and coastal zones. During 1990's World Bank promoted vetiver for soil conservation under watershed management projects in India and other tropical countries like China, Malaysia, Thailand, Sri Lanka, Madagascar, South Africa, Nigeria, Costa Rica and Guatemala [16,17]. The densely tufted vetiver roots are reported to create and effective vegetative barrier across a deep slope, control runoff, and increase water infiltration to a great extent [18,19,20]. In that way, on slopes under 5%, contour hedgerows of vetiver, planted at 1m vertical intervals, have reduced surface runoff by an average of 30% and 47% compared to conventional practices of graded banks and across slope cultivation [13]. Vetiver roots offer high strength against pulling, ranging between 10 MPa to 50 Mpa, and it is inversely proportional to the diameter of the roots, which results in soil stability under slopy lands [21].

A study was conducted in two different locations on steep hill slopes of Dhaka, Bangladesh, on the erosion control potential of vetiver using a physical model. There was 94-97% reduced soil loss along with a 95% low soil detachment rate, and the runoff rate was reduced by 21 % under open sandy soil conditions [22]. Vetiver was also used in highways, rail, and road side hill slope projects across the world for erosion control, hill stabilization, prevention of landslides and hazard mitigation [15, 23]. A study on bioengineering technology by using vetiver vegetation in river cliffs to control erosion demonstrated an average reduction in erosion rate of 85-87 % at 103-107 mm/h rainfall intensity, followed by a 66% reduction in erosion rate at high-intensity rainfall of 130 mm/h in Indonesia [24].

In Thailand, the systematic planting of vetiver grass on hill slopes not only solved landslide and soil erosion problems but also played an important role in creating awareness amongst local communities about soil and water conservation concepts. In turn, resulted in increased agricultural productivity, reduced poverty rates, and improved the quality of life of the Huai Khayeng and Yanree communities [25].

A hedgerow planting of vetiver grass in the Somodo watershed area of Ethiopia recorded an accumulation of 36 cm of soil above the watershed area, resulting in a reduction of 2.5% field slope and soil conservation of 20.88 t/ha/year. It took about two years to complete the establishment of the grass row, and the phosphorous availability increased from 1 ppm to 9 ppm above vetiver hedge row [14]. Similarly, another study in Nigeria demonstrated accumulation of 98% more soil in vetiver strips than control and planting of vetiver increased cowpea seed and stover yields by 11.1% and 20.6%, respectively, and increased soil moisture storage by 1.9-50.1%, depending on the soil depth. Soil loss and runoff water were 70% and 130% higher on non-vetiver plots than vetiver plots. Eroded soils on non-vetiver plots were consistently richer in nutrient contents than on vetiver plots and nitrogen use efficiency in vetiver row was enhanced by 40% [26].

The grass was found to be nonpalatable to cattle and thus, it can be easily maintained without fencing. Besides, the vetiver planted across the slope was reported to increase crop and fodder yield by at least 50 % due to *in situ* moisture conservation and upsurging underground water, rivers, ponds, and waterbodies down streams [16]. It was observed that vetiver was moderately slat tolerant and highly tolerant to saline conditions in Australia. It was found growing in a salinity of 8 mS cm^{-1} and more. However, increased soil EC at 17.5 mS cm^{-1} reduced the plant growth by 50% during the initial stages of growth. Mature plants were tolerant to higher EC and can survive up to 47.88 mS cm^{-1} salinity. The grass was found to be resistant for sodic coal mine soil and can be established on highly alkaline and acidic pH (3.3- 9.65) with a temperature range of -15º to 55ºC [27,28].

3. ROLE OF VETIVER IN PHYTOREMEDIATION:

Vetiver grass was found to be eco-friendly for the creation of green space in polluted locations, wastelands, and mined areas. The grass strip can be effectively used for removing pollutants like heavy metals, organic matter, toxic chemicals, and industrial effluents from land and water, even under extreme weather conditions, and can produce a biomass of 100 t/ha/year [28-30]. Depending on the ecotype, heavy metals were absorbed and stored in the root system by involving soil microorganisms. Vetiver can absorb a wide range of heavy metals, viz., As, Cd, Cr, Cu, Hg, Ni, Se, and especially Pb (1% in root; 0.4% shoot) and Zn (1% in root and shoot) [29]. Likewise, vetiver accumulated a high concentration of Cu in roots and shoots (754 and 55 mg kg^{-1}, respectively in root and shoot) [31]. (Danh et al., 2010). However, the essential oil content and yield were not influenced by Cu and Zn content, but Pb and N reduced the oil yield. Though phytoremediation depends on variety, soil type, substrate concentration and pollution, vetiver augments phyto stabilization of contaminants through rhizofiltration, phytoextraction and rhizobiodegradation [29,32].

In South Africa, vetiver was used for the rehabilitation of gold mines and resulted in the accumulation of large amounts of heavy metals in roots and restricting their translocation to shoots, including physiological mechanisms viz., chelation of toxic metals by phenolics, glutathione S-tranferase, and low molecular weight thiols; sequestration and accumulation of metals within the cell wall [33]. Also, vetiver grass was effectively used for rehabilitation and soil stabilization of sites contaminated with high levels of heavy metals, particularly Fe, Mn, Zn, and Cr [34]. Studies on the reclamation of iron ore mine spoil dumps using vetiver have minimized the toxicity level of iron and stabilized the degraded soil owing to the high soil binding property of web-forming roots. Utilization of aboveground biomass as safe fodder ensures the renewability and sustainability of such eco-plantations [35]. The essential oil extracted through hydro distillation from vetiver roots grown in contaminated areas was free from heavy metals, implying plants can generate revenue through land rehabilitation [31,36].

Vetiver grass grown in endosulfan-affected vertisol and lixisol soils of France was found to reduce the chemical concentration substantially by root absorption (6.53-9.73 mg kg^{-1}) due to the promotion of endosulfan degrading microorganisms in vetiver-grown soil, and in six months a complete absorption of endosulfan was noticed in the soil [37]. Additionally, Vetiver could take up and accumulate atrazine from submerged land with a concentration of 1.0 mg kg^{-1} in leaf at 20 days of application. The metabolites Hydroxyatrazine, deethylatrazine, Deisopropylatrazine, and didealkylatrazine were detected in the leaf in 30 days, indicating vetiver could degrade atrazine inside the leaf tissue. The atrazine removal rate in the vetiver planted and unplanted jars was 69.72 and 60.29%, respectively, signifying 9.43% higher atrazine removal by vetiver [38].

Vetiver grass was also reported to rehabilitate petroleum oil-contaminated areas of Venezuela, one of the largest oil producers in the world. Even though oil contaminants inhibit the growth of vetiver, it can tolerate up to 5 % of the oil contamination. The use of vetiver grass in relation to petroleum-contaminated soils was promising for amelioration of slightly polluted sites to allow other species to get established [39].

An experiment was conducted at a thermal powerplant in West Bengal, India, to study the effect vetiver growth on coal fly ash control. Vetiver grown on the fly ash effluent covered the entire area in three months, causing a phyto-stabilizing effect. Further, vetiver shoots could be safely grazed by animals as very few heavy metals in fly ash were found to be translocated to the shoots. These features make planting of vetiver a practical and environmentally compatible method for restoration of fly ash dumpsites. There was no nuclear DNA damage to vetiver, implying long-term survival of the plant in the rehabilitation site [40-41].

The phytoremediation potential of vetiver for antibiotic, tetracycline-contaminated hydroponics system was studied in the USA. Vetiver was effective in the complete removal of tetracycline in 40 days from contaminated aqueous media [42]. Similarly, more than 90 % of ciprofloxacin and tetracycline were removed by vetiver grass during secondary wastewater effluent treatment [43]. It also removed some nutrients from the effluent, *viz*., nitrate (>40%), phosphate (>60%), total organic carbon (>50%), and chemical oxygen demand (>40%), denoting vetiver planting, a cost-effective *in situ* phytoremediation technique for removal of anti-biotics and organic compounds from wastewater. A study on wastewater reclamation using vetiver grass was conducted in Kerala, India, and reported that the grass could remove 80- 85% BOD, 85-90 % COD, as well as 85 % total coliform microorganisms. All the quality parameters tested for vetiver-treated water were within the permissible limits [44]. Vetiver roots were also used in low-cost domestic water filter systems as a purifying material and defluoridation. Vetiver roots can reduce the influent fluoride concentration from 12 ppm to 0.82 ppm in 1 hour. The filter was also found to effectively reduce the coliform bacterial levels in the water (58 % reduction) [45].

4. VETIVER FOR CARBON SEQUESTRATION

Globally, soil holds three times more carbon than plants and two times more carbon than the atmosphere. Perennial fast-growing trees, shrubs, and grasses have the greater potential to sequester atmospheric CO_2. Roots are the key parts that translocate and contribute to carbon sequestration in different layers of soil [46]. Perennial grass, like vetiver produces an enormous deep root system and was found to contribute significantly to soil carbon. Vetiver has the ability to produce 161 Mg ha−1 of fresh shoot biomass and 107 Mg ha−1 root biomass annually [47].

In Australia, total carbon sequestration under vetiver was significantly higher (123 Mg ha-1) than pasture (93 Mg ha-1) and cropping soils (78 Mg ha-1). Further, vetiver litter accumulation and root decomposition contributed to the additional C stock (43.5%), indicating a significant C turnover through the whole soil profile, resulting in a modest net accumulation of soil C [48]. Likewise, in Southwest Ethiopia, vetiver sequestered more significant organic carbon (262 Mg C ha-1) than local vegetation coffee (178 Mg C ha-1) [48]. In India, vetiver was found to sequester organic carbon 15.24 Mg C ha−1 year−1 with an estimated C-sequestration of 150 Tg per year, compensating 46 % of the C emissions of the country [49]. The large root biomass produced does indeed contribute more to soil carbon accumulation, and faster root decomposition is crucial in releasing the carbon in the root exudates. It also speeds up its contribution to stable soil organic content and C-accumulation [47]. Hence, planting vetiver and similar tropical perennial grasses on degraded and less fertile soils could be a good strategy to rehabilitate degraded soils and for soil carbon sequestration.

5. CONCLUSION:

Hardy perennial, eco-friendly vegetative barrier, vetiver hedge row planting technology could be globally applied for regulating soil erosion, stabilizing hill slopes and waterways, and remediating mined, barren, and polluted lands in order to improve crop growth and yields. Hence, it can be effectively used as a low-cost technology for soil and water conservation and can generate revenue for the farming community, in addition to enhancing water quality for irrigation. As the grass was found to be highly tolerant to extreme weather conditions, rapid growth and biomass production help create green space in polluted locations, wastelands, and mined areas, as well as enhance soil organic matter and soil organic carbon content.

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