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Role of *Vetiveria zizanioides* in soil protection and carbon sequestration

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Abstract
Soil degradation, contamination and low organic matter status of soils assume significance as major factors contributing to soil fertility decline and low crop productivity. Soil erosion results in loss of nutrients and soil organic carbon, which ultimately aggravates soil degradation. Soil contamination is caused mainly by release of industrial wastes, sewage sludge, land application of fertilizers and pesticides etc. resulting in accumulation of heavy metals ultimately turning the soil unproductive and unfit for cultivation. This situation demands adoption of efficient strategies that would aid in protecting the soil. *Vetiveria zizanoides* (*Chrysopogon zizanioides)* has been identified as a hardy plant with various economic and environmental applications. This article attempts to throw light on the potential of vetiver grass in protecting the soil and carbon sequestration.

Keywords: Vetiver grass, soil erosion, soil contamination, carbon sequestration

Introduction
Vetiveria zizanioides (*Chrysopogon zizanioides*) is a perennial tufted herbaceous plant native to India. This grass grows in the tropical and sub-tropical parts of the world, thrives well in a wide range of soil and climatic conditions. Also, the herb exhibits tolerance to salinity, prolonged water logging, drought, fire and is resistant to pests and diseases (Grimshaw, 2008) [1]. It can be easily maintained with little effort. The leaves of this plant are thin with sharp edges while the shoot grows upto 2m. The mature foliage is coarse and tough. It possesses root system that is abundant, complex, extensive and vertical in nature. The root grows almost straight down with few lateral surface roots, not interfering with the growth of other plants. In the first year of planting the roots of vetiver plant can reach 3-4 m while after a period of 36 months it attains a total length of 7m. The roots are very strong with an average tensile strength ranging from 75-85 MPa. Vetiver is regarded as a miracle plant due to its multiple benefits (Figure 1). The current article majorly throws light on the potential of this grass in soil protection and carbon sequestration.

I. Soil protection
a) *Erosion control*
Soil erosion, the process by which primary particles and aggregates are removed and lost from their point of origin by the action of wind or water has become a major issue of concern threatening the sustainable use of world's soil resources. It leads to loss of top soil rich in nutrients and organic matter contributing towards soil degradation. Adoption of suitable soil and water conservation strategies would aid in minimizing the risks associated. Vetiver grass planting in erosion prone areas could be regarded as an efficient, cheap and sustainable means to control soil erosion and its hazardous impacts. A vetiver grass strip is a vegetative barrier or a hedge of grass which is placed preferably along the contour, perpendicular to the direction of water flow in the field in order to trap sediments, reduce runoff velocity and encourage water infiltration. The stiff foliage of the grass and the dense but porous nature of the hedge formed by the strip makes vetiver grass strip suitable to serve the purpose (Grimshaw, 1993) [2]. Experiments conducted by various researchers have demonstrated the efficacy of vetiver grass in curtailing soil erosion. Reduction in soil loss to the tune of 70%, runoff by around 130% in comparison to control was attained when vetiver grass strips were built at 20 m surface intervals (Babalola *et al*. 2003) [3]. Vetiver grass strips augmented the nutrient and water uptake efficiency of the soil (Babalola *et al*. 2007) [4]. Vetiver grass could be used as slope covers to reduce the infiltration of rainwater into slopes, the presence of roots increases the cohesion of the original soil leading to increase in shear strength of the soil covered with

vegetation (Rahardjo *et al*. 2014) [5]. Owing to high tolerance level of this herb to Al and Mn toxicity, it has been successfully used for the stabilization of drainage channel banks in acid sulfate soils (Truong *et al*. 2003) [6]. Runoff simulation experiment using three varieties of grass on slope revealed that grasses were effective in controlling soil runoff. The efficiency followed the order Bahia grass (0.12 m s^{-1}), vetiver grass (0.17 m s^{-1}), daylily (0.19 m s^{-1}) (Cao *et al*. 2015) [7]. The application of 1.0 and 7.5 t ha^{-1} vetiver grass mulch resulted in soil loss reduction to the tune of 32.4 and 61.7% respectively (Donjadee and Tingsanchali, 2016) [8]. Vetiver grass roots can increase the soil water content and density, reduce soil erosion by locking the finer grains. Analysis on grain size distribution revealed that the percentage of grain size 0.075~0.005 mm and that < 0.05mm in rooted soils is higher than in non-rooted soil by 18.2 and 39.1% respectively (Xu *et al*. 2018) [9]. Vetiver buffer strips at 5m interval significantly reduced runoff, soil losses and increased yields of the crops under study (maize and cassava) Oku *et al*. 2015 [10]. Vetiver could rehabilitate and maintain slopes affected by landslides even after 4 years of planting (Eboli *et al*. 2011) [11] and also proved useful in coastal erosion control (Lucena and Leao, 2011) [12].

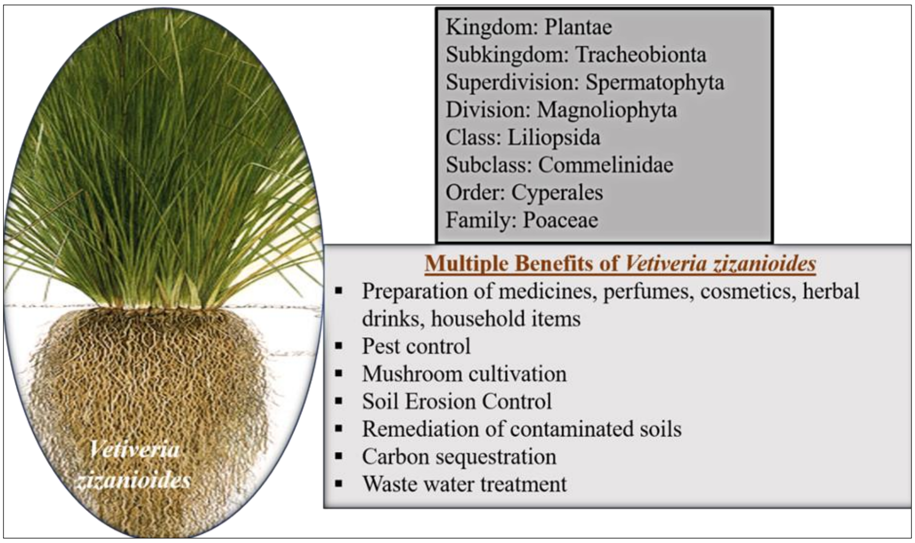

Fig 1: Multiple benefits of *Vetiveria zizanioides*

b) *Remediation of contaminated soils*

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan *et al*. 2008; Zhang *et al*. 2009) [13, 14]. Remediation of heavy metal contaminated soils is necessary to reduce the associated risks, make the land resource available for agricultural production, enhance food security and scale down land tenure problems arising from changes in the land use pattern (Wuana and Okieimen) [15]. Vetiver by virtue of its extensive rooting system can uptake heavy metals and establish itself in polluted soils (Yang *et al*. 2003; Chin *et al*. 2006) [16, 17]. High shoot biomass, tolerance to metals coupled with high metal accumulating capacity makes this herb ideal for extraction. Ramkrishna *et al*. 2016 [18] reviewed several plants including vetiver grass that could be utilized towards addressing the problem of heavy metal pollution and concluded that vetiver plant is an effective accumulator of metals *viz*. chromium, lead, nickel and zinc. Vetiver grass also exhibited its potential in amelioration of petroleum contaminated soils which would aid in establishment of other species (Brandt *et al*. 2006) [19]. It holds very high capacity for uptake of nitrogen and phosphorus and can tolerate high levels of chromium, cadmium, copper, lead and zinc (Truong and Truong, 2011) [20]. Vetiver is tolerant to very high levels of soil Cd and majorly accumulate the heavy metal in its roots (Phusantisampan *et al*. 2016) [21]. (Riccarda *et al*. 2007) [22] reported vetiver grass to be hyper accumulator of Pb and Zn (0.4% in shoots and 1% in roots for Pb and 1% both in shoots and in roots for Zn, after 30 days).

II. Carbon sequestration

Carbon sequestration implies capture and secure storage of C that would otherwise be emitted to or remain in the atmosphere. C sequestration is an efficient strategy to mitigate climate change. Vetiver holds prominence as one of the world's best carbon-sequestering plants. Four mature vetiver plants would sequester the same amount of atmospheric carbon as one fast-growing poplar tree, the best of all trees for carbon sequestration. As an example, one 'carbon footprint' would be negated by planting 50 to 60 vetiver plants, or approximately 8 m of vetiver hedgerow (Grimshaw, 2011) [23]. Taranet *et al*. 2011 [24] highlighted the efficiency of vetiver grass to elevate levels of soil carbon stocks. Vetiver's enormous capacity to produce biomass, and its impressive deep root system that can possibly capture more carbon than any other grass. (Pinners, 2014) [25]. Trials conducted at Bangalore revealed that vetiver sequesters 15.24 Mg C $ha^{-1}year^{-1}$ in shoot and roots, much higher than that for lemongrass with 5.38, palmarosa with 6.14, and trees with 2.92 (Singh *et al*. 2014) [26]. Lavania and Lavania (2009) [27] reported that vetiver grass could be an ideal global candidate with a holding potential of 1 kg atmospheric carbon, sequestered annually deep into the soil pool from one sq. metre surface area.

Conclusion

Vetiver grass holds vast potential to abate soil erosion, remediate contaminated soils and enhance carbon sequestration. Vetiver grass technology is ecofriendly, sustainable and cost-effective approach aiding in soil protection and climate change mitigation. This green technology could be regarded as a viable strategy that could be adopted by resource poor farmers inhabiting arid and semi-arid regions (prone to soil erosion) which would aid in achieving economic gains along soil protection.

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