VETIVER GRASS MODEL AND PHENOMICS OF ROOT SYSTEM ARCHITECTURE*

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Tufted roots of the vetiver grass, *Chrysopogon zizaniodes* (L) Roberty have been in traditional use for cooling applications, and for its essential oil that is valued in perfumery industry. Lately, its deep penetrating roots have emerged as an eco-friendly candidate in environmental applications. Keeping in fitness with its biological potential a "vetiver grass model" for sequestration of atmospheric carbon into subsoil horizon to mitigate global warming likened to forest trees has earlier been proposed by the present author. With rising global interest in vetiver root system a need has been felt to explore diversity in its root architecture for its multifarious applications to make the vetiver plantations ecosystem sustainable and globally acceptable, necessitating identification or development of designer genotypes. Two different approaches are required to be adopted to implement Vetiver Grass Model for: (a) Industrial applications, or (b) Environmental applications. For industrial applications it is desirable to identify plant types that sport thicker roots with least lateral roots, lysigenous cavities containing higher number of essential oil secretary cells, shorter crop cycle and lower distillation period. For environmental applications the key requirements besides others are non-seeding habit and low essential oil in the roots to realize non-invasive feature and deterrence to uproot the plantations for its otherwise industrial utility. In addition, the root architecture for ecological plantations should be such that the roots are able to penetrate deep into the subsoil horizon to realize Carbon sequestration; impart high soil binding potential achievable through fast growing web forming tufted roots; realize high absorbance of toxic chemicals and metalloids for pollution mitigation; should have capacity to sustain high lysis in the cortical region for enhanced aeration to sustain its survival under submerged conditions. An illustrated account of phenomic diversity in root architecture vis-a-vis its prospective industrial and environmental applications is presented in support of Vetiver Grass Model.

Keywords: Vetiver grass model, vetiver root architecture, root web, root diversity.

Vetiver, *Vetiveria zizaniodes* (L) Nash. syn. *Chrysopogon zizaniodes* (L.) Roberty, fam. Poaceae, is a densely tufted C4 grass native to India (Lavania UC 2002). It is nicknamed as Miracle Grass on account of its wide ecological adaptation occupying a wide variety of habitats (Chomachalow and Henle 1998). This grass is bestowed with tolerance to diverse climate and soil conditions ranging from dry to marshy to submerged to floating, capable to sustain 04-50 ^{0}C environmental temperature, and pH range 4-11. The plant has its natural occurrence all across India and Sri Lanka covering a temperature range of 15-45^{o} C and altitudinal variation upto 1200 m (Lavania 2008). The grass is widely distributed in south east Asia, and is said to have been introduced in all other continents including Australia, Africa and Latin America for its environmental applications. The plant offers tremendous phenotypic and reproductive diversity for which descriptors have been defined (Lavania S 2002). In India two diverse reproductive forms are encountered. The north Indian type is profuse flowering and high seed forming, whereas the south Indian type is either late flowering or low or non flowering without any / low seed set (Ramanujam and Kumar 1964).

This grass sports deep penetrating tufted roots valued for its essential oil used in perfumery industry, and for root-mats / curtains for cooling applications (Lavania 2008). Lately, it has occupied prominent place in multifarious environmental applications, including carbon sequestration in sub-soil horizons (Lavania and Lavania 2009, Lavania *et al* 2016), and multifarious environmental applications (Lavania and Lavania 2000, Lavania et al 2004). Tremendous phenomic diversity is encountered in vetiver for root phenotype architecture and qualitative features of the essential oil. It is therefore desirable to pinpoint characteristic features that may be most appropriate for specific applications. This will help to identify an ideal plant type from the

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available diversity or to develop designer genotype meeting required characteristics. This article is intended to pinpoint and outline such characteristics.

The Vetiver Plant

Vetiver grass sports deep penetrating tufted root system and prolific clump of tillers above ground reaching the height of upto 2.5 meters, and the roots growing indeterminately reaching upto 3 meters in one year. The plant can be propagated vegetatively through planting of tillers / ratooning under cultivation or multiplies in nature through seed dispersal primarily along the river banks and marshy lands.

Breeding habit and plantations: economic *vs* environmental considerations

As stated above two diverse morphotypes varying for reproductive features are encountered in India. The north Indian types sport profuse flowering, open pollination and high seed formation. Whereas, heterogenous plant populations originating through seed propagation serve as a valuable genetic resource to tap genetic diversity to isolate desirable genotypes, but seed forming types are not preferred in ecological plantations on account of possibility of becoming weedy. Further, to utilize vetiver as an essential oil crop it is desirable to identify plant type where there is high root biomass containing higher concentration of essential oil of desirable quality. On the other hand for utilization of vetiver for ecological plantation the roots with least essential oil are preferred to avoid uprooting of plantations by commercial interests.

The root physiography and the root oil

The root complex of vetiver is comprised of a tuft of fibrous roots that grow vertically and penetrate deep into the soil (Lavania and Lavania 2009). However, this penetrating root system may have diverse architectural pattern, ranging from somewhat spread to vertically penetrating, smooth or with lateral branching along-with different grades of thickness, lysigenous cavities, cortical sclerenchyma and essential oil secreatory cells (Lavania 2003) . The primary fibrous roots are main source of essential oil, and there is little oil in the lateral hairy roots, but latter does help in formation of root-web facilitating strong soil binding. The qualitative composition of the essential oil may vary with respect to composition and concentration alcohols and ketones, oil density and optical rotation (Lavania 2008).

Organization of Vetiver Root System

The vertically growing root system comprises a tuft of primary fibrous roots supported with an array of secondary hairy roots (Figs. 1, 2). Whereas, the Juvenile primary / secondary roots are solid with persistent cortex and little

Figure 1. Tufted roots of vetiver showing variation in growth, length and density in different morphotypes of same age.

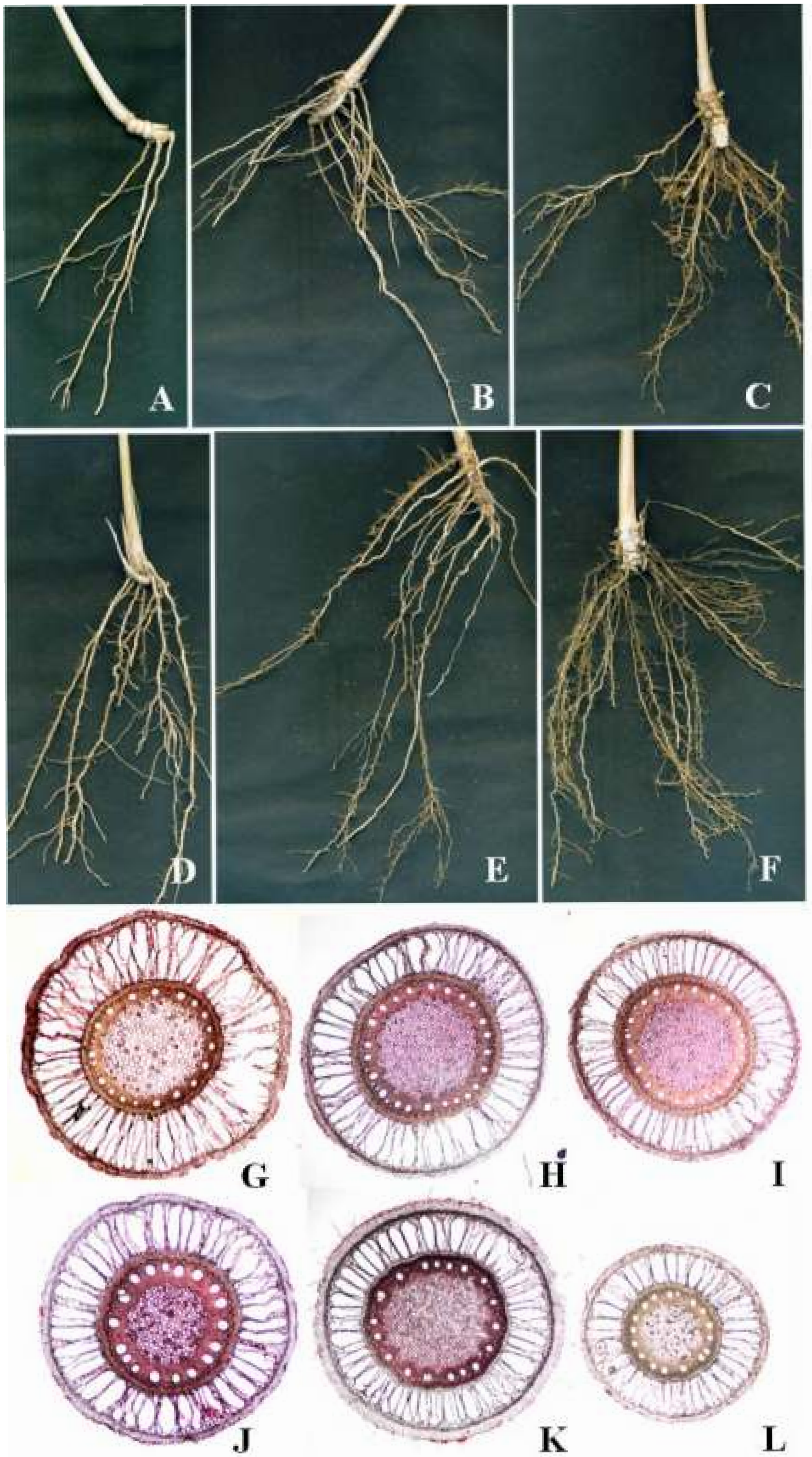

Figure 2. A-F. Representative architectural diversity in primary roots depicting smooth to hairy with secondary and tertiary roots ; G-L. Transverse section of primary roots showing diversity in root thickness, variation in cortex / stele ratio and cortical aerenchyma .

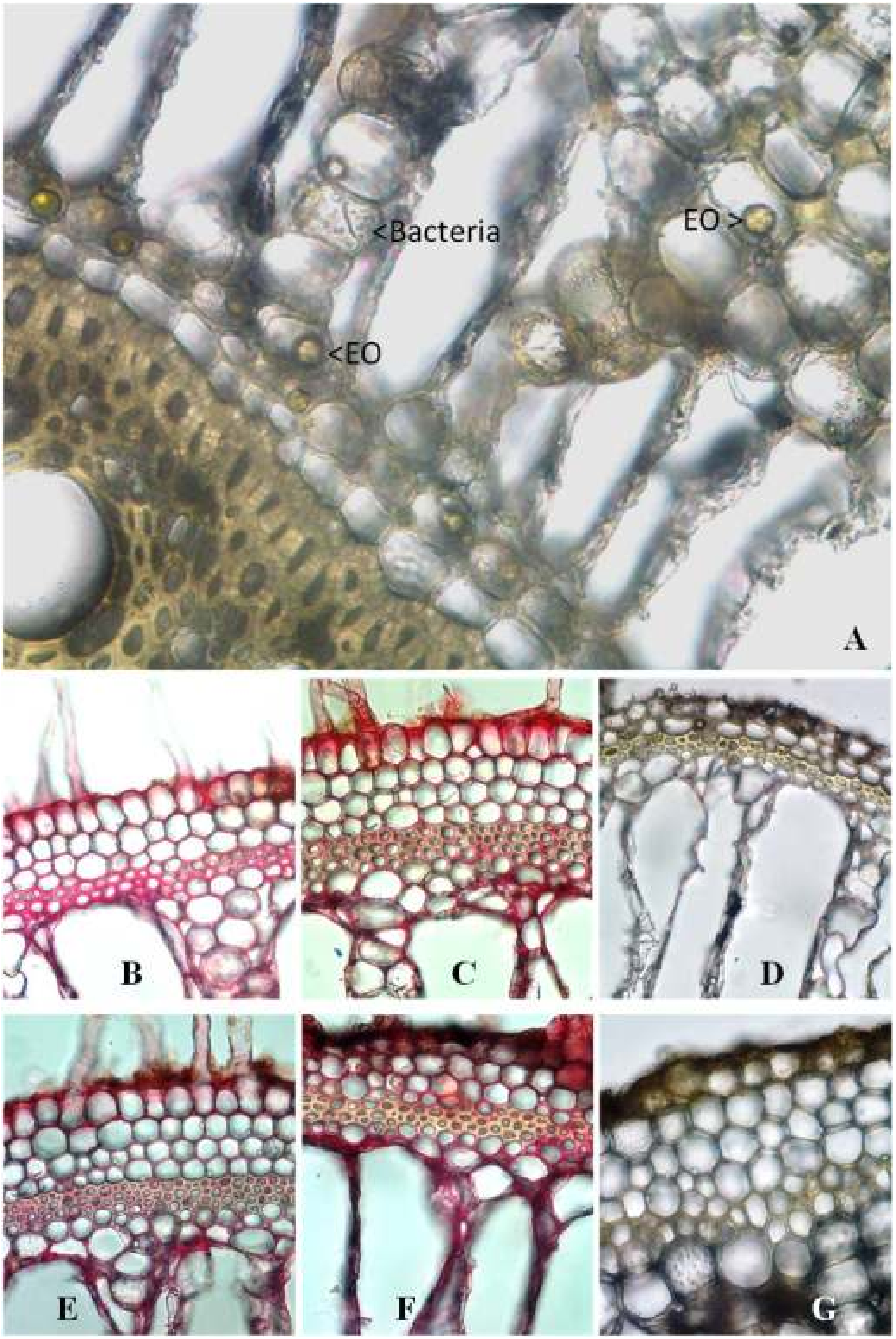

Figure 3. A. Transverse section of root showing essential oil secreatory cells (EO) in the cortical region and associated Bacteria, B-G. Transverse section of primary roots showing diversity in cortical sclerenchyma. Note variation in density and number of rows of sclerenchyma in the peripheral cortical region observed in different morphotypes of vetiver

oil; the mature thick roots are spongy with aerenchymatous cortex and well developed phloem. The lysigenous cavities in the inner cortical region are the sites of essential oil secretion and storage wherein essential oil synthesis is facilitated by microbial / bacterial association (Fig. 3). A solid vascular cylinder and sclerenchymatous peripheral cortex provides tensile strength to the roots, and the central aerenchymatous cortical region facilitates root aeration suitable for submerged conditions.

Taping the root diversity and visualizing root system architecture

In the back drop of occurrence of tremendous organizational and architectural diversity in root characteristics (Figs. 1-3), as well as possibility of designing environment friendly genotypes there is a need to identify ideal characteristics of vetiver root system to realize specific applications of vetiver grass for industrial or environmental applications. The specific features that may be ideal in the two types of applications and worth considering for realising target objectives could be as follows:

Ideal root type for diverse applications

(A) Industrial Applications

Essentials:

Oil productivity: Smooth- thick vertically growing roots with minimum branching, well developed cortical region with optimum lysigenous cavities.

Desirables:

(i) Root-Oil quality - High concentration / Superior Quality levorotatory essential oil rich in Veteverols (for fixation) or Ketones (for perfumery note)

(ii) Cropping System: Short duration 6-12 month crop cycle, and low distillation duration (12-14 hours)

(B) Environmental Applications / Ecological Plantations:

Essentials:

Reproductive System: Non-invasive / non-seeding type and least essential oil in roots to deter the root diggers

Desirables:

(i) Land /Slope Stabilization / Bioengineering : Profusely branching, spreading type with least essential oil

(ii) Water and Soil Reclamation : High absorption potential for soluble N, P and pesticidal residues

(iii) Phytoremediation and Pollution Mitigation :High absorption potential and tolerance to heavy metals, as well as their retention in root zone

(iv) Management of Waterlogged areas: Spongy roots with aerenchymatous cortex

(v) Carbon sequestration : Deep penetrating faster growing roots with low essential oil, thick vascular cylinder and suberised epiblema and endodermis.

DISCUSSION

At the interface of soil and plant, roots are quite important to plant facilitating nutrient and water uptake, anchoring and mechanical support through an optimally designed root architecture depending upon environmental, substrate, soil and nutrient conditions (Smith and Smet 2012). Gravity-guided penetrative and branching property of roots that enables soil and rocky substrates to be explored makes the root as the lifeline of plant machinery. Thus, in a true perspective roots are the most vital components strongly in contrast with their modest outward appearance just as physical support axes (Jackson, 2001). In vetiver, the roots are one of the most important organizational system of the plant that make vetiver a miracle grass for its multifarious applications in soil and water conservation, soil health, and raw material for vetiver root handicrafts, environmental and perfumery products. A lot of diversity is found in vetiver root system in nature, and a search for root morphology and geometry could lead to a desired root type (Lavania S 2003).

The soil holds twice as much carbon as does the atmosphere, and the roots take the carbon derived from the atmosphere deep into below-ground storage for Carbon sequestration (Kell 2012). Likened to forest trees, the Vetiver grass has been considered ideal for C – sequestration deep into subsoil horizon (Lavania and Lavania 2009). Suitable genotypes have accordingly been designed (Lavania *et al.* 2016). Also, efforts have been made to identify genotypes with desired quality of essential oil and economic harvest of economic product (Chauhan *et al.* 2017) on one hand, and on the other hand genotypes with high absorption potential of metals from mine spoil dumps have been identified (Banerjee *et al.* 2019). It is therefore believed that keeping in fitness with desired objectives ideal plant types could be indentified / designed to meet the specific applications.

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