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.

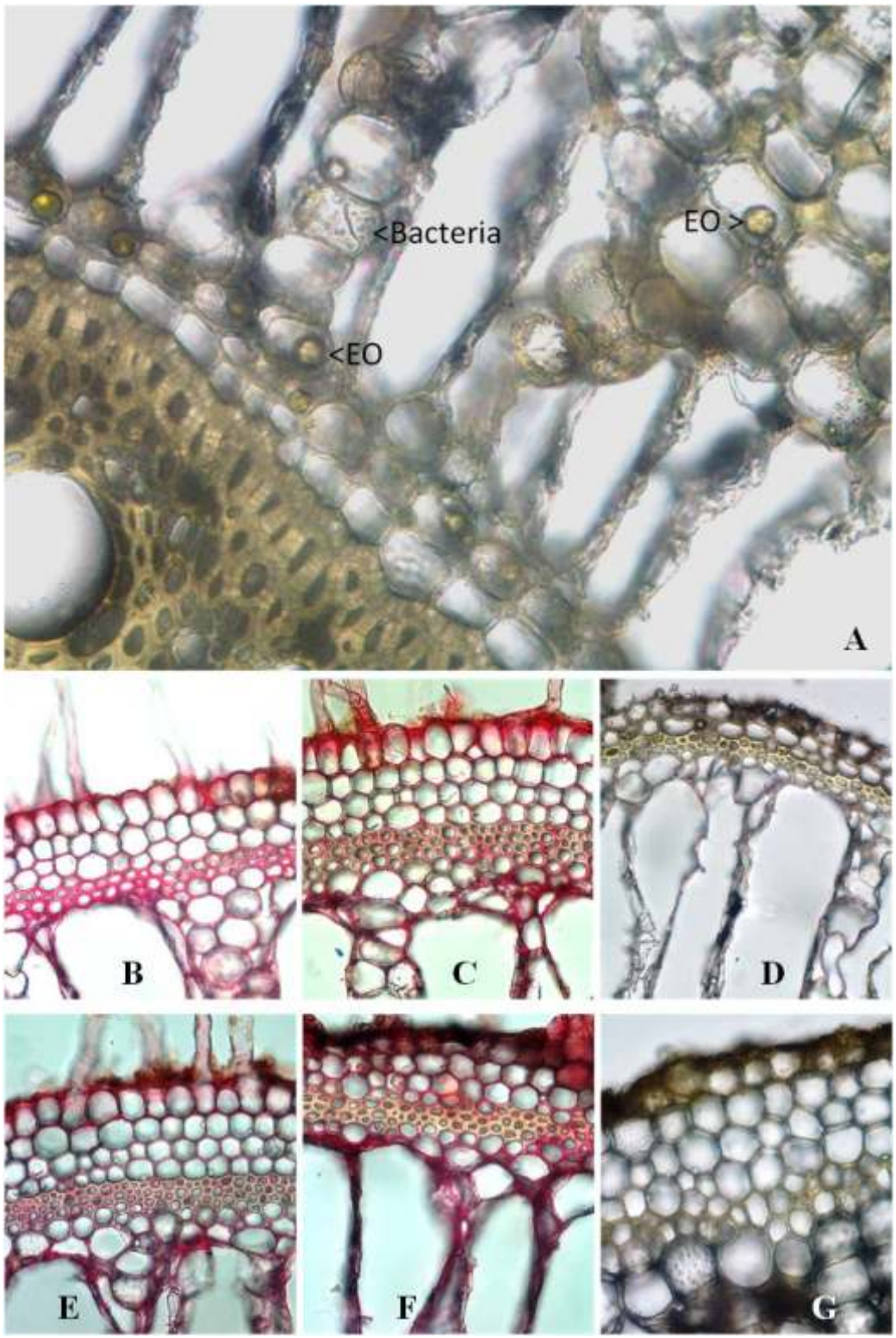

Figure 3. A. Transverse section of root showing essential oil secreatory cells (EO) in the cortical region and associated Bacteria, B-G. Transverse section of primary roots showing diversity in cortical sclerenchyma. Note variation in density and number of rows of sclerenchyma in the peripheral cortical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

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.

While developing the Vetiver Grass Model and executions thereof I am benefited with interaction and collaboration with Dr. UC Lavania. I gratefully acknowledge the Indian Science Congress Association, Kolkata for necessary permission to publish the presidential address article in the journal.

REFERENCES

Banerjee R, Goswami P, Lavania S, Mukherjee A and Lavania U C 2019 Vetiver grass is a potential candidate for phytoremediation of iron ore mine spoil dumps. *Ecological Engineering* **132:**120-136.

Chauhan H S, Singh H P, Chanotia C S, Shasany A K, Lavania U C, Tomar V K S, Kalra A and Singh A K 2017 : Vetiver plant named 'CIMAP-KHUSINOLIKA' US Plant Patent - US PP28,388 (Sept 12, 2017), pages 09. www.google.com/patents/USPP28388

Chomachalow N and Henle H V, eds. 1998 *Proc. Ist Intl. Conf. Vetiver: A Miracle grass***.** Royal Development Projects Board, Bangkok, Thailand.

Demchenko K N and Demchenko N P 2001 Changes of root structure in connection with the development of lateral root primordial in wheat and pumpkins. *In* : Gasparikova O, Ciamporova M, Mistrik I, and Baluska F. (eds.), *Recent Advances of Plant Root Structure and Function*, Kluwer Academic Publishers. 39-47.

Kell D B 2012 Large-scale sequestration of atmospheric carbon via plant roots in natural and agricultural ecosystems: why and how. *Phil. Trans. R. Soc.* B 367:1589–1597. doi:10.1098/rstb.2011.0244

Lavania S 1998 Vetiver: A miracle grass that can serve as a bio-control measure to mitigate environmental degradation of soil and facilitate poverty alleviation. *In* : SK Agarwal et. al. (eds). Perspective in Environment (Prof RR Das Commemoration Volume). APH Publishing Corporation, New Delhi, pages 117-124.

Lavania S 2002 Descriptors for vetiver. *Vetiverim* **21**: 5-10.

Lavania S 2003 Vetiver Root System: Search for the Ideotype. Proc. 3rd International Conference on Vetiver. Pages 495-499. http://www.vetiver.org/ICV3-Proceedings/IND_ideotype.pdf

Lavania U C 2002 Primary and secondary centres of origin of vetiver and its dispersion. In: N Chomachalow and M. Barang (eds.) *Proc. IInd Intl. Conf. Vetiver : Vetiver and Environment*, pp. 424-426. Royal

Development Projects Board, Bangkok, Thailand.http://prvn.rdpb.go.th/files/CP5-12.PDF

Lavania U C 2008 Vetiver in India: Historical perspective and prospective for development of specific genotypes for environmental and industrial application. in: Proceedings. Ist Indian vetiver workshop on Vetiver System for environmental protection and natural disaster management, Cochin, India. Pages 40–47. http://www.vetiver.org/TVN_INDIA_1stWORKSHOP_PROCEEDINGS/Chapter%201-4.pdf

Lavania U C and Lavania S 2000 Vetiver grass technology for environmental protection and sustainable development. Curr. Sci. 78 944-946.

Lavania U C and Lavania S 2009 Sequestration of atmospheric carbon into subsoil horizons through deep-rooted grasses – vetiver grass model. *Curr. Sci*. 97:618-619.

Lavania U C, Lavania S and Vimala Y 2004 Vetiver system ecotechnology for water quality improvement and environmental enhancement. *Curr. Sci*. **86**:11-14.

Lavania U C, Rai S K, Lavania S, Basu S, Dubey B K and Ujagir R 2016 Autotetraploid Vetiveria zizaniodes plant useful for carbon sequestration and soil conservation named 'CIMAP-KH 40'. US Plant Patent - US PP26474 (Mar 8, 2016), pages 11 https://patents.google.com/patent/USPP26474

Ramanujam S and Kumar S 1964 Metroglyph analysis of geographical complexes in Indian vetiver. Indian J Genetics 24: 144-150.

Smith S and Smet I D 2012 Root system architecture: insights from Arabidopsis and cereal crops. Phil. Trans. R. Soc. B 367, 1441–1452 doi:10.1098/rstb.2011.02345