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Diversity and distribution of vetiver grass (*Chrysopogan zizanioides* (L) Roberty) and its manifold uses: A review

Ankit Pandey* & S C Tiwari*

Department of Forestry, Wildlife and Environmental Sciences Guru Ghasidas Vishwavidyalaya
Bilaspur, Chhattisgarh.
**Email: sct_in@yahoo.com*

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Abstract

During the last few decades essential oils derived from different herbs and aromatic plants have received a growing focus of scientific investigation due to their multifunctional uses beyond their traditional roles as food additives and scents. Over 3000 species have been identified as medicinal plants that produce essential oils. Vetiver grass has wide range of diversity throughout the world with diverse genotype variability. It has multifarious uses in various agricultural, medicinal, aromatic, engineering, conservational and in industrial sectors. The *C. zizanioides* is well known in various regions of South Asia, Southeast Asia, and West Africa. Vetiver roots, particularly those from Karnataka, have been utilised to make herbal drinks that are energising to combat tiredness. The vetiver grass, referred as "vetiver" or "vetiver–vetiver" in India, serves a variety of purposes in aromatic, pharmaceuticals, food, and beverage industries. This paper presents a review of the diversity and distribution of this crop along with its various uses and applications.

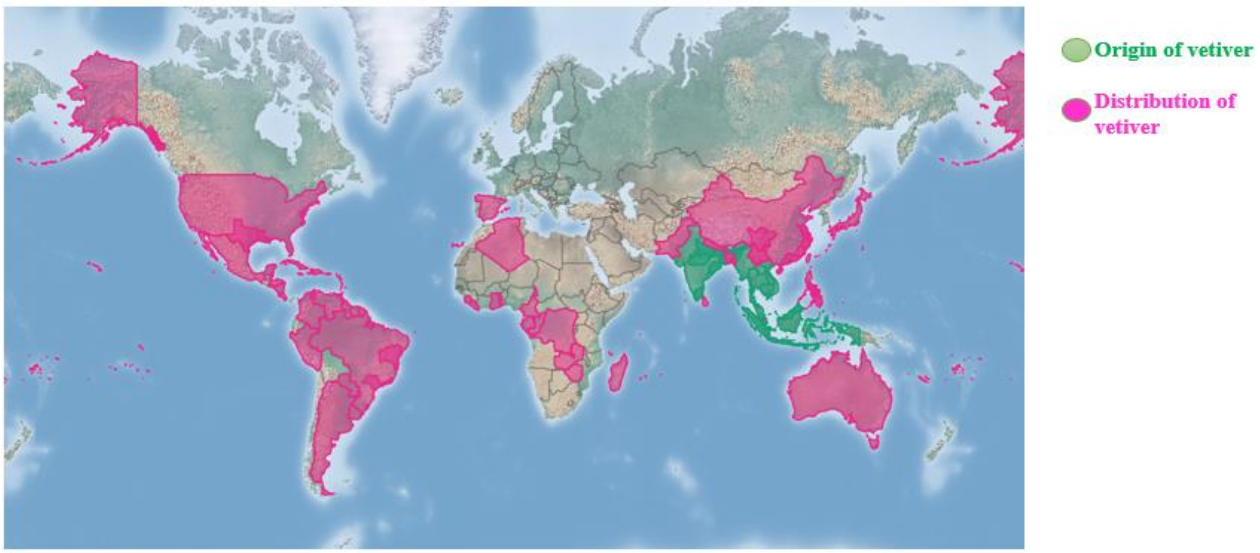
Keywords: aromatic, diversity, uses, distribution, vetiver.

Introduction

Vetiver (*Vetiver zizanioides* (L.) Nash, syn. *Chrysopogan zizanioides* (L.) Roberty is an important perennial aromatic grass that belongs to the Poaceae/ Gramineae family. The plant is well known for its medicinal property, perfumery, and flavour values. Vetiver was originated from India and is cultivated throughout tropical countries. Roots and essentials oil of vetiver have high industrial demand mainly due to their fixative properties. The cultivation of aromatic plants, particularly essential oil yielding plants such as vetiver grass, lemon grass, patchouli, mint, etc. is enhancing the scope of agriculture (Shabbir *et al.,* 2019). Among the various horticultural crops, medicinal and aromatic plants play a significant role in continuous supply of raw material to pharmaceutical, perfumery as well as for cosmetics industries in India (Raviprasad & Venugopal 2017). Among the thousands of aromatic plants, only a few are grown as commercial crops widely, vetiver is one of them (Raviprasad *et al.,* 2019). The lower hills and

plains of India are covered in a thickly tufted grass, especially along riverbanks and in soil that is rich in marshy vegetation and on the hilltops up to 800–1200 m elevation (Lavania, 2000; Rao & Suseela, 2000). The vetiver plant can endure several harsh ecological circumstances, such as drought, floods, submersion, and temperatures between –15 °C to +55 °C. It can also withstand a wide range of soil pH from 3.3 to 12.5 without any requirement of soil treatment, and is particularly resistant to heavy metals (Troung *et al.,* 2008; Joseph *et al.,* 2017). Socio–economic position of rural people is greatly influenced by vetiver, which is utilized to make mats, hand fans, baskets, root for essential oil and other various domestic as well as economical uses. Vetiver has distinctive physical and physiological properties, giving it the name "wonder grass" and making use of it for numerous industrial, environmental, conservational, and protection purposes (Lavania, 2004; Dudai *et al.,* 2006). According to a recent analysis by Grand View Research, Inc., the size of the global vetiver oil market is anticipated to reach USD 88.0 million by 2027, growing at a revenue–based CAGR of 9.4%. The Vetiver System (VS) has been promoted by the World Bank since the 1980s for various purposes, including reduction of soil erosion, sedimentation, conservation of water, the prevention of landslides and riverbank erosion, and most recently, for reducing of pollution (Wagner *et al.,* 2003; Mondal *et al.,* 2019).

Plant description: *Vetiveria zizanioides* (2n=20) diploid, 40 in tetraploid, is a grass developed from rhizome up to the height of 2 m; with narrow leaf, thick fibrous roots and panicle inflorescence, up to 15–45 cm long (Rao and Suseela, 2000). The vetiver grass has a huge, intricate root system that spreads quickly. In some situations, it can go down up to three to four metres (Troung, 2002) and its deep root system, makes it highly resistant to drought and when exposed to a high water flow, becomes extremely difficult to uproot (Dudai *et al.,* 2006). The leaves are small, upright, keeled, and have scabrous margins (Shabbir *et al.,* 2019). Roots of vetiver were traditionally used in soft drinks, pan masala and beverages industry (Tiwari, 2014; Raviprasad *et al.,* 2019). It is spreading across the world's tropical and subtropical plains, especially along riverbanks and across marshy terrain (Lavania, 2008). The renowned "vetiver" oil is extracted from the roots of vetiver, which is an important industrial product and is utilised as a fixative in the perfume and cosmetics industries (Lal, 2013; Yaseen *et al.,* 2014). The vetiver contains antifungal, antibacterial, anti-inflammatory as well as anticancer effects in root oil (Chou *et al.,* 2012). The grass is also grown for multiple uses such as phytoremediation, erosion control, as a cover and nurse crop, live fence and for biofuel production (Kumar and Nikhil, 2016).



[Source: www.CABIorg/isc, International, Invasive spices Compendium, 2021.]

Fig. 1. Origin and distribution of vetiver (*Chrysopogan zizanioides*).

Common name: Vetiver is a C_4 plant (Srivastava and Lal, 2012), is now grown all over the world for a wide range of uses under multiple local and popular names in different countries and in various regions of India (Table 1).

Table 1. Some common names of vetiver in India and in the world.

S. No.	Country	Language	Common Name
1.	India	Sanskrit	Abhaya, Amrinala, Avadaha, Reshira, Haripriya, Indragupta, Ishtakapatha, Bala, Jalavasa, Jalamoa, Laghubhaya, Katayana, Nalada, Rambhu, Reshira, Sevya, Shishira, Ushira, Vira, Virabhadara, Virana, Viratary, Vitanamulaka
2.		Hindi	Balah, Bala, Bena, Ganrar, Khas, Onei, Panni
3.		Tamil	Ilamichamver, Vettiver, Vilhalver, Viranam
4.		Telugu	Avurugaddiveru, Kuruveeru, Vattiveru, Vadavaliveru
5.		Malayalam	Ramaccham, Ramachehamver, Vettiveru
6.		Marathi	Vala, Khas–Khas
7.		Gujarati	Valo
8.		Bengali	Khas–Khas
9.		Punjabi	Panni
10.		Kannada	Vattiveeru, Laamanche, Kaadu, Karidappasajje hallu
11.	China		Xian Geng–Sao
12.	Burma		Miyamoe
13.	Sri Lanka		Saivendra, Savendramul
14.	Malaysia		Akar Wangi, Ramput Wangi (fragrant root), Kusu–Kusu
15.	Indonesia		Usar, Narawastu, Janur, Larasetu, Raraweatu
16.	Ethiopia		Yesro mekelakeya

[Source: Greenfield, 1989; Maffei, 2002; Snigdha *et al.,* 2013]

Geographical distribution: Vetiver was originated from India but is currently grown throughout tropical and subtropical area of Asia, Africa, and America. According to Carey (2006), vetiver is indigenous to South and Southeast Asia. Worldwide, vetiver is grown in various countries from ancient times (Mondyagu *et al.,* 2012). Haiti, Reunion, and Indonesia (Java) are the countries that produce most of the world's vetiver oil (Shabbir *et al.,* 2019). The cultivation

of vetiver began in India (South India) to produce fragrant oil from its roots, and the method later spread around the world (Maffei, 2002; Lal *et al.,* 2018). This vetiver variety from southern India is of the domesticated type/ cultivated type, most probably developed by humans from the wild grass (Lavania, 2008: Mondal and Patel, 2020; Vanoh and Troung, 2020). It is extremely effective in controlling erosion because it does not require seeding or mowing (Mondal and Patel, 2020). All over India, especially in Rajasthan, Haryana, Uttar Pradesh, Gujarat, Bihar, Odisha, Madhya Pradesh, and numerous southern states, it is seen spreading profusely (Shabbir *et al.,* 2019). Vetiver is systematically cultivated as a crop in southern states such as Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh and in northern states such as Rajasthan, Uttar Pradesh, and some regions of Madhya Pradesh (Smitha *et al.,* 2014; Raviprasad and Venuopal, 2017). Vetiver trials were started in more than 25 countries as part of extension efforts by World Bank to utilize its potential in soil and water conservation and for other uses (Maffei, 2002). Additionally, vetiver is being grown in more than 100 nations for its use in environmental applications such as carbon sequestration and soil/water conservation (Lal *et al.,* 2018; Lal *et al.,* 2021).

Types: There are two unique morphological vetiver groups that grow in geographically separate regions of India: one is located predominantly in the states of Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala, in south runs along the east and west shores of the Indian peninsula. Second one is mainly in Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar and in the Indo–Gangetic plains and its surrounding regions, (Lavania, 2002; Lavania, 2008; Lal *et al.,* 2018). Chrysopogon is a genus of plants that includes 21 species in India. These species are *C. aciculatus, C. asper, C. aucheri, C. castaneus, C. copei, C. fulvus, C. gryllus, C. hackelii, C. lancearius, C. lawsonii, C. nodulibarbis, C. orientalis, C. polyphyllus, C. pseudozeylanicus, C. purushothamanii, C. rigidus, C. serrulatus, C. tadulingamii, C. nigritanus, C. velutinus, and C. verticillatus* (Grover *et al.,* 2021).

Table 2. Key features of Indian vetiver grass from the north and the south.

South Indian	North Indian
Domesticated type / Bharatpur type	Wild types
Late or non–flowering	Profuse flowering
Only from underground stock	Propagated through seeds
Non seeding or infertile seeds	Sets fertile seeds
Highly useful for erosion control	Due to shallow roots not suitable for erosion control
Wider leaves	Narrow leaf
Low quality oil	Superior quality oil
Dextrorotary root oil	Vigorous roots produce laevorotatory root oil

[Source: Lavania, 2008; Leite, 2012; Verma, 2020.]

The Indian subcontinent has a very high natural genetic variability in this crop with respect to morphometric features, reproductive behaviour, ecological/ geographical adaptation, and essential oil concentration and composition (Lavania, 2008; Lal *et al.,* 2018). The CSIR–Central Institute of Medicinal and Aromatic Plants, (CSIR–CIMAP) Lucknow has undertaken several breeding programmes and plays a leading role in the extensive production and

cultivation of vetiver in the various agroclimatic zones (Yadav *et al.,* 2013; Lal *et al.,* 2018). The genetic variability of this crop is very high, CSIR–CIMAP maintains 180 indigenous and exotic collections of vetiver that are representative of 13 states of the country (UP, Uttarakhand, Rajasthan, Bihar, Punjab, MP, Gujarat, Jammu and Kashmir, Odisha, Maharashtra, Kerala, West Bengal and Andhra Pradesh) (Lal *et al.,* 2021) as well as 4 exotic collections from Indonesia, Haiti, Thailand, and Reunion Island. Additionally, CSIR–CIMAP created and marketed 12 high yielding vetiver varieties with various essential oil notes for commercial cultivation: KS–1, Sugandha, KS–2, Dharini, Gulabi, Kesari, CIM Vriddhi, CIMAP–Vetiver 40 (induced tetraploids), G22, G15, CIM–Vetiverinolika, and CIM Samriddhi (Srivastava and Lal, 2012; Smita *et al.,* 2014; Lal *et al.,* 2018). The Bharatpur, Akila, and Musanagar (northern India) are thought to be of greater quality oil in the world (Lal, 2013) but vetiver crop planted in southern India produce more oil yield (Lal *et al.,* 2021).

Production and major production areas: Due to its distinctive smell and fixative qualities, the global demand for vetiver oil is increasing. An average of 3.0–4.5 tonnes of dry roots are produced from one hectare of vetiver cultivation which yields 12–20 kg of oil after steam distillation (Ramanjaneyulu *et al.,* 2021). Raviprasad *et al.* (2019) stated that demand for vetiver oil is around to 400 tonnes annually, while the current global production is just about 250–300 tonnes. Around the world, 80% of the vetiver oil is produced in Haiti and Indonesia. Approximately, India produces 20 to 25 tonnes of vetiver oil annually, which is far lower than the 100 tonnes of need and the shortfall is met through imports. Among the Indian states, Uttar Pradesh has the highest production of vetiver oil in terms of quantity mainly through wild source (Lal *et al.,* 2018a & 2018b).

Manifold uses of vetiver

Agricultural

Soil erosion reduction: Besides being utilised for oil production, vetiver has also been effectively employed to check soil erosion. Being a perennial grass with a strong root structure, vetiver strongly binds soil. This trait has been employed to reduce erosion of soil particles, particularly on slippery terrain and in sensitive locations (Maffei, 2002; Rao *et al.,* 2015). Rao *et al.* (2015) stated that on cropland with 1.7 percent slope, vetiver reduces soil loss from 14.4 tonnes per ha to 3.9 tonnes per ha and runoff (as a percentage of rainfall) from 23.3% (control) to 15.5% in vetiver based hedge row cropping system. Truong *et al.* (2008) found that sorghum output increases from 2.52 tonnes per ha to 2.88 tonnes per ha over a four year duration. Babalola *et al.* (2003) reported that vetiver is utilised to preserve soil and water in the Nigerian environment. The first strip of vetiver on the slope accumulate about 98 % more soil than the second and subsequent strips. By using vetiver grass strips and mulch, the capacity of soil to retain nutrients and water is enhanced and soil resources is preserved (Babalola *et al.,* 2007).

Mulch and compost: Vetiver leaves make excellent mulch due to their strong and long–lasting nature. In various tropical countries, mulching by vetiver shoots is one of the most important conservational methods for early

stage of plant as well as soil moisture conservation. Vetiver leaves provide shade to the plot like other mulching materials and help to lower the temperature as well as maintain good moisture content in soil and check the growth of weeds (Balasankar *et al.,* 2013).

Fodder: At the early growth stage of vetiver, the leaves can be chopped up and fed to fish and animals, but older leaves cannot be used due to lower nutritional value, roughness and higher silica content than other grasses (Troung *et al.,* 2008). The nutrition quality of vetiver grass depends upon season, growth stage and soil fertility. Young shoots of vetiver are nutrient rich to feed cattle when pruned and trimmed at regular intervals of one to three months (Nguyen *et al.,* 2004).

Wind break: Vetiver hedges that are tall and dense can serve as windbreaks to reduce the speed of strong winds in addition to keeping dust, heat and cold away from farmland. Chomchalow (2003) reported that between the rows of jojoba, vetiver hedgerows at 6–8 m intervals ran erect to the way of the strong wind coming from the South China Sea. By the end of the second year, hedges of vetiver were more than two meter height and could serve as effective windbreaks to prevent sand from spreading and protected the fields.

Soil quality enhancement: Vetiver can be used to enhance the stability and structure of agricultural soil, prevent soil erosion, and enhance water permeability of the field aspects that can promote increased growth and enhance crop productivity. Sujatha *et al.,* (2011) conducted an experiment on the viability of vetiver grass inter planted in arecanut (*Areca catechu* L.) plantations and found that total system productivity of the vetiver and arecanut was increased to 3231 kg per ha, which was significantly higher than the sole productivity of arecanut (1400 kg per ha). Gesesse *et al.* (2013) stated that usage of vetiver grass enhanced the cations exchange capacity, soil moisture content, soil organic matter, total nitrogen, available phosphorus and potassium levels of the soil.

Vetiver for mushroom cultivation: Several chemical compounds found in vetiver leaves, including cellulose, hemicellulose, crude protein, and a variety of minerals may be consumed by certain mushrooms (Chomchalow, 2003). Thiribhuvanamala *et al.* (2018) carried out an experiment and suggested that vetiver straw, either by itself or combined with paddy straw, can be used for commercial farming of oyster mushrooms, bringing in additional income for farmers and being compatible with vetiver integrated farming systems.

Botanical insecticide, pesticide and fungicide: The excessive usage of insecticides has resulted in severe impact on ecosystem services, human health, and the environment. In addition to its well known ability to save soil, vetiver grass is said to keep off a variety of insects. Lu *et al.* (2019) reported that vetiver grass can act as a trap to attract mature *C. suppressalis* to lay eggs thereupon, but in some cases larvae cannot finish their life cycle. Van de berg *et al.* (2003) stated that vetiver is strongly favoured for oviposition, but, there was very little chance of larvae surviving on it. Thus, vetiver could be a significant biopesticide and worked as a termite repellent too.

Non agricultural

Ornamental: Due to its appealing form and aesthetic value, vetiver is occasionally used as a decorative potted plant or as an ornamental plant in landscaping. It is an ornamental plant for gardens, patios, decks and also used as a hedge. Additionally, vetiver is cultivated in pots for use as a decorative houseplant. We can bundle together cut vetiver leaves and use them in bouquets (Chomchalow, 2003; Ramanjaneyulu *et al.,* 2021). Fully grown vetiver bears light purple, extremely attractive flower heads that can be used in landscaping, and gardens as well as other public spaces like lakes and parks (Troung *et al.,* 2008).

Phytoremediation/bioremediation: It is employed in the treatment of waste water and the restoration of mined area. Heavy metals like Al, Cd, Cr, Cu, Pb, and Ni as well as polycyclic aromatic hydrocarbons have been proven to be removed more quickly in the soil when vetiver grass is present.

Medicinal: Essential oil of vetiver has various medicinal properties such as vulnerary, cicatrisant, nervine, sedative, tonic, and aphrodisiac properties, which are responsible for its health advantages. Essential oils are widely used in aroma therapy and have a variety of medicinal benefits. The various portions of the grass are used by many tribes to treat a variety of illnesses, including mouth ulcers, fever, boils, epilepsy, burns, snake bite, scorpion sting, rheumatism, fever, headaches etc. (Snigdha *et al.,* 2013).

Anti–inflammatory: This essential oil has a highly calming and cooling impact that soothes and reduces inflammation of all kinds (Verma, 2020). It works particularly well to relieve nervous system and circulatory system inflammations. It has been discovered as an effective treatment for inflammations caused by sunburn and dehydration (Kumar and Kumar, 2016).

Antiseptic: Hot and humid environment that exists in tropical regions is conducive for microbial and bacterial growth. The *Septicemia aureus*, bacteria that causes septic, is effectively stopped from growing by this oil, and they are also removed, aiding in the treatment of septicemia, and providing protection against it (Balasankar *et al.,* 2013).

Antioxidant: The densely tufted grass is used in aroma therapy to ease tension, nervousness, stress, and sleeplessness. In this context, ethanol is used to extract the essential oil from roots of vetiver, which was then used to assess a variety of *in vitro* antioxidant activities, such as the ability to reduce, the superoxide anion radical scavenging activity, the deoxyribose degradation assay, the total antioxidant capacity, the total phenolics, and the total flavonoid composition (Snigdha *et al.,* 2013).

Vetiver oil is widely used in the treatment of cancer patients because it can soothe cancer related discomfort and reduce symptoms including anxiety, severe pain, and insomnia. Various detailed investigations revealed the key qualities, such as antifungal and bacterial activity, sedative, aphrodisiac, cicatrisant and anti–malarial properties (Durge *et al.,* 2021).

Aromatical/perfumery: The vetiver oil, known across the world, is extremely important to the perfume and cosmetics industries. (Chomchalow, 2001). Rich, earthy, green woody,

and nut like aromas can be recognized in vetiver oil. It is a thick light brown oil. A sweet tone is produced using vetiver oil and a calming, cool impact in its diluted form (Balasankar *et al.,* 2013). Since ancient times, with its typical aromatic properties, vetiver oil has frequently been used in skin treatments, hair pomade, and potpourri. In some part of south India roots of vetiver grass are dipped in coconut oil overnight, and the coconut oil with a nice scent is applied to the hair (Durge *et al.,* 2021). Due to its complicated chemical makeup, oily smell, and high solubility in alcohol, it becomes highly soluble with other perfumery ingredients and is used as a raw ingredient for a variety of fragrant items, including lotions, soaps, cosmetics, deodorants and fragrances (Chomchalow, 2001; Balasankar *et al.,* 2013). The worldwide demand for vetiver oil was estimated as 408.8 tonnes in 2019 and according to Grand View Research, the international vetiver oil market was projected to reach up to 169.5 million USD by 2022 (Gnansounou *et al.,* 2017; https://www.grandviewresearch.com/industry–analysis/vetiver–oil–market).

Vetiver oil chemistry is complex mainly due to involvement of more than 150 constituents (Yogendra *et al.,* 2021) with sesquiterpenes and their derivatives making up the majority of those. Sesquiterpene hydrocarbons and their alcohol derivatives, vetiverols like vetiverimol and vetiverinol, carbonyl derivatives, vetivones (ketones), and three carbonyl compounds, including vetivone and vetiverimone, are some of the main constituents (Chahal *et al.,* 2015). Vetiver oil is also known as "Oil of tranquillity" and has a distinct fragrance with no other synthetic substitute (Raja *et al.,* 2018; Yogendra *et al.,* 2021). It involves mainly complex mixture of terpenes, sesquiterpenes, alcohols, hydrocarbons *etc.,* therefore the essential oil of vetiver has unique demand in world market with high price. Haiti has set the global standards in terms of quality and leads in production of vetiver. Haitian vetiver oil has 155 constituents while a total of 29 and 35 compounds were identified in south and north Indian vetiver oil, respectively, in an investigation of Indian vetiver oil. On a dry weight basis, vetiver fibrous roots have about 1–2 % oil content which can be easily extracted with steam distillation (Rao *et al.,* 2015; Durge *et al.,* 2021). As the age of the root increased, the oil density increased as well, becoming increasingly viscous and creating crystal structures in elderly roots (Bertea and Camusso, 2002).

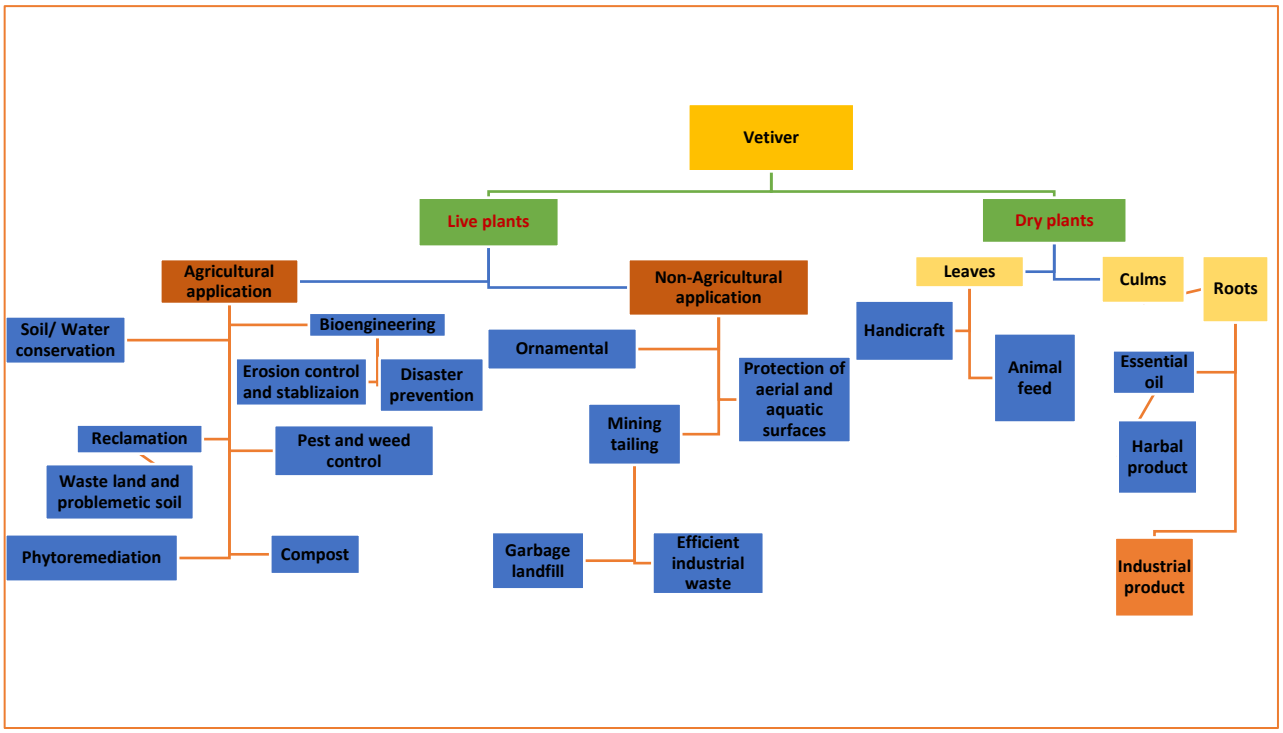
Other uses: Some examples of non processed products from the vetiver plant include animal feed, thatch for roofs, mulch to keep the soil moist, mushroom medium, bouquets and compost. Likewise, semi processed products from the vetiver plant include handicraft, pots, low cost silos, and furniture. Finally, fully processed products from the vetiver plant primarily include essential oil and its derivatives, as well as herbal medicines, food additives and pulp and paper.

Pulp and paper: Vetiver, as a raw material can be used in the pulp and paper industries. Research conducted at the Forest Research Institute in Dehradun, India, found that vetiver can produce pulp appropriate for manufacturing strawboard when digested with lime (Anon,

1976). Hemicelluloses are abundant in vetiveria. It has a 45.8% of cellulose content. A chemical pulp produced by vetiveria can be used to manufacture writing and printing paper (Verma *et al.,* 2020).

Roof thatching and hut making: Vetiver culms and leaves have been used as roof thatching for centuries by many rural populations around the world. The endurance of the culms and leaves of vetiver depend on thickness and neatness and have a distinctive aroma that protects it from fungus and insects, making vetiver grass better choice for roof thatching (Chomchalow, 2003). Since ancient times, dried vetiver roots have been utilised in India to erect temporary shelters and cabins because of the cooling effect in the summer season (Lavania, 2003).

Handicrafts: The majority of vetiver sticks are used in wicker works to make baskets. Vetiver leaves are used to make high quality handicrafts, which is a significant way to increase income for rural inhabitants in Latin America, Thailand, Indonesia, the Philippines, and Africa (Troung *et al.,* 2008).



[Source: Ramanjaneyulu 2021]

Fig. 2. Manifold uses of vetiver grass

Conclusion

The Indian subcontinent appears to be the natural home and centre of origin for vetiver, as evidenced by its well established morphogenetic variability as well as high genetic and ecological diversity found in our country. It has numerous environmentally beneficial applications that are sustainable for managing agriculture, agroforestry, stabilising slopes and embankments, conserving soil, and water and mitigating natural disasters. The yield of vetiver root can be significantly increased by improved agricultural practices and the recycling of agricultural waste. Comprehensive data on vetiver collected from literature revealed signifi cant level of variability of vetiver in terms of nucleolar chromosome quantity and shape, as well as chromosome morphology. Farmers can readily diversify their methods of production. For instance, vetiver can be used as intercrop

in horticultural crops as well as a cheap source of feed for animals thus improving net productivity as well as livelihoods of the farmers. Vetiver also helps farmers by reducing soil erosion, it removes some insect pests from their crops and is used for the extraction of vetiver oil. Minor industries based on vetiver and its value–added products could be produced at the village level. In order to provide protection from soil erosion and landslides, vetiver can also be planted on riverbanks, roadside embankments and areas affected by landslides. There are numerous uses for vetiver essential oil in food, fragrance, pharmaceuticals, beverages, nutraceuticals, and flavouring milk, drinks, ice cream, and syrups. Due to synergistic effect of chemicals, it is also used as a biopesticide and an insecticide. The main properties of this vetiver crop needs to be investigated further.

References

Anon 1976 Vetiver In: Wealth of India, Publication & Information Directorate, Council of Scientific and Industrial Res., New Delhi. X: pp. 451–457

Balasankar D, Vanilarasu K, Preetha P S, Umadevi S R M & Bhowmik D 2013 J. medicinal plants studies. J. of Medicinal Plants 1(3):191–200.

Babalola O, Jimba S C, Maduakolam O & Dada O A 2003 Use of vetiver grass for soil and water conservation in Nigeria. In Proceedings of the 3rd Int. Conference on Vetiver and Exhibition. Vetiver and Water. Guangzhou, China, pp. 293–300.

Babalola O, Oshunsanya S O & Are K 2007 Effects of vetiver grass (*Vetiveria nigritana*) strips, vetiver grass mulch and an organomineral fertilizer on soil, water and nutrient losses and maize (*Zea mays*, L) yields. Soil and Tillage Res. 96(1–2): 6–18.

Bertea C M & Camusso W 2002 Anatomy, biochemistry, and physiology. In Vetiveria (pp. 25–49).

Carey B 2006 Monto vetiver grass for soil and water conservation. Natural Resource Sciences, Queensland, Australia. Council of Scientific and Industrial Res. (CSIR).

Chahal K K, Bhardwaj U, Kaushal S & Sandhu A K 2015 Chemical composition and biological properties of *Chrysopogon zizanioides* (L.) Roberty syn. *Vetiveria zizanioides* (L.) Nash–A Review. Indi. J. of Natural Product and Res. 6 (4): 251–260

Chou S T, Lai C P, Lin C C & Shih Y 2012 Study of the chemical composition, antioxidant activity and anti–inflammatory activity of essential oil from *Vetiveria zizanioides*. Food Chem. 134 (1): 262–268.

Chomchalow N 2001 The Utilization of Vetiver as Medicinal and Aromatic Plants with Special Reference to Thailand. Tech. Bull. No. 2001/1, PRVN / ORDPB, Bangkok, Thailand. ISBN No.: 974-7774-75-5.

Chomchalow N 2003 Other uses, and utilization of vetiver. AU J.T. 7(2) 81-91.

Dudai N, Putievsky E, Chaimovitch D & Ben–Hur M 2006 Growth management of vetiver (*Vetiveria zizanioides*) under Mediterranean conditions. J. Environ Manage, 81(1): 63–71.

Durge A A & Moon U R 2021 *Vetiveria zizanioides* l. Nash–a wonder plant: an industrial perspective. J. Adv. Sci Res., J. Adv. Sci. Res.: ICITNAS:12: 01–06.

Greenfield J C 1989 Vetiver grass (*Vetiveria* spp.): the ideal plant for vegetative soil and moisture conservation. Washington, DC: World Bank. Washington, DC, United States of America. ISBN 0-8213-3144–2.

Gnansounou E, Alves C M & Raman J K 2017 Multiple applications of vetiver grass–a review. Int. J. Edu Learn System, 2: 125–141.

Gesesse A, Balemi T Natarajan P & Amha Y 2013 Effect of vetiver grass hedges in maintaining soil fertility and productivity at anno agrfathio industry farm, gobu sayo district, oromiya region, Ethiopia. J. Sci Sustainable Development, 1(1): 37–49.

Grover M, Behl T, Virmani T, Bhatia S, Al–Harrasi A & Aleya L 2021 *Chrysopogon zizanioides*—A review on its pharmacognosy, chemical composition and pharmacological activities. Environ. Science and Pollut. Res. 28(33): 667–692.

Joseph J K, Haridasan A, Akhildev K & Kumar A P 2017 Applications of Vetiver grass (*Chrysopogon Zizanioides*) in eco system–based disaster risk reduction–studies from Kerala state of India. J. Geogr. Nat. Disast. 7(192): 2167–0587.

Kumar D & Nikhil K 2016 Effect of FYM, NPK and Algal Fertilizers on the Growth and Biomass of Vetiver Grass (*Vetiveria zizanioides* L. Nass). Int. J. Eng. Appl. Sci. 3(3): 85–89.

Kumar D & Nikhil K 2016 Vetiver grass for manifold uses: a critical review. Int. J. of Engineering & Technical Res. (IJETR) 4(2): 146–152.

Lal R K 2013 On genetic diversity in germplasm of vetiver '*Vetiveria zizanioides* (L.) Nash. Industrial Crops and Products 43: 93–98.

Lal R K, Chanotiya C S, Dhawan S S, Gupta P & Sarkar S 2018 Genotypic and morphological appearance of the traits in relation to genetic diversity of essential oil yield in vetiver grass (*Chrysopogon zizanioides* Roberty). Acta Sci. Agric. 2(8): 62–72.

Lal R K, Gupta P & Sarkar S 2018 Phylogenetic relationships, path and principal component analysis for genetic variability and high oil yielding clone selection in vetiver (*Vetiveria zizanioides* L.) Nash. J. Plant Genet. Breed 2(1): 105–113.

Lal R K, Mishra A, Gupta P, Chanotiya C S & Sarkar S 2021 National and Int. Scenario, Conventional Breeding and Plant Descriptor of Vetiver (*Chrysopogon zizanioides* (L.) Roberty)" Sougata Sarkar (Eds). Rubicon Publications London, England. Studies in Medicinal & Aromatic Crops (ISBN No. 978–1–913482–36-7). Chapter 1.1.,1–117.

Lavania U C 2000 Primary and secondary centres of origin of vetiver and its dispersion. In Int. Vetiver conference, Proceedings. Thailand: TVN. pp. 424–426.

Lavania U C 2003 Other uses and utilization of vetiver: vetiver oil. In the Third Int. Vetiver Conference, Guangzhou, China, pp.486-491.

Lavania U C 2004 Meeting Report: Vetiver system ecotechnology for water quality improvement and environmental enhancement. Curr. Sci. 86(1): 11–14.

Lavania U C 2008 Vetiver in India: historical perspective and prospective for development of specific genotypes for environmental or industrial application.

In Proc. Ist Indian Vetiver Workshop–Vetiver System for Environment Protection and National Disaster Management, Cochin, India. Troung, P.(ed.) pp. 40–47.

Leite B 2012 Extraction of essential oils from vetiver (*Vetiveria zizanioides*) grass. M.sc environ. Thesis, School of Chemical Engineering at the University of KwaZulu Natal.

Maffei M 2002 Introduction to the genus *Vetiveria*. In Vetiveria (pp. 9–51). CRC Press.

Mondyagu S, Kopsell D E, Steffen R W, Kopsell D A & Rhykerd R L 2012 The Effect of Nitrogen Level and Form on the Growth and Development of Vetiver Grass (*Chrysopogon zizanioides*). Transactions of the Illinois State Academy of Science, 105 (1&2): 1–10.

Mondal S & Patel P P 2020 Implementing Vetiver grass–based riverbank protection programmes in rural West Bengal, India. Nat. Hazards 103(1): 1051–1076.

Nguyen V H, Nguyen T H N VO A & Pham V N 2004 Digestibility of Nutrient Content of Vetiver grass by Goats Raised in the Mekong Delta, Vietnam Contents: pp. 41–44.

Rao P E V S, Akshata S, Gopinath C T, Ravindra N S, Hebbar A & Prasad N 2015 Vetiver production for small farmers in India. Sustainable agriculture reviews, 337–355.

Raja M B, Rajamani K, Suresh J, Joel A J & Uma D 2018 Chemical composition of Vetiver root oil obtained by using GCMS analysis. J. of Pharmacognosy and Phytochemistry 7(6): 1709–1713.

Ramanjaneyulu A V 2021 Multifarious Uses of Vetiver Grass. Chron. of Bioresource Management 5(2): 26–32.

Rao R R & Suseela M R 2000 *Vetiveria zizanioides* (Linn.) Nash–a multipurpose eco–friendly grass of India. ICV–2 held in Cha–am, Phetchaburi, Thailand, pp. 18–22.

Raviprasad Sajjan M & Venugopal C K 2017 Studies on the effect of planting methods and nutrition on growth, yield and essential oil content in vetiver (*Vetiveria zizanioides* (L.) Nash). Int. J. of Chemical Studies 5(3): 225–229.

Raviprasad, Sajjan M, Venugopal C K, Chandranath H T, Balachandra K N & Mokashi AN 2019 Physico–chemical properties of essential oil in vetiver (*Vetiveria zizanioides* (L.) Nash) as influenced by different planting methods and nutrition. Int. J. of Chemical Studies 7(1): 1443–1447.

Srivastava N K & Lal R K 2012 Variations among commercial cultivars of *Vetiveria zizanioides* (L.) in the photosynthetic and metabolic characters associated with essential oil accumulation. Int. J. Med. Plant Res. 1: 45–49.

Sujatha S, Bhat R, Kannan C & D Balasimha 2011 "Impact of intercropping of medicinal and aromatic plants with organic farming approach on resource use efficiency in arecanut (*Areca catechu* L.) plantation in India." Industrial crops and products 33 (1): 78–83.

Smitha G R, Varghese T S & Manivel P 2014 Cultivation of Vetiver [*Vetiveria zizanioides* (Linn)]. Published by: Dr. Jitendra Kumar,

ICAR–Directorate of Medicinal and Aromatic Plants Res. Anand press, Boriavi, Gujrat, India, pp.7–16.

Snigdha M, Kumar S S, Sharmistha M & Deepa C 2013 An overview of *Vetiveria zizanioides*. Res. J. of Pharmaceutical, Biological and Chem. Sciences 4(3): 777–783

Shabbir A, Khan M, Ahmad B, Sadiq Y, Jaleel H & Uddin M 2019 *Vetiveria zizanioides* (L.) Nash: a magic bullet to attenuate the prevailing health hazards. In Plant and Human Health 2: pp. 99–120. Springer, Cham.

Tiwari J P 2014 Development and Field Evaluation of Vetiver Root Digger. Agricultural Engineering Today 38 (3): 1–4.

Thiribhuvanamala G, Raja M B, Amirtham D & Rajamani K 2018 Exploitation of Vetiver (*Chrysopogon zizanioides* L.) shoot biomass for production of oyster mushrooms. Medicinal Plants–Int. J. of Phytomedicines and Rel. Industries 10(2): 133–137.

Troung P 2002. Vetiver grass technology. In: Maffei, M. (Ed.), *Vetiveria* the Genus *Vetiveria*. Taylor & Francis, New York, pp. 114–132.

Troung P, Van T T & Pinners E 2008 Vetiver system applications technical reference manual. The Vetiver Network Int. p. 89.

Verma A B 2020 *Vetiveria zizanioides* (L.) Nash: A review of magic grass. J. of Medicinal Plants 8(1): 58–61.

Van den Berg J, Midega C, Wadhams L J & Khan Z R 2003 Can Vetiver grass be used to manage insect pests on crops. In Proceedings of the Third Int. Conference on Vetiver and Exhibition, Guangzhou, China pp. 254–264.

Vanoh R & Troung P 2020 Training Manual – Vetiver System" in Fiji in February/March 2020.

Wagner S, Troung P, Vieritz A & Smeal C 2003 Response of vetiver grass to extreme nitrogen and phosphorus supply. In Proceedings of the Third Int. Conference on Vetiver and Exhibition, Guangzhou, China pp. 6–9.

Yadav H K, Singh S, Kumar V & Kumara A 2013 Varietal Preferences and Adoption Pattern of Economically Viable Medicinal and Aromatic Crops by the Indian Farmers. AGRIS on–line Papers in Economics and Informatics, 5(665–2016–44989): 91–97.

Yaseen M, Singh M & Ram D 2014 Growth, yield, and economics of vetiver (*Vetiveria zizanioides* L. Nash) under intercropping system. Industrial Crops and Products 61: 417–421.

Yogendra N D, Baskaran K, Niranjana K A, Sundaresan V, Satya Sirnivas K V N & Kalra A 2021 Validation of harvesting time in vetiver crop for enhancing root and oil yielding in Tsunami affected coastal regions of Tamil Nadu. Journal of medicinal and aromatic plant science 43 (3–4): 148–153.