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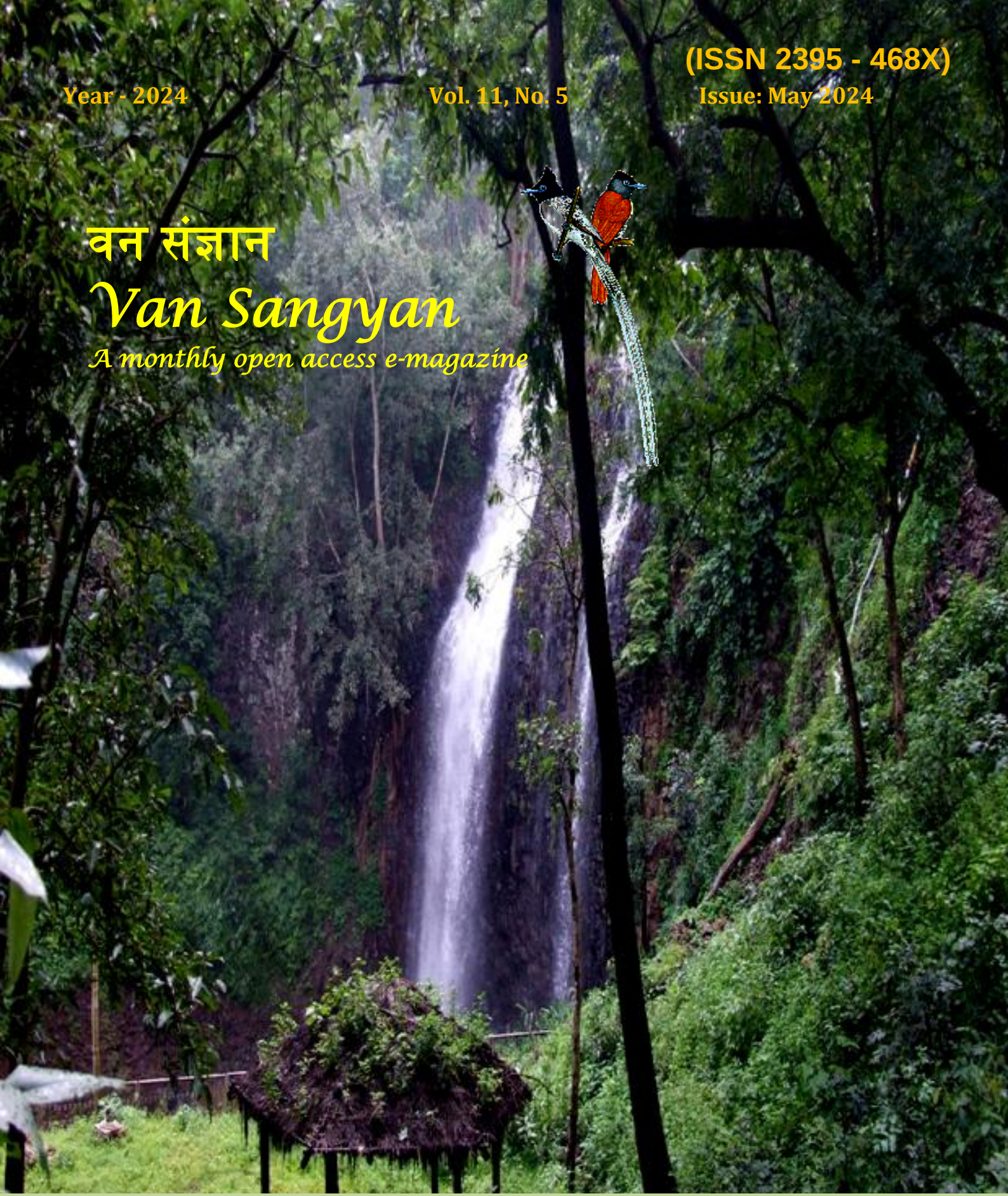

वन संज्ञान
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Van Sangyan

Note to Authors:

We welcome the readers of Van Sangyan to write to us about their views and issues in forestry. Those who wish to share their knowledge and experiences can send them:

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or, through post to The Editor, Van Sangyan,
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The articles can be in English, Hindi, Marathi, Chhattisgarhi and Oriya, and should contain the writers name, designation and full postal address, including e-mail id and contact number. TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

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From the Editor's desk

Balanites aegyptiaca is a remarkable tree species that thrives in the harsh conditions of the Lake Chad basin. Known for its deep roots and long lifespan, it can adapt to a variety of soil types, including sandy loams, clays, and even cracked clay. Its resilience to grass fires and periodic flooding makes it a valuable asset in arid regions.Despite its slow growth, Balanites aegyptiaca offers several benefits. Its deep taproot and thick bark protect it from fire damage, while its versatility allows it to thrive in diverse environments. While it may attract insects, it remains remarkably hardy. Although not as widely used in desertification combat efforts due to its slow growth, planting Balanites aegyptiaca is still highly encouraged. This species is well-suited to arid ecosystems and provides numerous benefits.

In line with the above, this issue of Van Sangyan contains an article on Balanites aegyptiaca - Nature's resilient gift to arid lands. There are also useful articles viz. Lemon grass (Cymbopogan flexuosus), Trichogramma: Importance in Agri-horti ecosystem, Agroforestry: A boon for farmers, वृक्ष अनोखा, मिलिया दुबिया, *Environmental and economic significance of Phanera vahlii for indigenous communities in central India, The non-Apis bee pollinators: Conservation of alternative bee pollinators for cross pollination, Tree and plants species for pollution management, Biochar in relation to agriculture and its role in sustainable crop production and Plant tissue culture: A tool to forestry.*

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Contents **Page**

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Balanites aegyptiaca - Nature's resilient gift to arid lands

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Introduction

Balanites aegyptiaca, commonly known as the desert date or soapberry tree, is a plant species native to various regions in Africa, the Middle East, and the Indian subcontinent. It belongs to the family Zygophyllaceae and is a resilient and adaptable tree that plays a significant role in the ecosystems of arid and semi-arid regions. It is a small to medium-sized tree that can reach heights of up to 10 meters (33 feet). The tree has a distinctive greyish-brown bark and an irregular, spreading crown. Its leaves are pinnately compound, consisting of several pairs of leaflets, and they are typically dark green and leathery in texture. The tree produces fragrant, small, greenish-white flowers that are either male or female and are borne on separate trees.

Taxonomic classification:

Domain	-	Eukaryota
Kingdom	-	Plantae
Phylum	-	Spermatophyta
Subphylum	-	Angiospermae
Class	-	Dicotyledonae
Order	-	Geraniales
Family	-	Balanitaceae
Genus	-	Balanites
Species	-	*Balanites aegyptiaca*

Distribution

B. aegyptiacus is native to African forests along the Sahara's southern edge. It is distributed in a vast ecological range, including the Saharan, Sahelian, and Sudanian zones, as well as further south in Katanga and Tanzania. It is prevalent in Israel, Jordan, the Arabian Peninsula, and the arid areas of Pakistan and India. It is grown in Cape Verde, the Dominican Republic, and Puerto Rico. It is drought resilient and survives with an annual rainfall of 200 mm or less when there is an additional water supply (e.g., Nile banks in Sudan). With up to 900 mm of annual rainfall, it spans from the desert's edge to the woodland savannahs. It favors deep sandy loam soils with continuous water availability, such as valley bottoms, riverbanks, or the foot of rocky slopes (Orwa *et al.*, 2009).

Vegetative Biology

Leaves

Arrangement

The leaves of *Balanites aegyptiaca* are alternately arranged along the stems.

Shape

Each leaf is compound, meaning it consists of multiple smaller leaflets. The leaflets are typically lanceolate (long and narrow) or elliptical in shape.

Venation

The leaves have pinnate venation, with prominent, straight veins running parallel to the midrib.

Margin

The leaf margins are typically entire (smooth), although they may have some serrations or irregularities.

Stems

Bark

The bark of *Balanites aegyptiaca* is gray-brown and corky in texture. It is deeply furrowed and may have fissures.

Thorns

One of the distinctive features of this tree is the presence of sharp thorns along its branches and trunk, serving as a defense mechanism against herbivores.

Roots

Balanites aegyptiaca typically has a deep and extensive root system that enables it to access water and nutrients from the soil in arid and semi-arid environments.

Hairs and Glands

The vegetative parts of the tree, including the leaves and stems, may have small, fine hairs or glandular structures, contributing to the tree's drought resistance and protection against herbivores (Booth and Wickens, 1988).

Note. It's important to note that the specific characteristics of the vegetative parts can vary somewhat depending on environmental conditions and the age of the tree. This botanical description provides a general overview of the typical features of Balanites aegyptiaca's vegetative parts.

5. Reproductive biology

Reproductive parts are essential for the tree's reproduction and play a crucial role in the propagation of the species in its natural habitat.

Flowers

Inflorescence

Balanites aegyptiaca produces small, greenish-yellow flowers typically arranged in clusters or racemes.

Symmetry

The flowers are usually radially symmetrical, divided into similar parts around a central axis.

Calyx (Sepals)

The calyx consists of five sepals, usually small and green.

Corolla (Petals)

The corolla consists of five greenish-yellow, narrow, and elongated petals.

Androecium (Stamens)

Typically, five stamens, the male reproductive parts, are located in the center of the flower, bearing the pollen-producing anthers.

Gynoecium (Carpels)

The female reproductive part consists of a single pistil, which may have three to five carpels. The pistil is located in the center of the flower and contains the ovules, which develop into seeds after fertilization.

Nectar

Balanitesaegyptiaca flowers may produce nectar to attract pollinators.

Fruits

Type

The fruit of *Balanitesaegyptiaca* is a drupe, a fleshy fruit with a hard, woody pit or stone inside.

Shape and Size

The drupes are typically spherical or ovoid, ranging from 2 to 4 centimeters in diameter.

Color

When ripe, the drupes turn from green to yellow.

Texture

The outer flesh of the drupe is often sweet when fully ripe.

Seeds

Size and Shape

The seeds are typically ellipsoid or ovoid, varying in size but generally several centimeters in length.

Color

The seed coat can range from light brown to dark brown.

Endosperm

The seed contains a nutritious endosperm, serving as a source of food for animals and humans.

Seed Dispersal

Balanites aegyptiaca seeds are often dispersed by animals that consume the sweet, outer flesh of the ripe drupes. The hard seed coat helps protect the seed during digestion and aids in its dispersal (Ndoye *et al*., 2004).

Nursery management

Seeds

This is the most common method of propagating Balanites aegyptiaca. The tree produces seeds within its fruit. Here's how to propagate it from seeds:

- Collect ripe fruits with seeds.
- Extract the seeds from the fruit pulp and clean them.
- Scarify the seeds by gently nicking or scratching the hard seed coat. This helps improve germination rates.
- Soak the scarified seeds in water for about 24 hours.
- Plant the seeds in well-draining soil, either in pots or directly in the ground, with a planting depth of about 2-3 cm.
- Keep the soil consistently moist, and the seeds should germinate within a few weeks to a few months, depending on conditions.

Root Cuttings

*Balanitesaegyptiaca*can also be propagated from root cuttings. Here's how:

- Dig up a healthy, mature root from an established tree during the dormant season (usually in the winter).
- Cut the root into sections, each about 15-20 cm long, making sure to include at least one bud or growing point.
- Plant the root cuttings horizontally in well-draining soil, burying them about 5-10 cm deep.
- Keep the soil consistently moist, and new shoots should emerge from the cuttings in a few months.

Suckers

The tree can produce suckers or shoots from its base. These can be dug up and transplanted to propagate new trees. Here's how:

- Identify healthy suckers growing near the base of a mature tree.
- Dig carefully around the sucker, ensuring you don't damage its roots.
- Transplant the sucker to the desired location, ensuring it is planted at the same depth it was growing before.
- Water the transplanted sucker well and provide appropriate care.

Air Layering

Air layering is a more advanced propagation method. It involves encouraging roots to develop on a branch

of the tree before detaching it to plant as a new tree. Here's how to do it:

- Select a healthy, mature branch.
- Make a small cut through the bark and cambium layer, typically in a ring shape.
- Apply rooting hormone to the cut area.
- Wrap the cut section with moist sphagnum moss and cover it with plastic wrap.
- Secure the moss and plastic wrap in place with twine or tape.
- Keep the moss consistently moist, and roots should develop in a few months.
- Once roots are well-developed, cut the branch below the new root system and plant it in soil. (Arap Sang *et al.*, 1985)

Pollination Mechanisms

Balanites aegyptiaca is primarily pollinated by insects, and it is considered to be an entomophilous plant, which means that it relies on the activity of various insects for the transfer of pollen between flowers.

Insects, such as bees and beetles, are attracted to the flowers of *Balanites aegyptiaca* by their nectar and scent. As they visit the flowers in search of nectar, they come into contact with the flower's reproductive structures, transferring pollen from the male parts (anthers) to the female part (stigma) of the same or different flowers, facilitating pollination. This process is essential for the production of fruit and seeds in the plant. (Flora Zambesiaca, 2016).

Economic Utilization

Food

Both unripe and ripe fruit have edible fleshy pulp that can be eaten dried or fresh. In Ghana, the fruit is made into a drink and sweetmeats, an alcoholic beverage in Nigeria, and a soup ingredient in Sudan. Young leaves and fragile shoots are prepared as a vegetable by boiling, pounding, then frying or adding fat. In West Africa, the blooms are used as a complement to food and as a flavoring in 'dawadawa' in Nigeria. To obtain nectar, flowers are licked (Prota, 2016).

Fodder

Livestock consumes the fresh and dried leaves, fruit, and sprouts as fodder. In a Burkina Faso trial, *B. aegyptiaca* contributed up to 38% of the dry-matter intake of goats during the dry season. Kernel meal, the waste left behind after oil extraction, is commonly utilized as a stock feed in Senegal, Sudan, and Uganda. In India (Maharashtra, Madhya Pradesh, Tamil Nadu, and Rajasthan), the tree is lopped for fodder.

Fuel

The wood is great for interior use since it produces a lot of heat while emitting very little smoke. It yields high-quality charcoal, and it has been argued that the nutshell is appropriate for industrial activated charcoal. The calculated calorific value is 4600 kcal/kg.

Timber

The wood is pale yellow or yellowish-brown in color. Heartwood and sapwood are difficult to distinguish. The wood is firm and sturdy, and it may be easily crafted into yokes, wooden spoons, pestles, mortars, handles, stools, and combs.

Gum or resin

The stems produce a greenish-yellow to orange-red resin. When it is fresh, it is sucked and chewed. It is used as an adhesive to adhere feathers to arrow shafts and spearheads, as well as to repair handle cracks and arrows.

Lipids

The kernels yield edible oil, which is used in cooking. Because the oil is stable when heated and has a high smoking point, its free fatty acid content is minimal. It has a pleasant aroma and taste.

Alcohol

The fruit of *B. aegyptiaca* can be used to make an alcoholic beverage.

Poison

An emulsion prepared from the fruit or bark is fatal to freshwater snails that house the miracidia and cercaria stages of bilharzia, as well as a water flea that hosts the guinea worm. The fruit, root, and bark can be used to make a fish poison. Saponin is the active ingredient in the toxin. The substance is poisonous to fish but not to mammals and quickly degrades, making the retrieved fish edible. However, in the Fada region of Cote d'Ivoire, the poison is said to impair fishermen's vision after 5-6 years of use.

Medicine

Malaria is treated using a decoction of the root. Oedema and stomach aches are treated with boiling roots in soup. The roots are used as an emetic, while an infusion of the bark is used to cure heartburn. To cure chest symptoms, wood gum combined with maize meal porridge is utilized. In Rajasthan, the bark is used to deworm livestock. The thorns are utilized in leprosy treatment. Plant leaves are used to treat anthrax, as antihelminthic agents, and to clear cancerous sores. The fruit has the ability to treat oral ulcers, whooping cough, sleeping sickness, and skin problems. Fruit kernel has been discovered to be a moderate laxative, an antidote to arrow poison, and a vermifuge (Yadav and Panghal, 2010).

Pest and disease management

Cultural Practices

Proper spacing and pruning to improve air circulation and reduce disease spread. Remove and destroy infected plant parts to prevent the spread of diseases. Maintain good soil health and proper irrigation to keep the tree vigorous.

Pest Management

Inspect the tree regularly for signs of insect infestations, such as chewed leaves or visible pests. Apply neem oil or insecticidal soap as a natural remedy for common pests like aphids or mealybugs.

Disease Management

Common diseases in *Balanites aegyptiaca* include fungal infections like powdery mildew and rust. Apply appropriate fungicides when necessary. Ensure proper drainage to prevent root rot. Avoid overhead watering, as wet foliage can promote fungal diseases.

Biological Control

Encourage beneficial insects like ladybugs and parasitic wasps that can help control pest populations naturally.

Pruning and Sanitation

Regularly prune dead or diseased branches to improve tree health. Collect and dispose of fallen leaves and fruit to reduce disease reservoirs.

Monitoring

Keep a close eye on your tree's health, as early detection of pests and diseases is key to effective management (Janick and Paull, 2008).

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Lemon grass *(Cymbopogan flexuosus nees ex steud wats)*

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Introduction

Lemon grass (*Cymbopogan flexuosus* Nees ex steud wats) is a tropical perennial grass which is the source of lemon grass oil obtained from the leaves and shoots of the plant. The name of lemon grass is given to this crop because of typical strong lemon like odour of the plant which is predominantly due to high citral content in the essential oil present in the leaves. The essential oil is popularly known as Cochin oil in the world trade as 90% of it comes from Cochin ports.

Vernacular name

Lemon grass, (Hindi) Nimbehullu (Kannad), Lemon grass (English), Trade - Lemon grass

Botanical Description

Lemon grass belongs to family poaceae (Graminae) and the genus cymbopogan which has three identified species

Cymbopagan flexuous

It is known as east India, Cochin or Malabar grass. Under this species two varities are identified based on the stem color.

***Cymbopogan flexuous* Var. flexuosus**

The red grass locally known as chumannapullu. The stem is reddish; or purplish in colour. It is recognized as true lemon grass and is commercially cultivated. The citral content is very high (75-90) in essential oil although oil yield is poor.

***Cymbopogan flexuous* Var. albescens**

The White grass; locally known as vellapullu, is characterized by the white colour of the stem. The oil yield is high but poor in citral content (60-75%). The oil is also poor in solubility.

Cymbopogan citratus

It is known as West Indian and American lemon grass. It is stem less perennial grass with numerous stiff tillers arising from shoot rhizomatous root stocks making

large tussocks. It seldom flower in cultivation.

Cymbopogan pendulus

It is known as Jammu lemon grass. It is white- stemmed and dwarf in stature. The

plant is frost resistance and suited to subHimalaya areas of northern India.

Cymbopogan khasianus

It is discovered recently and is important for its geraniol content.

Varieties

Pragathi, Nima, Cauvery, Krishna, NLG 84, Sugandhi (OD- 19), ODP-1

Soil

It is generally grown on poor soils along hill slopes; though it flourishes on a variety of soils ranging from rich loam to poor laterite. This grass grows best on well drained sandy loam soil. Calcareous and waterlogged soil should be avoided as they are unsuitable for its cultivation.

Climate

It requires a warm humid climate with plenty of sunshine and a rain fall ranging from about 2000-2500mm, well distributed over the year. In areas where rainfall is poor; it requires irrigations. This crop is well suited for rainfed agriculture. It grows well at altitudes from 1000 to 1200 meter.

Propagation

Lemon grass is generally propagated through seeds, vegetative propagation and rooted slips. It is reported that both the seedling and rooted slips performed equally well; with respect to growth and yield. But due to the high cost of transplanting, direct seeding is wildly practiced.

For raising the crop direct seeding a seed rate of 20-25 kg is recommended. While sowing the seeds must be thoroughly mixed with dry river sand in a ratio of 1: 3 to ensure the uniform distribution of seeds during sowing.

Nursery raising

For raising the seedling required for planting 1 ha of land 1000 m^2 area is required. The nursery area is well prepared and raised beds of 1 to 1.5m width and of convenient length are made. The recommended seed rate is 3 to 4kg/ha. The seeds are uniformly broadcasted in the beds and are covered with a thin layer of soil, followed by watering at regular intervals. The seeds collected during the months of January-February are usually sown in the nursery during April - May

Planting

The field is prepared by repeated ploughing and harrowing and beds of 1 to 1.5 m with and convenient length are made with a spacing of 30 to 50 cm between beds. Three to four leaved 50 - 70 day-old seedlings are planted during the monsoon season. A spacing of 30×30 cm with a plant density 1, 11, 000/ha is recommended. A wider spacing of 60×45 cm for seedlings and 90×60 cm for slips has been recommended for fertile and irrigated land under north Indian conditions.

Manures of fertilizers

Lemon grass is an exhaustive crop and it requires a heavy dose of fertilizers ie 275 kg N, 25 kg P2O5 and 175 kg k2o/ha/annum. Under south Indian condition it was found that an application of 100 kg N in 3 to 4 split doses was found to be optimum; though a response upto 200 kg was recorded.

Intercultural

The earthing-up of the plant after about 4 months of planting and again after every harvest is beneficial, as the root region of lemon grass has a tendency to grow above the soil. The field is kept stubble free generally 2-3 weeding are necessary during the year. Herbicide, Diuran@1.5 kg a.i. /ha and oxyflurofen@1.5kg a.i./ha are

effective for weed control Interculturing can be done by a tractor-dawn cultivator or a hand-held hoe in row planted crop.

Irrigation

After planting of seedling or slips in the field; if there are no rains the crop should be irrigated every alternate day for about a month. It is recommended that 4 to 6 irrigations are given during the period February to June under north India condition, for an optimum growth and oil yield.

Pests and Disease

Insect and nematode pests infestation is very low for this crop. However the infestation by spindle-bug (*Cloviabipunctata* from south India and sever damage by the stemboring caterpillar of chilotrea under north Indian conditions have been reported. Spraying with Malathion (0.2%) can control the insects. Nematodes have also been found to infect grass; but the extent of damage to the crop is not known.

Diseases

Several diseases are reported to lemon grass, but none are serious enough to a cause major reduction in oil yield. Little leaf, malformation of inflorescence is reported to reduce the seed yield. Leaf spots, leaf blight smut, grey blight, clump rot, root rot, leaf-speck are some other diseases reported. These leaf diseases can be controlled by prophylactic sprays of Diethane M-45 and Diethane Z-78 @ 3G/lit trice, at intervals of 15 days.

Harvesting and yield

The lemon grass crop is perennial in nature and gives good yield for 5 years. Harvesting is done by cutting the grass 10 cm above the ground level. During the first year of planting, 3 cutting are obtained and subsequently 5-6 cuttings per year are taken subject to weather condition. The harvesting season begins in May and continuous till end of January. The first harvest is done about 90 days after planting.

The interval from sowing to harvest exerts a considerable influence on the yield and quality of oil. Both immature and over matured grass gives a lower quality of oil.

A herbage yield of 15t/harvest and recovery of oil about 0.3 to 0.5% from fresh grass. The oil is extracted by steam-distillation. An oil-yield of about 350-400 kg/ha from the second years onwards is considered satisfactory.

The following factors influence the oil production during distillation:

(1) Storage of the plant material

(2) Treatment of the material

(3) The method of distillation

- The major source of loss is by oxidation and rensification of the essential oil. So if the herb material is to stored before processing, it should be kept in a dry atmosphere within limited air circulation.
- The cut- grass when stored in a shade can increase the oil recovery up to 96 hours and storages for a further period will only decrease the oil yield.
- The essential oils are enclosed in a oil glands; oil- sacks and glandular hairs of the plant. Therefore, before distillation the herb material must be cut into small pieces to enables them to directly expose as many oil glands as is practically possible.
- Once the herb material has been reduced in size, it must be distilled immediately. Otherwisethe

essential oil, being volatile, will be lost by aerial evaporation.

- Dipping the chopped lemon grass in sodium chloride solution for 24 hours at 1-2 % concentration before distillation has been found to increase the citral content

Utilization of spent material

- The plant residue thrown out after the extraction of the essential oil is called spent material of lemon grass.
- Cattle relish it when it is hot or is converted into silage by adding a dilute solution of molasses.
- It is also a excellent source of manure it is applied either after composting or in the form of ash by burning.
- The waste lemon grass also used a fuel for distillation after drying.
- It is also a cheap packaging material for glass ware or other fragile objects.

Chemical composition of essential oil of lemon grass

The gas chromatographic analysis of oil showed the presence of the terpinene (0.5%), beta terpineol (0.40%), alpha terpineol (2.25%) triphenyle acetate (0.90%) borneol (1.90%) gereniol+nerol (1.50%), citral-b (27.7%) , citral-a (46.60%), farnesol (12.80%) and farnesal (3.00%) with rest being unidentified compounds.

Commercial uses of essential oil

- The essential oil of lemon grass is mainly used in the manufacturing of perfumes for soaps, hair oils, scents and medicines. It has also antibacterial properties
- Ionone prepared from the citral present in lemon grass oil is one of the most important raw materials for the preparation of vitamin A.
- It is also use in perfumery; Ionone is used in certain types of confectionery and liquors. The oil can be used to improve the flavors of some fish and can be used to flavour wines and sauces.
- The essential oil can also used for headaches, toothaches, baths, fomentations, as adiuretic agent for fever andas an insect repellent especially mosquito and house flies.

Trichogramma: Importance in Agri-horti ecosystem

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Trichogramma is a genus insect egg parasitoid which includes near about145 known species, parasitize Coleoptera, Diptera, Hemiptera and Lepidoptera. This genus plays a vital role in biocontrol of many economically important pests, makes this wasp group a valuable bio-control agent in various Agri-horti-silvi ecosystems. Trichogrammatids are natural enemy of many major crop pests, the inadequate and indiscriminate use of pesticides had adverse effect on the naturally occurring Trichogramma population, and therefore their natural population is often augmented with laboratory cultured individuals as it has short life cycle and high intrinsic rate of increase in population. More than 250 species of Trichogramma have been described from USA, India, Brazil, China and Russia, among which *T. achaeae, T. agriae, T. atopovirilia, T. brevicapillium, T. breviciliata, T. brevifringiata, T. chilonis, T. chilotraeae, T. convolvuli, T. cuttackenis, T. deion, T. dendrolimi, T. evanescens, T. exiguum, T. fuentesi, T. giriensis, T. hebbalensis, T. hesperidis, T. japonicum, T. kankerensis, T. kashmirica, T. latipennis, T. manii, T.minutum, T. nubilale, T. ostriniae, T. pallidiventris, T.pieids, T. plasseyensis, T. platneri, T. poliae, T. pretiosum, T.rabindrai, T. raoi, T. sankarani, T. semblidis and T. thalense*.Most frequently exploited in integrated pest management stratigies. *T. chilonis, T. pretiosum T. minutum and T. deion*

Host range of Trichogramma

The most dominant species in India, *T. chilonis* is reported to have host range of more than 80 phytophagous insects of economic importance in agri-horti ecosystem *viz*., *Achaea janata, Acherontia styx, Acigona steniellus, Acrobasis caryae, A. juglandis, Aglossa dimidiata, Agraulis vanillae, Agrius cingulata, A. convolvuli, Ampillia dioscoridea, Anomis flava, Arctia coerulea, Argyroploce schistaceana, Ascotis selenaria, Atherigona soccata, Cerura vinula, Chilo indicus, C. infuscatellus, C. partellus, C. sacchariphagus, C. suppressalis, C. venosatus, Clanis bilineata, Clostera anachoreta, Cnaphalocrocis medinalis, Cocytodes coerulea, Corcyra cephalonica, Creatonotus transiens, Crocidolomia binotalis, Danaus plexippus, Deilephila nerii, Diatraea saccharalis, Earias insulana, E. vitella, Emmalocera depressella, Ephestia cautella, Ergolis merione, Etiella zinekenella, Eucosma schistaceana, Euproctis flavinata, Eutectona machaeralis, Gastropacha populifolia, Grapholitha glycinivorella, Helicoverpa armigera, Heliothis assulta, Heliothis zea, Hemerophila atrilieneata, Herse convolvuli, Homona coffearia, Hyblaea puera, Hymenia recurvalis,*

Jaspida distinguenda, Laspeyresia caryana, Macroglossum pyrrhosticum, Mycalesis gotama, Naranga aenescens, Oebia undalis, Olethreutes schistaceana, Ostrinia furnalis, O. nubilalis, Papilio xuthus, Parasa consocia, Parnara guttata, Pelopidas mathias, Philosamia cynthia ricini, Pieris rapae, Plutella xylostella, Procera sacchariphagus, P. venosatus, Prodenia litura, Prodesaia kurosawai, Samia cynthia, Scirpophaga excerptalis, S. incertulas, S. innotata, S. nivella, Sesamia inferens, Sitotroga cerealella, Spilarctis obliqua, Spodoptera litura, S. mauritiana, Tiracola plagiata, Trichoplusia ni, Tryporyza inceretulas.

Biology and mass multiplication of Trichogramma

Trichogrammatids are egg parasites of different insect orders especially Lepidoptera. Trichogrammatids have been used extensively in integrated pest management strategies in various agroecosystems. The female of Trichogramma lays eggs inside the host egg, the number of eggs deposited inside the host egg may vary from 1 to 20, depends on the size of host eggs. A single female is capable of parasitizing up to 50-60 eggs in her adult life span of 4-14 days. At the time of oviposition, the Trichogrammatid female inject venom for the predigestion of the content of host egg. After hatching the parasitoid larva feeds upon the content of host egg, pupates inside and after 7-14 days emerges out from the host egg as an adult wasp. Under laboratory conditions Trichogramma spp. mass multiplied on ultra-violet exposed *Corcyra* eggs glued on Tricho-cards. For this infestation and insecticide free 2.5 kg of sorghum or maize or bajra grains, after sterilization at 100^0C for 30 minutes placed in trays along with proportionate quantity of groundnut kernel powder as protein source in *Corcyra* rearing cage.Yeast tablets as nutritional supplement, streptomycin as antibiotic and sulphur as acaricide also incorporated in these trays. In each tray one cc of viable *Corcyra* eggs were added, and this culture is to be maintained at 26^0C. Emergence of moths starts after 40-45 days, these moths were collected regularly and placed in fecundity cage for three days, supplemented with honey-based food, the eggs thus obtained were collected daily and sieved to remove scales. These freshly collected eggs were exposed to U V light and pasted on Tricho-cards. These cards were placed inside the parasitization chamber having nucleus culture of required species of Trichogramma. After 5-6 days these cards were taken out and usually stored in cold chambers for a certain period as per the need. From a single Tricho-card approximately 12,000 adults of Trichogramma emerge out.

Use of Trichogramma in various crops for pest management

Sugarcane early shoot borer

4-6 releases of *Trichogramma chilonis* @ 50,000/ ha at 10 days interval starting from 45th day after planting or with appearance of the pest.

Sugarcane top shoot borer

4-6 releases of *Trichogramma japonicum* @ 50,000/ha at 10 days interval starting from 60th day after planting and onwards.

Sugarcane plassy borer

9-11 releases of *Trichogramma chilonis* @ 50,000/ha at 10 days interval starting from 70th day onwards or with the appearance of the pests.

Maize stem borer

6 releases of *Trichogramma chilonis* @ 75,000/ha from 45th day onwards at an interval of 10 days or with the appearance of the pests.

Maize

Fall Armyworm, *Spodoptera frugiperda*: *Trichogramma pretiosum* @ 1,50,000/ha at weekly intervals.

Tomato fruit borer

6 releases of *Trichogramma brasiliensis* @ 1,00,000/ha from 45th day after transplanting at weekly interval or with the appearance of the pests.

Rice stem borer

Trichogramma japonicum @ 50,000/ha with the appearance of the pest or 30 days after transplantation, 6 releases to be made in one session.

Brinjal Shoot and fruit borer, *Leucinodes orbonalis: Trichogramma chilonis* @100000/ha 4-5 release.

Tomato, American pinworm, *Tuta absoluta*

T. achaeae, T. pretiosum each @ 50000/ha or *Trichogramma pretiosum* alone @ 1 lakh nos. /ha/release at an interval of ***7 days*** starting from flower initiation stage.

Okrashoot & fruit borer

Trichogramma chilonis @ 1-1.5 lakh/ ha starting from 30-35 days after sowing, 4-5 times at weekly interval.

Agroforestry: A boon for farmers

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The word agroforestry is not something new it is practiced since thousands of year ago fromvedicperiod.Agricultural crops are raised with forest tree spp.Agroforestry, historically, is as old as agriculture when domestication of both trees and herbaceous plants and crops in the vicinity of each other was practiced by early humans in ancient times. Incidentally, there are several examples of forest and fruit trees mentioned in ancient literature throughout the world. Recognizing the ability of agroforestry systems to address multiple problems and deliver multiple benefits, most of the scientific achievements in agroforestry research developments took place only during the last three decades. Now, it is considered a problem-solving science and can both sequester carbon and produce a range of economic, environmental, and socioeconomic benefits. Adaptation to climate change is now inevitable, and research on agroforestry as an adaptation to climate change and as a buffer against climate variability is one of the priority areas of research. Traditionally, trees in agroforestry systems improve soil fertility through control of erosion, the maintenance of soil organic matter and physical properties, increased biological nitrogen fixation, extraction of nutrients from deep soil horizons, promotion of more closed nutrient cycling, and ameliorating micro-climate favorable for crop growth and increased biological production. In recent years, Agroforestry can occur at a variety of spatial scales ranging from woodlot, farm, and watershed to the landscape in different regions of the world and cultures. Agroforestry provides approaches and technologies for mitigating the effects of harsh and erratic climatic conditions, restoring degraded ecosystems and landscapes, and enhancing soil fertility for sustainable production of food, feed, fuel, timber, fiber, medicines, and several other industrial products for the ever-increasing human population. Agroforestry is becoming increasingly important because of its multiple roles and services for biodiversity conservation, carbon sequestration, adaptation and mitigation of climate change, restoration of degraded ecosystems, and providing livelihood security to people.(Swaminathan MS)

Agroforestry is the production of forest crops(perennialtrees and annual crops) or animals on same unit of land at same time.It employs integrated concepts which make this land use management system the most self- sustaining and ecologically sound of any agricultural system(Sharma et al. 2017a.

It includes a integrating trees, crops and grazing animals in a conservative and productive manner. It can be consider more as an approach than a single finished technology.The flexibility of agroforestry

approach is one of its advantages (sharma et al., 2017b).

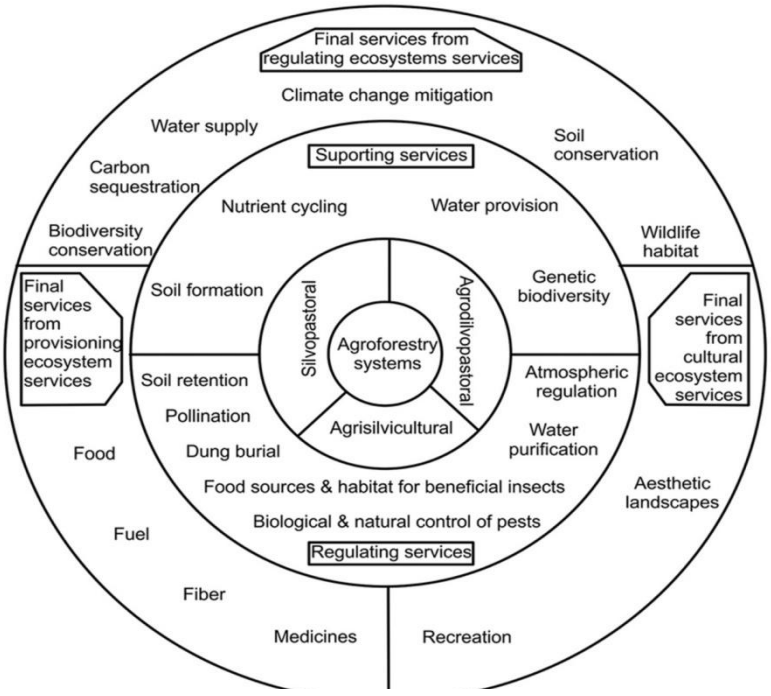
Agroforestry is any land use system to maintain or increase the total yield by combining annual food crops with perennial forest crop and / or grazing animal (livestock) on the same unit of land.Either alternatelyor at the same time using, management practices that suit the social andcultural characteristics oflocal people and the economic & ecological condition of the area".(DwivediA.P., Agroforestry principles and practices, International book distributor, Dehradun 2006)

An agroforestry implies that

- Agroforestry normally involves two or more species of plants (plants or animals)at least one of which isawoodyperennial.
- An agroforestry system always has two or more output.
- Thecycle of an agroforestry systemic always more than one year.
- Even the verymost simple agroforestry system is more complex ecologically (structurally and functionally)and economically than a monocropping

Why we need agroforestry?

Agroforestry will fulfil the socioeconomic need of rural people and it also beneficial like environmental,economicaland ecological. It also enhances the socioeconomic status of rural people. These are following important benefits from agroforestry. Agroforestry is a management system at combines' food crops and trees to address conservation need and build more profitable and weather –resilient farm, ranches and local communities and rural people. It is providing opportunities to integrate productivity and profitability with environmental status results sustainable that can be beneficial for future aspects



Objectives of Agroforestry

- To manage land efficiently so that its productivity is increaseand restored.
- To us e available resources efficiently and economically
- To generate the employment opportunity for rural people.
- One of the main objectives of agroforestry is the raise the production of the agricultural crops and forest crop with more economical an ecological value.
- Agroforestry aims to raise the supply for small timber used by village for agricultural implements,house construction other domestic purpose. in this way agroforestry canmeet this requirement of the rural population and reduce pressure on forest.
- To raise supply of fuel in the rural areas at convenient distance for consumer in India above to 70 million tonesof dried cow dung issuedevery years,which can be used for natural organic fertilizer moreover under pressure in on traditional forest for obtaining fuelwood.

Characteristics of agroforestry and trees

- we should choose that tree crops which not compete or interfere with agricultural crops &each other.
- Trees and crops spp. should not compete for nutrient, soil fertility and solar radiation and moisture also.
- tree spp. should be high survival rate and easy establishment.
- Tree spp. should be fast growing and deep root with easy management and the leaves of selected tree will be easily decomposable nature in soil.
- we should choose that type of tree spp. don't have any toxic effect or **allelopathic effect** like somechemical **ferulicacid**,**cinnamic acid,tarpenes,phenols, phenolic acidamines,coumarines** , **juglones, leptospermone** and some plant family viz; maple **family (aceraceae),beech family(fagaceae),walnut family(juglandaceae)** because it can reduce the yield of crops.
- Adequate shade regulation and trees bole should be straight and high growing.
- high yield potential & efficiently and profitability also.
- we should select the tree spp. that suit the social andcultural characteristicslocal people.

Environmental benefits

- Agroforestry can reduced the pressure on forest enhanced better protection of ecological system.
- Agroforestry augments diversity by favouring environmental condition.
- Agroforestry improve the micro climate of the area by lowering of soil temperature , reduction of evaporation and maintenance leaching and soil moisture and soil erosion .
- Agroforestry can reduced run off nutrient leaching and soil erosion.

- Agroforestry enhance efficient recycling of nutrient with in soil at different depths.
- Agroforestry is good tactic to improve the soil by addition the organic matter on soil.
- Agroforestry improves the soil
- Fertility through addition N_2 fixation from environment to soil. and also by the litter fall.

Ecnomical benefits

- Agroforestry can increased yield and output per unit are(more crops per unit area with addition economic value of timber, fuel etc).
- Agroforestrysystem reduced the crop failure.
- All thesebenefits increase and results the increase of total farm income.

Social benefits :-

- Agroforestry improve the rural living standard by increasing their income in a sustained manner.
- Agroforestry improves the health and nutrition of the people by providing diverse, nutrient rich farm produce.
- Agroforestry gave the multiple outputs without the risk of total failure stabilize the farm communities

Potential and scope of Agroforestry

The tremendous scope of agroforestry are following

- Alarge hectarage is available in the form of boundaries, bunds, wasteland where agroforestry system can be adopted.
- By using fast growing tree spp. in the field where most annual crops are growing well and the advantage of soil.
- Agroforestry can be severea power tool for social forestry in India
- Agroforestry has potential of at least partially meeting the challenges of present scarcities ofunemployment and has a vital role to play in rural development.
- Agroforestry can be adopted on agricultural land, forest land, marginal& sub marginal wasteland not presently available for cultivation of arable crops.
- India has achieved them selfsufficiency in food production. to its attention is becoming focused on the problems of acute shortage of fodder,fuel and other products.
- Agroforestry has vast scope inmeetingtheserequirementsbecaus eitcombineswithmostlymultipurpos etreespp. which will solve the problem of fuel, fodder, fruits,timber shade protection etc.
- Size of land holding are decreasing order day by day resulting in an increase in no. of small & marginal farmers, for rural people to provide employment.Agroforestryare labour intensive hence employment opportunities to unemploymentrural people to provide the employment
- Since agroforestry system involves intensive use of land under proper management without deterioration of its fertility that results in more output which add in nationaleconomy.Thusagroforestry in India is inevitable bright future.

Enormous Potential of agroforestry

- The humid zones of India havethe highest for carbon sequestration through agroforestry. Among the different type of agroforestry system with combine the agricultural crops with tree spp. and livestock have the highest potential to storecarbon.
- Expanding the area under agroforestryby five percent of the current area, in five year interval could help ofset India's total projected emission by 2050
- It's believed by expert and scientist that increasing the area under agroforestry could also fulfil multiple sustainable development goals established and will achieved
- Increasing the area under agroforestry system which integrate trees alongside crops, is a promising strategy to offset greenhouse gas emission and could help achieve India'snationally determined contribution in climate change.
- Recognising the potential of agroforestry in meeting various development and environmental goals, India launched a ***"National Agroforestry Policy in 2014"***,by increasing the area under agroforestry, the policy aims to ' ***Address the increasing demand'*** for timber,fruit,food,fodder and fiber&creating employment and generating income to farmers.

Classification of Agroforestry

Agroforestry system can be grouped on the basis of anyone factor of the farming system. P.K.Ramchandran Nair (1985)classified the agroforestry system into four groupsas following

A.On the basis of structure	B.On the basis of socioeconomic
C.On the basis of function	D.On the basis of ecological

On the basis of Structural

(A)Nature of component

1.Agrisilviculture system 2.Silvipasture system	3.Agrisilvipasture system 4. Other system

Agrisilvicultural system

Agrisilvicultural system refers as the raising of agricultural crop with forest tree spp. At same time at same unit of land, for maximum production of food crop with forest crop. By practicing of agroforestry it provides the food, fruit, fodder, timber and medicine and resin & gums and other forest produce as well as to reduceds the pressure on forest. Agroforestry can fulfil the needs of rural people.

Agrisilvicultural Sub System

1.1 Improved fallow (in shifting cultivation)	1.6 Hedgerow cropping or alley cropping
1.2 Taungya System	1.7 Crop combination with plantation crop

1.3 Multispecies Tree Garden	1.8 Agroforestry fuelwood plantation
1.4 Multipurpose trees and shrubs on farm land	1.9 Shelterbelts & windbreak
1.5 Tree and shrubs on pastures	1.10 Soil conservation hedges

The following are example of agrisilviculture system viz.

1. Wheat (Triticum aestivum) + Poplar (Populus deltoids) based agroforestry system
2. Wheat (Triticum aestivum) + Eucalyptus hybridbased agroforestry system
3. Wheat (Triticum aestivum) + Shisam (Dalbergia sissoo) base agroforestry system

Fig 1.1 Populus deltoids (popler) based agroforestry system

Fig1.2. Triticum aestivum) + Eucalyptus hybrid based agroforetry system

Fig 1.3 Wheat + Shisham based agroforestry system

Silvipasture system

The production of woody plants combined with pasture is refferd to as a silvipasture system. The trees and shrubs may be used primarily to produce fodder for livestocks on they may be grown for timber, fuelwood, and fruit or to improve the soil.A silvipasture system is need in dry areas,in order to meet out the demands of wood and fodder throughoutthe year. There are three main categories of silviculture system.example-

1. Protein bank
2. Live fence of fodder trees & hedges
3. Trees shrubs on pasture

Protein bank

In this system various multipurpose trees (protein rich trees) are planted on or around farmland and rangelands for cut and carry fodder production to meet the fodder requirements of livestock during the fodder deficit period in winter.

These trees are rich in protein:- 1.*Grewia optiva,2.Bauhinia variegate,3.Morus alba, 4.Artocarpus spp. 5.Angeissus latifolia,6.Cordia dichotoma, 7.dalbergia sissoo, 8.Eutralobium saman,9. Zizyphus jujube, etc (ICAR –iasri.res.in)*

Fig 2.1 A model of Silvipastural system

Other system

(3.1) Aquaforestry,
(3.2) Apiculture with forestry,
(3.3) Sericulture with agriculture
(3.4) Lac cultivation with trees

Fig. 3.1 Aquaforestry
Fig. 3.2 Sericulture with trees (Morusalba)
Fig. 3.3 Apiculture with trees
Fig. 3.4 Lac cultivation with trees

Suitable Agroforestry components (food crops + tree) for Ecological Zones

In India with a wide variation in climatic, edaphic and physiographic conditions and with a large biological diversity of flora and fauna, it is difficult to have a perfect ecological classification.

Sr No	Region/area	Agricultural component	Forestry component
1.	Alluvial region	Rice,wheat,sugarcane,pulses, oilseed	*Eucalyptus spp.,Populus spp., Delbergia sissoo, Morus alba,Acacia nilotica, Bombax ceiba,etc*
2.	Arid and semiarid areas	Maize, jowar,bajra, small millets wheats, pulses etc .	*Acacia nilotica. Prosopis cineraria, eucalyptus camaldulensis,Azadirachta indica, Ziziphus species*.
3.	Northern hill areas	Maize ,Paddy, wheat, fruits and vegetables	*Grewia optiva, Morus serrata, Celtis australis, Albizia chinensis, Populus ciliata, etc*
4.	Central region	Rice,wheat,jowar,bajra,pulses and oil seed	*Bamboos , Mangifera indica,Delberia sissoo, Moringa oleifera, Acacia nilotica,Azadiracta indica,Terminalia arjuna,Albizzia spp.,tectona grandis, Eucalyptus hybrid*
5.	Southern region	Rice tobacco , Chillis, sugarcane	*Casurina equisetifolia, Eucalyptus hybrid, Eucalyptus tereticornis, Acacia spp., Dendrocalamus hamiltoni, Tamarindus indica, Ancrdium occidentale*
6.	Coastal areas	Rice	*Casurina equisetifolia, Cocus nucifera, Areca catechu*
7.	Plantation crops areas of south and eastern states	Tree ,coffee, cocoa, banana, black pepper, Pineapple	*Albizia odoratissima, Erythrina spp., A. chinensis*
8.	North eastern areas	paddy	*Dendrocalmus hamiltonii, Cocus nucifera, Areca catechu, Diptocarpus macrocarpus, Anthocephalus chinensis*

Conclusion

Agroforestry system is sustainable and multifunctional approach to land use system, management, integrating trees with crops and / or livestock. It offers a range of environmental, economic, ecological social benefits, including improvement of health, increased biodiversity, enhanced resilience to climate change, and diversified income stream for farmers. Through careful planning and implementation, agroforestry can contribute to addressing various global challenges such as food security, poverty alleviation, and environmental conservation. However, successful adoption knowledge sharing, and capacity, embracing agroforestry

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वृक्ष अनोखा, मिलिया दुबिया, 3 साल में 30 फीट

अजीत विलियम्स
बैरिस्टर ठाकुर छेदीलाल कृषि महाविद्यालय एवं अनुसंधान केंद्र,
बिलासपुर छ.ग.

बेहद अनोखा इसलिए है क्योंकि एग्रोफारेस्ट्री प्रजाति का यह वृक्ष 3 से 8 साल की उम्र में 30 से 35 फीट की ऊंचाई हासिल कर लेता है। देश के 4 राज्यों में सफल पौधरोपण के बाद इसके पौधे अब छत्तीसगढ़ में भी मिलने लगे हैं।

आदर्श है मेड़ों पर रोपण के लिए क्योंकि इसकी पत्तियाँ प्राकृतिक कीटनाशक मानी जाती हैं। नदी तट पर लगाए जाने की सिफारिश इसलिए की जा रही है क्योंकि जड़ें गहराई तक जाती हैं और मिट्टी को बांधकर रखतीं हैं। अहम है मिलिया दुबिया की लकड़ियाँ उन काष्ठ उद्योगों के लिए] जो लकड़ियों से पैकिंग बाक्स का निर्माण करते हैं। यही वजह है कि पौधरोपण के लिए बनाई जा रही योजना में यह प्रजाति शीर्ष पर रखी गई है। वन विभाग की रोपणियों और निजी क्षेत्र की नर्सरियों में पौधे तैयार किए जाने की शुरुआत हो चली है।

3 साल में 30 फीट

मिलिया दुबिया एकमात्र ऐसी प्रजाति है, जिसमें सबसे तेज बढ़वार पाई गई है। 30 से 35 डिग्री सेल्सियस जैसे मानक तापमान पर यह प्रजाति 3 से 8 साल की छोटी सी उम्र में 30 से 35 फीट की ऊंचाई हासिल कर लेती है। इसलिए मिलिया दुबिया को दुनिया का सबसे तेज बढ़ने वाला वृक्ष माना गया है।

पत्तियों से कीटनाशक

नीम की पत्तियों से मिलती जुलती हैं मिलिया दुबिया की पत्तियां। महत्व इसी से जाना जा सकता है कि मानव और मवेशियों में संक्रमण को पत्तियों से रोका जा सकता है। पशु आहार के काम आने वाली इसकी पत्तियां फसलों में कीट प्रकोप को भी खत्म करतीं हैं। यही वजह है कि मेड़ों में रोपण की सलाह दी जा रही है।

लकड़ियों से यह सामग्री

मिलिया दुबिया के परिपक्वता अवधि पूर्ण कर लेने के बाद इसकी लकड़ियों से पैकिंग बॉक्स] सिगार बॉक्स] कृषि उपकरण] पेंसिल] माचिस बॉक्स] टी बॉक्स] वाद्य यंत्र और नाव के आउट रिगर बनाए जाते हैं। कृषि उपकरण भी इस प्रजाति की लकड़ियों से बनाए जा रहे हैं।

यहां सफल

तमिलनाडु, केरल, आंध्र प्रदेश और कर्नाटक में सफल रोपण के बाद अपेक्षित परिणाम मिलने लगे हैं। इसलिए छत्तीसगढ़ की निजी नर्सरियों और वन विभाग की रोपणियों में मिलिया दुबिया के पौधे तैयार किए जा रहे हैं क्योंकि मांग क्षेत्र लगातार बढ़त ले रहा है।

गुणों की खान

औषधीय गुणों से भरपूर मिलिया दुबिया 15&18 वर्षों में 10&12 मीटर साफ तने और 120&150 सेंटीमीटर परिधि के साथ 20&25 मीटर ऊंचाई तक बढ़ता है। इसकी छाल चिकनी] युवा होने पर हरी और परिपक्व होने पर गहरे भूरे रंग की हो जाती है।

Climbing to prosperity: The synergy of environmental and economic significance of *Phanera vahlii* (Wight & Arn.) Benth. for indigenous communities in central India

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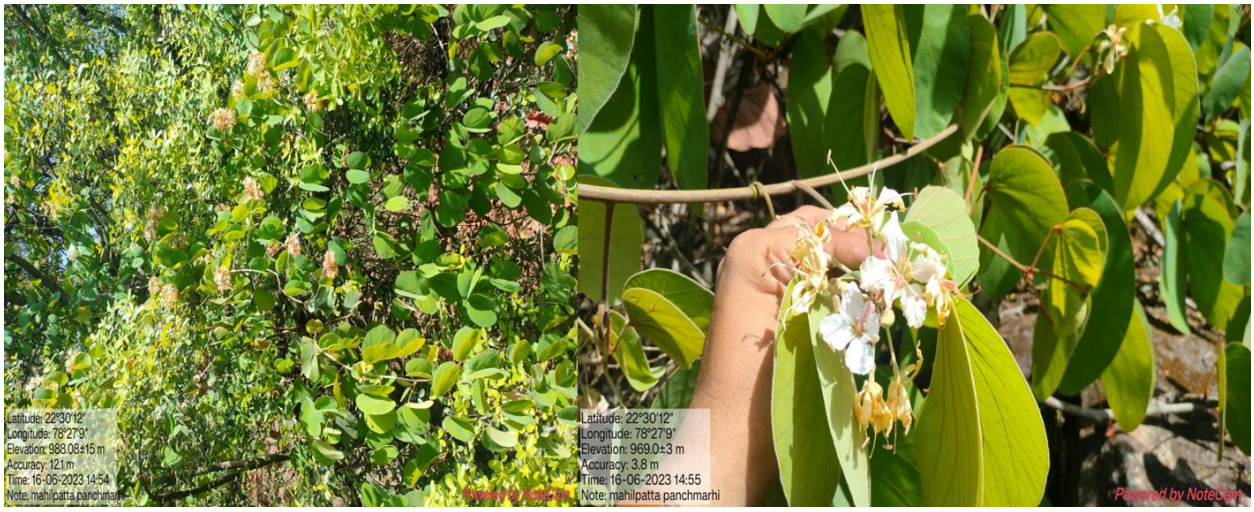
Introduction

Central India's indigenous communities have long depended on *Phanera vahlii* (Wight &Arn.) Benth., affectionately known as the Camel's Foot Climber, for their livelihoods and cultural practices. This article explores the dual significance of *Phanera vahlii*, shedding light on its crucial role in the environmental and economic landscape of Central India. From an environmental perspective, Phanera vahlii emerges as a harbinger of biodiversity, an alternative to plastic based cutleries and a guardian of sustainable resource management. Its growth and propagation contribute to the region's ecological balance while offering valuable lessons in conservation. On the economic front, this unassuming plant proves to be a cornerstone for indigenous communities, supplying sustenance, medicine, and income. It enhances local economies, ensures food security, and enriches the quality of life for those who depend on its resources.



Economic significance

The importance of Phanera vahlii within Central India's indigenous communities is undeniably profound. This plant's cultivation not only supports the livelihoods of indigenous communities and local farmers but also makes a significant contribution to environmental sustainability. This economic value is particularly prominent in the tribal regions of Central India.

Plates and Packing Material

The utilization of Mahul leaves as plates and packing material is an eco-friendly alternative that holds great significance. Grocery shops, eateries, and various businesses employ Mahul leaves for crafting plates and packaging. These

leaves take center stage during community feasts and ritual gatherings, offering an environmentally responsible substitute for disposable plastic ware. Mahul leaves are traditionally used as plates, cups, and wrappers during occasions like weddings, festivals, and religious ceremonies. They also serve as a practical solution for packing cooked food and meat, prominently used in small hotels and butcher shops within villages. The demand for Indian leaf-based cutlery extends beyond domestic borders, finding resonance in international markets. Companies like Leaf Republic in Germany import leaf plates from their Indian subsidiary, Bilotech, further processing them for distribution in the German market. Indian enterprises, such as Bioworld, are actively engaged in exporting leaf-based cutlery, expanding its global reach.

Year-Round Livelihood Option

Mahul leaves present a year-round source of income for local tribal communities, available for collection approximately 9-10 months annually. Tribal individuals collect an average of 5 to 6 kilograms of leaves per person per day, contributing to their economic well-being. The collected leaves are directly sold in local markets without requiring additional processing.

Stem Fiber

The versatile applications of Bauhinia vahlii stem fiber encompass various traditional crafts and industrial innovations. The stem fiber of Bauhinia vahlii is extensively employed for crafting durable ropes. Tender stems are harvested year-round, with a notable collection period during the transition from the wet to the winter seasons. These ropes exhibit resilience, lasting for over a year if not frequently exposed to moisture. They serve purposes such as tying cattle, bundling dry pods, and drawing water from wells using buckets.The stems are skillfully separated and utilized in the creation of baskets, mats, and other wickerwork products, showcasing the plant's adaptability in traditional crafts. Researchers have harnessed the fiber extracted from Bauhinia vahlii stem bark to develop composite materials. These innovative materials serve various purposes, including reinforcement in mats.

Bark

The bark contains a significant tannin content, approximately 17%, which can be extracted and applied in various applications.

Seeds

The seeds of P. vahlii are highly versatile and carry economic significance. These seeds are consumed both in their raw and fried forms, representing a traditional food source for tribal communities. When ripe, fried, or roasted, they are known for their flavor, akin to cashew nuts. They can even serve as an almond substitute after roasting. The seeds are actively sold by tribal women in local open-air vegetable markets, highlighting their economic importance and contribution to local livelihoods. The de-seeded pods of the plant have found application as traditional firewood and as a source of fertilizer for agricultural fields, further diversifying their significance.

Environmental significance

Phanera vahlii, vernacularly known as the Mahulpatta, not only holds economic significance for indigenous communities but also contributes to environmental

sustainability by reduction of plastic pollution and lowering carbon foot print. Plastic pollution is a global environmental concern, with single-use plastic items like cutlery contributing significantly to this issue. *Phanera vahlii*-based cutlery provides a sustainable solution that reduces the need for plastic utensils. By using these biodegradable alternatives, we can help mitigate the negative effects of plastic pollution on ecosystems, wildlife, and human health. Plastic cutlery, while widely used, poses significant health risks due to the release of toxic compounds when exposed to hot food and the hazards it presents after disposal. Non-biodegradable plastic plates, often consumed by stray cattle and wild animals in urban environments, create a multitude of health disorders and threats to these animals. An eco-friendly alternative exists in the form of utilizing *Phanera vahlii's* fibers and leaves to craft various utensils, including plates, bowls, spoons, and forks. These eco-friendly utensils not only serve their purpose effectively but are also entirely biodegradable, mitigating the environmental impact linked to single-use plastic cutlery. India's food delivery aggregators generate an estimated 22,000 metric tons of plastic waste every month. A large-scale transition from plastic-based utensils to plant-based cutlery has the potential to revolutionize the industry, particularly benefitting forest-dwelling communities traditionally involved in its manufacturing. This shift can enhance soil quality, reduce carbon footprints, and contribute to climate change mitigation. When consumed by animals, leaf plates provide valuable nutrition and health benefits. The composting of used leaf plates as organic manure through vermicomposting also creates income-generating opportunities for progressive groups in an eco-friendly manner. These biodegradable plates, renowned for their durability and non-toxic nature, are the preferred choice for serving food in various regions, especially during religious ceremonies and community gatherings. Central Indian forests, rich in sal, siali, and palash leaves, serve as the primary raw materials for these biodegradable plates. States like Chhattisgarh, Maharashtra, Madhya Pradesh, Odisha, Gujarat, and Andhra Pradesh present significant markets for such utensils, and with adequate support, the market for alternative cutlery can be further developed. Phanera vahlii-based cutlery is often produced locally in regions where the plant is abundant, reducing the need for long-distance transportation. This localized production can lower the carbon footprint associated with the manufacturing and distribution of cutlery, contributing to a more sustainable and eco-friendly option.The plant parts are edible by the wildlife particularly by Asian Elephants and other herbivorous. The flowers also attract the pollinators and butterflies, help in ecological dispersal.

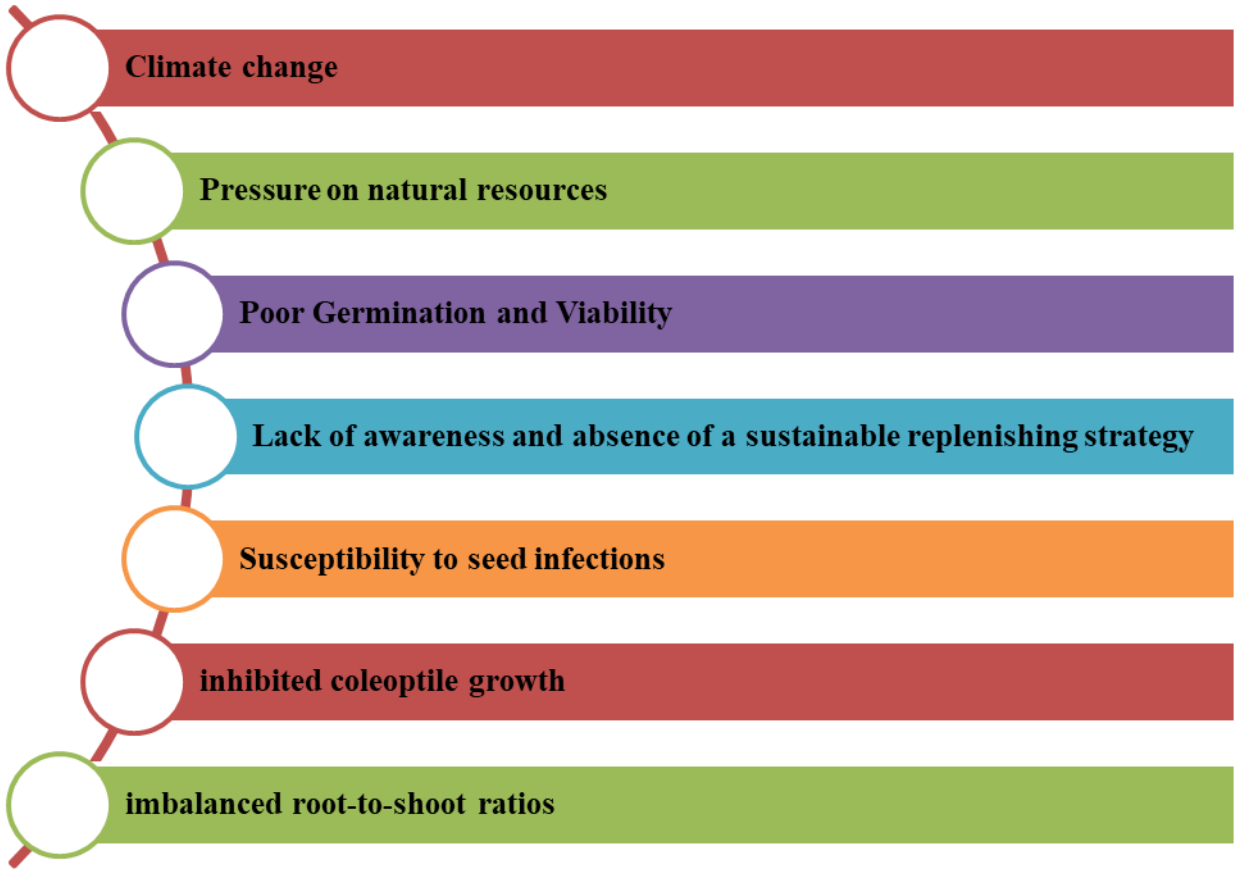
Medicinal significance

Bauhinia vahlii, a botanical marvel of Central India, emerges as a rich source of medicinal and antioxidant properties across its various components. Mahul leaves, in particular, exhibit antimicrobial, antioxidant, anti-diabetic, and anti-inflammatory attributes, owing to the presence of quercetin flavonoids. Their polyphenol-rich composition makes them ideal natural antioxidants, well-suited for

safeguarding food as meal plates and packaging material. Siali leaves, on the other hand, have been studied for their immunomodulatory and antidepressant potential, with indications of nephroprotective effects. The leaves of *Bauhinia vahlii*, replete with quercetin flavonoids, offer in-vitro antioxidant potential, suggesting their role in combating oxidative stress. Additionally, the plant's roots and stem bark may hold medicinal properties, including analgesic effects and potential applications in alleviating hyperthermia, while their antifungal properties open doors for exploration in natural medicine. The seeds of Bauhinia vahlii carry their own medicinal significance, used traditionally to address infertility issues in women, ground into a fine powder and consumed with milk as a remedy. This treasure trove of health-enhancing attributes within Bauhinia vahlii underscores its potential for traditional medicine and pharmaceutical applications

Challenges and threats

The surging demand for MahulPatta, a product derived from Phanera vahlii, has triggered a surge in commercial leaf collection, domestically and internationally, intensifying the detrimental impact on plant populations within their natural environments. This burgeoning threat is compounded by habitat degradation, deforestation, overexploitation of resources, livestock grazing, insect-induced damage, the repercussions of shifting climate patterns, and the proliferation of invasive species. Urgent measures are imperative to manage Phanera vahlii populations, especially in the southern, central, and Northeastern regions, where viable habitats are anticipated to diminish due to impending climatic shifts. A protracted interval between pod formation and maturation, approximately 10-12 months in the case of Phanera vahlii, poses a challenge for ensuring an adequate seed supply for natural regeneration. Continuous monitoring is vital to precisely gauge seed physiological maturity within this context.



Conclusion

Phanera vahlii emerges as a versatile economic asset, encompassing a broad array of applications ranging from eco-friendly cutlery to the adaptable use of stem fiber and economically significant seeds. These diverse economic opportunities empower local communities, exemplifying the remarkable synergy between economic prosperity and environmental stewardship within the heart of Central India. The potential for further exploration and value enhancement in these domains remains promising. *Phanera vahlii* plays a pivotal role in the ecosystem as a vital food source for elephants and other herbivores, emphasizing the need for its protection and habitat restoration to maintain ecological equilibrium. A notable research gap exists in the analysis of *P. vahlii* seeds, presenting ample scope for future exploration. Additionally, enhancing the value of non-timber forest products (NTFPs) is pivotal for bolstering the livelihoods of local communities. There is a notable dearth of research in the realms of medicine and pharmacology, complicating the selection of components for bioassays and the extraction, purification, and characterization of active secondary metabolites. Given the plant's integral role in daily life, promoting the sustainable production of locally sourced goods is imperative for the well-being of both the community and the environment.

The non-Apis bee pollinators: Conservation of alternative bee pollinators for cross pollination

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Introduction

Pollinator decline will have serious socio-economic consequences for countries like India, which host a large population of small and marginal farms for whom falling yield level would be critical for subsistence. Pollinating insects are in decline worldwide resulting in pollination crisis, for trees as well as non-Apis plants and loss of natural biodiversity. Possible drivers for the decline of insect pollinators include habitat loss, intensive land use, globalization and introductions of foreign species, pollution including pesticides, worldwide presence of the invasive parasitic mite Varroa destructor, introduction and spread of other (new) parasites, loss of the honeybee's genetic diversity, and detrimental beekeeping practices and climate change. This demands a response from land managers, conservationists and political decision makers to the impending 'global pollinator crisis'. Understanding the causes of pollination failure in trees can aid the successful conservation and recovery of rare trees, maintenance of yields, and sustainable use of non-Apis plant resources such as forest timber.

Feasible conservation strategies involve making efforts to protect or restore plant resources and native pollinators, and the creation of new protected natural areas, which ensures food provision, and nesting sites for pollinators. The solita1y mason bees are effective pollinators at low temperatures (< l2°C) when honey bees are not yet active, and they are used for early-blooming fruits like apples and pears. The decline in pollinator population and diversity presents a serious threat to agricultural/ forestry production and conservation and maintenance of biodiversity in many parts of the country. One indicator of the decline in natural insect pollinators is decreasing yields and quality despite necessary inputs. Where numbers of these bees have been adequate, yields have increased. Non-Apis and domesticated non-Apis bees effectively complement honeybee pollination in many crops and trees. Honey bee population may also fluctuate naturally in response to climatic calamity, the attack of parasites and diseases. Reliance on a single pollinator is always prone to such crises. We conclude there is immediate need of diversification and conservation of non-Apis bee pollinators.

Large carpenter bees

Large carpenter bees (genus Xylocopa) are wood-nesting bees and there are difficulties in mass-rearing of Xylocopa and in the high levels of nectar robbing exhibited by the bees. They are generalist pollinators of broad geographical

distribution that exhibit varying level of sociality. Their foraging is characterized by a wide range of food plants, long season of activity, tolerance of high temperatures, and activity under low illumination levels. Current challenges to the commercialization of these attempts lie in the difficulties of mass-rearing *Xylocopa*, and in the high levels of nectar robbing exhibited by the bees. The carpenter bees (*Xylocopa* spp.) have not been cultured in a hue sense although their nesting area has been encouraged by placement of soft timbers in which they can construct nesting tunnels. Because of their large size (almost an inch in length and about half as wide), they resemble large bumble bees but do not have a pollen basket on the hind leg. They are usually metallic black.

Bumble bees

Bumble bees are important pollinators of various crops like tomato, pepper, cucumber, watermelon, cotton, kiwi and strawberries and various other crops. The use of hand pollination in ceria in greenhouse crops is very expensive, so it is necessary to exploit the bumble bee species for pollination purposes, which can be managed easily in the greenhouse than honey bees. In several countries beekeepers and scientists are looking for other pollinating insects like Bumble bees as an alternate pollinator. Economic aspects of the use of bumble bees as pollinators for many agricultural crops are nowadays receiving more attention. Bumble bees are commercially used in Netherland and Belgium from 1987. Commercial bumble bee colonies have been available in US since mid-1992 and arc now utilized by most tomato greenhouse growers (Kuencman, 1995). They estimated that 24 colonies of *B. hortorum* each with a queen and about 35 workers placed along one side of red clover maximized seed production. Short tongued bumble bees were found effective pollinators of crane berries, *Vaccinium* sp. (Macfarlane and Patten, 1997).

Leaf cutter bees

Honey bees continue to provide generally satisfactory and frequently excellent pollination of most of our introduced flowering crops. A few crops exhibiting obviously specialized pollinator needs, such as Lucerne and perhaps red clover, have been catered for by the introduction of specialist bees. Where numbers of these bees have been adequate, crop yields have increased. Alfalfa, *Medicago sativa* (L), is a high-quality forage and green manure crop that originated in the Middle East. Alfalfa is largely self-fertile, but for mechanical reasons, flowers require bee visitation for pollination. Solitary bees and bumblebees are the most efficient pollinators of alfalfa. Honey bee efficiency, on the other hand, is low after opening alfalfa flowers several times. Honey bee "learns" to collect nectar without tripping flowers, due to the specific structure of the alfalfa flower. For that reason, despite the abundance of honey bee in alfalfa fields, seed yield per hectare may be very poor when solitary bees and bumble bees are not present. The problem was successfully overcome for the first time in USA and Canada with the domestication and utilization of the solitary bee *Megachile rotundata* (Fabricius, 1793). Alfalfa flowers require visiting bees to trip the sexual column, thereby providing pollination and

subsequent pod and seed set. However, tripping is done by a specialized group of bees, which enter the flowers and press their keel by their own weight by releasing male and female organs to distribute pollen and effect cross-pollination.

Alkali bees

It is a highly gregarious solitary bee that nests in large numbers in saline soils with a silt loam or fine sandy loam texture. A solitary species is one in which the female prepares and provisions the cell, deposits the egg, and then seals the cell completely unassisted. More than one cell may be constructed, but only one at a time. After the cell is sealed, no further attention is given it, and the adult may die within a few days. observed that wild bee populations actually increased atleast in the eastern half of the United States because of i) opening up of forested areas, which created more favourable conditions for bees, ii) paving highways, which concentrated moisture along roadsides, iii) introduction of weeds upon which the bees forage, iv) growing numerous crops upon which the bees forage and v) bringing desert areas into bloom (with irrigation). The world's only intensively managed ground-nesting bee, the alkali bee has been used for >50 years as an effective pollinator of alfalfa (*Medicago sativa* L.) grown in the western USA (Cane, 2007).

Sting less bees

Members of the Apidae subfamily Meliponinae or "stingless bees" are social insects. Some species have clusters of as many as 80,000 individuals; other species, less than 100. The two important genera are *Melipona* and *Trigona*. They do not occur in the United States but are present and of economic significance in Mexico as well as Central and South America. *Trigona* spp. also occurs in Africa, Southern Asia, and Australia. They are mentioned here because of their widespread distribution over the tropical and subtropical areas of the world, their value in the pollination of many crops, and their long-time culture for the production of honey and "wax". These bees have been studied taxonomically by Schwarz (1948) and behaviourally by several men, especially by Nogueira-Neto (1948a, b, 1950, 1951), Nogueira-Neto and Sakagami (1966), Ken (1946, 1 948, 1951), Sakagami (1966), Sakagami and Oniki (1963), Sakagami and Zucchi (1967), and Zucchi *et al*. (1967). Meliponiculture was reviewed and discussed from the practical stand point by Ordetx and Perez (1966). The following discussion is drawn largely from the above references. The females possess weak or vestigial stingers but are unable to illicit pain with them, hence the term "stingless bees." Some species have mandibles sufficiently strong to inflict a rnild bite or to pull hairs, or they may crawl into the ears or nostrils of the intruders. When the wax is secreted from the glands on the abdomen of stingless bees it is similar in appearance to that of *Apis mellifera*, but it is then mixed with propolis and the product, called cerumen, is more or less black.

Conclusion and future strategies

Improved agricultural practices has increased food supply over the past 50 years but a depopulation in both number and species of bee pollinators within agricultural environment bas resulted from land clearing, cultivation, irrigation and pesticidal use. The population of honey bees presently is not sufficient to meet the

huge demand of pollination above this honey bees cannot pollinate all the crops. Honey bee population may also fluctuate naturally in response to climatic calamity, the attack of parasites and diseases. Reliance on a single pollinator is always prone to such crises. We conclude there is immediate need of diversification and conservation of pollinators. One third of human diet depends upon the services provided by pollinators. Besides, pollinators are also important for production of forage crops required for cattle to produce dairy products. As the beekeeping industry is in crisis and during the past 50 years, an almost 50 percent decline in the number of managed honey bee colonies have been reported. The honeybee colonies are plagued by new pests and diseases and most recently, and most alarmingly, the beekeeping community is facing Colony Collapse Disorder, where for still unknown reasons, worker bees simply abandon the hive. Evidently, it can no longer be safely assumed that honey bees will provide all of farmers' future pollination needs. Efforts are therefore needed to explore manage conserve and multiply the alternative pollinators. To diversify our pollinators, we must better understand how to manage a variety of bee species as well as the habitat that supports them and their wild counterparts. Perhaps the silver lining of 88 Colony Collapse Disorder is its wake-up call to invest time, research, and energy into new managed pollinators and new ways of looking at farm management for the betterment of all pollinators. For agriculture as a whole the diversification of pollination assemblages for crops is clearly important. The value of the alfalafa leaf cutting bee *M. rotunda* as a better pollinator than honey bees for alfalfa has been clearly demonstrated by Richard, 1987. He concluded that the real impact of introduction of Megachile bees stating that alfalfa seed yield increased from 50 kg/ha to 350 kg/ha and with more careful handling it can be raised upto l000kg/ha. Because information on the role wild pollinators in agriculture/forestry and the effects of plantation methods on pollinators is largely speculative, research is critical to provide an understanding of this interaction. Little effort has been made to ensure the diversity of wild populations resulting in poor pollination and reduced yields. Particular attention should be given to develop and improve techniques for the rearing of solitary bees and bumblebees, support bee taxonomic research, promote a thriving beekeeping industry and pollination services and advice to growers, encourage the use of native rather than exotic bees, monitor movement of commercially reared bees and the impact of diseases, and investigate the impact of honey bee introductions on native bee populations.

Fig.1: Large carpenter

Fig.2: Bumble bee

Fig.3: Leaf cutter bee

Fig.4: Alkali bee

Fig.5: Stingless bee

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Tree and plants species for pollution management: A comprehensive review

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Abstract

Pollution management is a pressing global concern with significant environmental and human health implications. Due to anthropogenic activity on a worldwide scale, large quantities of particulate matter (PM) and heavy metals are collected in the air, water, and soil. Heavy metals (including cadmium, copper, lead, chromium, zinc, and nickel) accumulate up as a result of industrial processes such mining, smelting, refining, manufacturing, and excessive fertiliser uses in farmers' field. Among the various strategies employed to mitigate pollution, the use of tree species has gained attention due to their potential to absorb and remove pollutants from the air, soil, and water. By accumulating hazardous compounds, plants are a vital part of the environment's cleaning process.An efficient and widely accepted method for reducing pollutants and improving the environment is to plant trees and plants. For bioremediation of urban environmental pollution, careful planning and planting should be done. Depending on the amount and kind of pollution, it is important to choose pollution-tolerant and dust-scavenging trees and bushes.One such mitigation strategy is agroforestry (the common production of both plants and trees), avenue planting, vertical garden, and urban greening etc.The paper highlights the importance of selecting suitable tree species based on specific pollutant types and environmental conditions. Overall, this review contributes to the understanding of the role of tree species in pollution management and provides valuable insights for policymakers, researchers, and practitioners.

Keyword: APTI, Climate change, Mitigation, Pollution, Urban greening.

Introduction

Pollution is the most serious worldwide issue.With the rapid expansion in urbanisation, industrialization, and population growth over the past few decades, there has been a sharp increase in the pollutants of the air, water and soil pollution (Kirthika and Vishnuprasad, 2021).Urban landscapes that are sustainable and healthful are becoming more crucial for human well-being, including human health, ecosystems, climate, and visibility (Chen et al. 2019),is now a days one of the main atmospheric pollution problems, and it is getting worse due to urban population growth, rising traffic density, and industry (Gulia et al. 2015). Pollution management is a critical global challenge that demands effective and sustainable solutions. Among the various strategies employed to combat pollution, the utilization of tree species has

emerged as a promising approach due to their inherent ability to absorb and remove pollutants from the environment. Trees play a crucial role in mitigating different types of pollution, including air pollution, soil contamination, and water pollution.Using some of the green plants to eliminate environmentally hazardous elements is known as phytoremediation, which is an ecologically beneficial and environment cleanup approach. In order to transfer and stabilise contaminants like pesticides, metals, and chlorinated hydrocarbons, it is one of the most affordable, simple, and environmentally friendly methods available (Randive and Jagtap, 2019).

Air pollution and its mitigation:

The health of the environment can be measured by plants as bioindicators (Salih et al. 2017).Gaseous pollutants such as sulphur dioxide (SO2), carbon monoxide (CO), nitrogen oxides (NOX), ozone (O_3), lead (Pb), and particulate matter ($PM_{2.5}$ and PM_{10}) are examples of anthropogenic or natural pollutants found in the atmosphere. These pollutants are referred to as the criterion pollutant (Enitin at al. 2022).Precipitation, wind, particulate matter concentration and size of PM have an impact on how much particulate matter (PM) is deposited in the air (Pepek et al. 2019). In Delhi, Mumbai, and Kolkata, respectively, vehicular pollution makes up up to 70%, 52%, and 30% of all air pollution (Karthika and Vishnuprads, 2021).The term "green belt" refers to the widespread planting of pollutant-tolerant trees for the purpose of reducing air pollution by filtering, intercepting, and absorbing pollutants in a sustainable manner (Prajapati and Tripathi, 2008; Isaifan and Baldauf, 2021).The biochemical, physiological, and morphological characteristics of a plant determine its tolerance to air pollution (Singh and Verma, 2007).The ability of leaves to act as dust detectors is influenced by their surface geometry, phyllotaxy, epidermal and cuticular characteristics, leaf pubescence, and tree height and canopy (Nithya et al. 2017).Chen et al (2017) reported that the ability to trap $PM_{2.5}$ was highest in acicular (needle-shaped) leaves, followed by lanceolate leaves.The ability of plants to withstand air pollution is described by the air pollution tolerance index (APTI).It is one of the crucial factors that might be considered while choosing the species of plants for traffic barriers (Shrestha et al. 2021). Four biochemical factors have been used to describe plant APTI: total chlorophyll, relative water content (RWC), ascorbic acid, and pH of leaf extract (Nadgórska et al. 2017). The table 1. Shows the APTI value of different tree species.

Formula for APTI estimation:

$$\text{APTI}=\frac{[A+(T+P)+(R)}{10}$$

Where,A= Ascorbic acid(mg g^{-1}), T=Total chlorophyll content (mg g^{-1}), P= pH of leaf extract, R= Relative water content (%)

Yang et al. (2015) found that the use of species with high $PM_{2.5}$ removal efficiency, particularly conifer species, has a significant deal of potential to improve the removal of $PM_{2.5}$from urbanair. Similarly, Kirthika and vishnupradas, (2021) reported that the Air Pollution Tolerance Index (APTI) values of plants are in decreasing order as follows: *P. roxburghii, P. pterocarpum, D. regia, P. longifolia, and A. scholaris* can be

employed as bio-indicators of air pollution and in its mitigation for the creation of green belts in urban areas.

Table 1 List of trees with APTI value

S. No	Botanical name of tree species	APTI value	References
1.	*Peltophorum Pterocarpum, Albezia Lebbeck, Saracaasoca, Spathodia, Campunalata, Michelia champaka,Muntingiacalabura, Cassia siamea, Pongamia pinnata, Delonix regia, Anacardium occidentale.*	12.85, 7.83, 16.56, 12.91, 10.76, 6.0, 11.65, 9.39, 7.39, 17.56	Kumar et al. 2018
2.	*Albizzia lebbeck, Cassia fistula, Zizyphus jujuuba, Azadirachta indica, Ficus religiosa, Psidium guajava, Phyllanthus emblica, Tamaridus indica, Moringa olifera, Delaonix regia, Tectona grandis, Morus alba*	32, 28, 25, 22, 20, 18, 14, 14, 12, 7, 6, 5	Kumar et al. 2013
3.	*Syzygiumcumini, Michelia champaca, Acacia melanoxylon* *Euculeptus sp., Ficus benghalensis, Delonix regia Raf., Morindapubescens, Millingtonia hortensis, Leucaena leucocephala, Saraca indica, Caesalpinia pulcherrima, Dalbergia lanceolariaL.f., Ficus religiosa, Azadirachta indica, Pongamia pinnata (L.), Madhuca latifolia Roxb, Diploknemabutyrace*	38, 32.6, 28.5, 24.2, 16.8, 14.5, 29.5, 15.6, 18.9, 14.7, 16.4, 32.5, 18.5, 35.6, 32.4, 34.6, 32.4	Begum et al. 2010
4.	*Acacia auriculiformis, Chrysophyllum albidum, Araucaria heterophylla, Mangifera indica L., Elaeisguineensis Jacq.* *Syzygium malaccense*	10.7, 10.4, 10.2, 8.03, 7.90, 4.79	Anake et al. 2019

Soil pollution and its mitigation

The functioning of ecosystems is adversely affected by soil contamination, which also poses threats to the environment and human health (Delerue et al. 2022). Soil pollution occurs due to various industrial and anthropogenic activity by which heavy metals/metalloids come from both natural and man-made sources, including the use of phosphate fertilisers in agriculture, sewage sludge, metal mining and smelting, the use of pesticides, electroplating, and the combustion of fossil fuels (Yan et al. 2020).Trees play a significant role in mitigating soil pollution through various mechanisms. They can absorb and accumulate pollutants, enhance soil microbial activity, and promote the breakdown and degradation of contaminants.In order to reduce soil erosion and stop the spread of pollutants to surrounding areas, tree roots help to bind soil particles together.Trees enhance the organic matter content, nutrient cycling,

and water-holding capacity of the soil, which helps with soil restoration. Planting trees to restore contaminated soils can encourage the restoration of ecosystem services and functions. The avoidance and tolerance are two defence mechanisms used by plants to combat the toxicity of heavy metals (Yan et al. 2020).Plants initially attempt to immobilise heavy metals through root sorption or by altering metal ions when they are exposed to them. In the rhizosphere, a range of root exudates, including organic acids and amino acids, serve as a heavy metal ligand to create stable heavy metal complexes (Dalvi and Bhalerao, 2013).Trees can reduce soil pollution through a variety of methods, including phytoremediation (degradation of pollutants by metabolic mechanisms) Labe and Agera, 2017,phytostabilization (use of plant root to limit contaminant mobility and bioavailability in the soil) Jadia and Fulekar,2009,photovolatilization (Plants change pollutants into less digestible forms), rhizodegradatio (degradation via microbialaction in the rhizosphere) (Labe and Agera, 2017; Yan et al. 2020). The example of some tree which is play significant role to mitigate the soil pollution is shown in table 2.

S. No.	Name of species	Heavy metals	References
1.	*Salix viminalis, Poplar* spp.,	Cd, Zn, Pb, and As	Hammer et al. 2003
2.	(*Populus deltoides x maximowiczii*-clone *Eridano and P. x euramericana*-clone	Zn, Cu, Cr and Cd	Sebastiani et al. 2004
3.	*Sasaella glabra, Sasa fortunei Sasa auricoma, Shibataealanceifolia*	pb	Cai et al. 2021

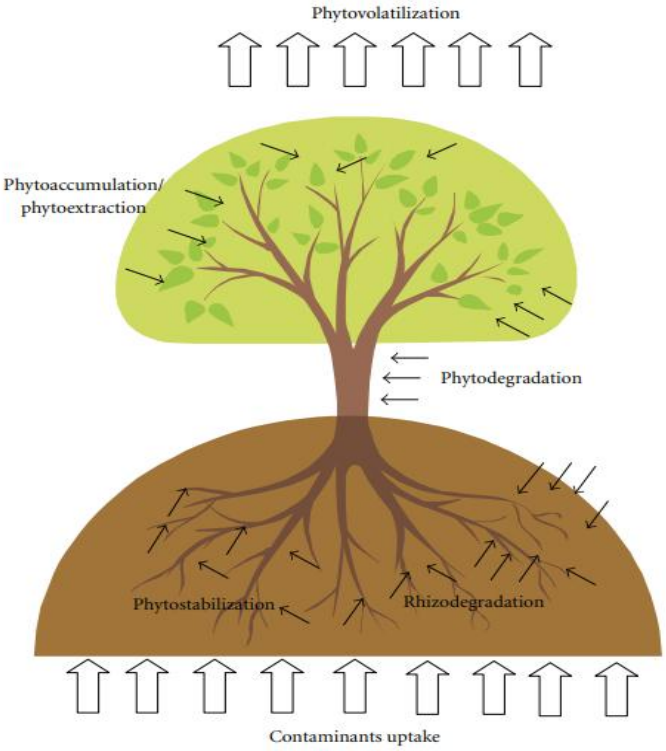

Fig: 1 The mechanisms of phytoremediation technique for heavy metal uptake by plants (Tangahu et al. 2011).

Water pollution and mitigation

Water shortage is an issue for about 40% of the world's population because of climate change, rising urbanisation, food demand, and unrestrained use of natural resources (Calzadilla et al. 2011).Rapid urbanisation, industrialisation, agricultural development, and the release of geothermal fluids and olive wastewater, particularly in places where olives are grown, increased the amount of toxic wastewater (Aguilar, 2009) such as heavy metals (HMs), oils, colours, phenol, cyanides, hazardous organic compounds, phosphorus, and suspended particles are all present in untreated industrial and domestic wastewater released into the environment(Rahman, and Hasegawa, 2011; Pakdel et al. 2018).Trees play a crucial role in mitigating water pollution through various mechanisms such as filtration, absorption, and biological processes. They can intercept and filter pollutants, stabilize riverbanks, and enhance water quality.In phytoremediation, plants collect pollutants through their roots and then move them to their aboveground parts of the body (Sharma et al. 2015).Aquatic plants serve as a natural absorber for pollutants and heavy metals (Pratas et al. 2014).The movement of water and pollutants via a vegetative filter strip can be a challenging procedure since it functionally consists of three distinct layers: the surface vegetation, the root zone, and the subsoil horizon. The efficiency of vegetative filter strips is influenced by field factors like soil type, rainfall frequency, slope, microtopography (surface soil roughness), infiltration capacity of the vegetated region, width of the strip, and height of the

plants(Kumar et al. 2013).Pedescoll et al. (2015) found that the two rooted macrophytes *Typha angustifolia* and *Phragmites australis* removed 14–85% of heavy metals from municipal wastewater, including zinc, lead, arsenic, nickel, iron, copper, aluminium, and magnesium.Manjunath and Kousar (2016) studied that *pistia stratiotes*, *azolla pinnata*, and *salvinia molesta* are aquatic plants that have been proven to be particularly effective at removing Fe, Cu, and Mn from textile effluents at a concentration of 25%.

Table 3. List of plant and trees for water treatment

S. No.	Name of plant	Heavy metals	References
1.	*Calendula officinalis L.*	Cd and Pb	Tabrizi et al. 2015
2.	*Calendula alata Rech. fil.*	Cs and Pb	Borghei et al. 2011
3.	*Acacia nilotica, Acacia moniliformis Andrographis paniculate, Ageratum conyzoides, Barleria terminalis, Celosia argentea, Calotropis gigantean*	Cd Cr Ni Zn Pb and Cu	Randive and Jagtap, 2019
4.	*Hydrilla verticillate, Spirodelapolyrrhiza, Bacopa monnierii, Phragmites karka,Scirpuslacustris, Azolla pinnata*	Pb, Cu, Cd, Fe, hg and chromium	Kumar et al. 2013
5.	Duckweed (Spirodelapolyrhiza L	Arsenate and dimethylarsinic acid	Rahman et al. 2008

Conclusion

Large amounts of gaseous and particulate matter are removed from the atmosphere by the many tree species, acting as biological filters.Many of the suggested plants are keystone species that are essential to the growth and upkeep of the ecosystem.Urban trees have a big impact on environmental issues including air quality.The development of a green belt is aided by the planting of trees, which is seen as an effective approach for climate change adaptation and mitigation. Native tree species with specific ecosystem functions are chosen, and locations are deliberately chosen based on the advantages to human health and the environment.For the restoration of soil contaminated by toxic heavy metals, the use of trees as a plant cover appears to be significantly more successful.For the restoration of soil contaminated by toxic heavy metals, the use of trees as a plant cover appears to have significantly greater impact.

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Biochar in relation to agriculture and its role in sustainable crop production

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Abstract

Biochar is also known as “Black carbon”, which is made up of carbon-rich organic materials and found in a solid and stable form in the soil. Charcoal derived from wood is a very good example of biochar, which stays for a long time at different depths of soil. The Terra Preta soils of the Amazon Basin are also one commonly known exampleof biochar (Rao *et al*. 2019). Biochar is an old concept, which was discovered when the “slash and burn” agricultural method was under process. The reason behind the limited supplement of oxygen is to avoid the complete burning of the material. It has been found that maintaining a low temperature of around 300°C-600°C results in more solid biochar, while high temperature above 700°C results in more liquid or gas biochar than solid biochar. Biochar has greater porosity and high specific surface area, which reduces the apparent density and changes water retention capacity, by soil incorporation (Rajapaksha *et al.*, 2016). Liang *et al.* (2006) also reported that it alters the chemical properties of soil and improves the soil fertility and availability of essential plant nutrients due to increased cation exchange capacity.The reaction conditions during the pyrolysis process are mainly responsible for producing biochar. Factors such as feedstocks, temperature, size of the particle, heating rate, etc. mainly influence biochar properties. These factors have a direct effect on the yield of biochar rather than its quality.Biochar has a great role in improvingsoil's physical, chemical and biological properties. As a result, it helps to improve plant growth and development in a sustainable way. In the present scenario of agriculture where climate change is a major issue, the use of biochar will help to minimize many greenhouse gases and it can be a better agricultural input for enhancing crop production.

Keywords: Biochar, Black carbon, physically, crop production, etc.

Introduction

Biochar is also known as “Black carbon”, which is made up of carbon-rich organic materials and found in a solid and stable form in the soil. Charcoal derived from wood is a very good example of biochar, which stays for a long time at different depths of soil. The Terra Preta soils of the Amazon Basin are also one commonly known exampleof biochar (Rao *et al*. 2019). Biochar is an old concept, which was discovered when the “slash and burn” agricultural method was under process. In

the old days biochar as soil deposits were also a result of natural forest fires. There are various types of biochar according to their parent material, which describes their physical and chemical properties. Artificially biochar is prepared by heating the biomass or wastes under a limited oxygen supply and the process is named as pyrolysis. According to Glaser *et al*. (2001), a high temperature between 300°C-1000ºC is maintained during biochar production. The reason behind the limited supplement of oxygen is to avoid the complete burning of the material. It has been found that maintaining a low temperature of around 300°C-600°C results in more solid biochar, while high temperature above 700°C results in more liquid or gas biochar than solid biochar. Basically, this is a waste-to-energy project, which produces 20% syngas (used for internal combustion of engines viz. carbon monoxide and hydrogen) along with bio-oil and biochar. Different types of by-products are used for biochar production ona commercial scale viz. agricultural and forestry by-products (such as straw, nut shells, rice hulls, wood chips, wood pellets, tree bark, and switch grass), industrial by-products (such as bagasse from the sugarcane industry, paper sludge, and pulp), animal wastes (such as chicken litter, dairy and swine manure), and sewage sludge. This is a good method of waste material reduction from the earth's surface. The preparation of biochar with desired properties can be used as a soil amendment and a cheaper absorbent of different organic and inorganic pollutants (Chen *et al*., 2011, Novak *et al.*, 2009). Biochar in combination with some fertilizers results in significant benefits in agriculture (Schulzet *et al*., 2013). Atkinson *et al*. (2010) and Biederman and Harpole (2013) have reported that in some crops like radish, rice, corn and wheat inclusion of biochar in plant nutrition increases crop yield from 45 to 250 %. Jeffery *et al.* (2016) mentioned that biochar also increasesthe water-holding capacity of soil, saturated hydraulic conductivity, and nutrient availability. Spokas *et al.* (2009) also observed that emission of the gases like CO_2, nitrous oxide and methane can be minimized by using sawdust-based biochar.

Role of biochar in improving soil health

Biochar has greater porosity and high specific surface area, which reduces the apparent density and changes water retention capacity, by soil incorporation (Rajapaksha *et al.*, 2016). Liang *et al.* (2006) also reported that it alters the chemical properties of soil and improves the soil fertility and availability of essential plant nutrients due to increased cation exchange capacity. Biochar application helps in improving numbers of PSB (Phosphate Solubilizing Bacteria) and the population increased for bacteria families like Streptosporangineae (~6%), Thermomonosporaceae (~8%), Bradyrhizobiaceae (~8%), and Hyphomicrobiaceae (close to ~14%). Among these families, Bradyrhizobiaceae and Hyphomicrobiaceae have a great role in the denitrification process (Anderson *et al.*, 2011).

Role of biochar on environmental benefit

This is well known that atmospheric carbon dioxide level increases due to the burning of fossil fuels and biomass decomposition. CO_2 emission and

concentration in the atmosphere can be reduced by biochar application in soil because it helps in carbon sequestration (50% from the feedstock) (Sohi *et al.*, 2010). Rondon *et al.* (2006) revealed that a mixture of 20g biochar and 1 kg soil can reduce emission of NO_2 up to 80% in grass pots and 50% in soybeans. Sohi *et al.* (2010) and Bai *et al.* (2010) explained that NO_2 emission reduced because biochar has the ability to adsorb and retain ammonium in soils and then decreases the nitrogen availability for the denitrification process. Day *et al.* (2000) mentioned that the application of biochar by the pyrolysis process into soil reduces the emission of greenhouse gases like CO_2, sulfur oxides and nitrogen oxides. It can reduce most of theenvironmental pollutants from the soil by absorption and many organic pollutants can be sequestered ultimately reducing environmental pollution. Biochar has resisting properties towards microorganisms and binds pollutants in the environment (Rehman and Razzaq, 2017).

Role of biochar on crop production

Biochar biochar-treated plot significantly increases yield than the untreated plot, because of an increase in soil fertility. Chan *et al.* (2007) revealed that dry matter production of radish was more in biochar plus nitrogenous fertilizer treated field but there was no increase in yield with a high rate of biochar @100 t ha^{-1} without nitrogenous fertilizer. Chan *et al.* (2008) also mentioned that using grass pruning residue, cotton waste and plant pruning residue as biochar @ 10-100 t ha^{-1} increased the yield of radish. Uzoma *et al.* (2011) found that there is an increase in grain yield of maize by 98% with 15 and 20 t ha^{-1} of biochar application. The use of biochar prepared from paper mill waste @10 t ha^{-1} in wheat fields increases germination (Van Zwieten *et al.*, 2010). On the same crop wheat, Batool *et al.* (2015) found that biochar application @40 Mg ha^{-1} from olive pruning waste, improved nutrient and water absorption, which resulted in increased dry matter and yield

Factors affecting biochar properties

The reaction conditions during the pyrolysis process are mainly responsible for producing biochar. Factors such as feedstocks, temperature, size of the particle, heating rate, etc. mainly influence biochar properties. These factors have a direct effect on the yield of biochar rather than its quality. The detailed knowledge of analyzing biochar properties is important for determining the biochar application. Various biomasses from different sources such as plant materials, agricultural residues, and biomass from wood, solid wastes, etc. has been used for producing biochar. Pyrolysis is a commonly used method for biochar production, which is generally carried out at 400-1000 °C. Solid wastes and animal wastes produce more biochar compared to other biomass materials such as wood biomass, agricultural residues, etc.

Feed Stocks

Logical, organic or inorganic material derived from living or living organisms. Biomass is characterized into two types (i) Woody biomass and (ii) non-woody biomass. Woody biomass essentially includes tree residues and forestry residues. The attributes of wood biomass are low dampness, low debris, less voidage, high density and calorific value. Non-woody biomass comprises animal

waste and industrial and agricultural solid wastes. The attributes of non-woody biomass are high debris, high dampness, high voidage, low density and calorific value. Among different attributes of biomass feedstock, moisture content has a great impact on biomass formation. The moisture in the biomass can exist as different forms such as liquid water, and water vapor and adsorbed within the pores of biomass. Higher moisture content in biomass majorly inhibits the formation of char and raises the amount of energy needed to attain the pyrolysis temperature.

Carbonization temperature

Pyrolysis is the most famous method for exchanging biomasses over to biochar through a thermochemical decay process under an oxygen-denied environment at a raised temperature. Contingent upon the conditions, pyrolysis cycles can be grouped into three fundamental classifications: (i) Slow pyrolysis (temperatures °C), (ii) moderate pyrolysis (temperatures of 300–500 °C) and (iii) quick pyrolysis (temperatures more prominent than 500 °C). Pyrolysis temperature influences the physicochemical properties and structure of biochar, for example, elemental components, pore structure, surface area and functional groups. The impact of pyrolysis temperature on such properties can be attributed to the influx of volatiles at high temperatures.

Residence time

Expanding the residence time at low pyrolysis temperature (300 °C) brought about a slow decrease in biochar yield and reformist expansion in pH and iodine adsorption number of biochars. Nonetheless, expanding residence time at high pyrolysis temperature (600 °C) had little impact on biochar yield or pH, while it diminished the iodine adsorption amount of biochar.

Pre-treatment of biomass

The potential biomass for biochar generation is utilized either independently or as mixes. Contingent upon the innovation utilized, the practical execution is as often as possible restricted by the moisture or mineral substance of the biomass. For example, the presence of chlorine and soluble base metals can cause consumption. Because of various production technologies and biomass, the properties of the produced biochar can go broadly. While components, for example, hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S) are volatilized during pyrolysis, minerals, for example, phosphorus (P), K, calcium (Ca), magnesium (Mg), and silicon (Si) remain and their concentrations increment in the resultant biochar.

Application of Biochar

- Remediation of pollutants
- As a Catalyst
- Soil Amendments
- Carbon sequestration
- Wastewater treatment

Conclusion

Biochar has a great role in improvingsoil's physical, chemical and biological properties. As a result, it helps to improve plant growth and development in a sustainable way. In the present scenario of agriculture where climate change is a major issue, the use of biochar will help to minimize many greenhouse gases and it can be a better agricultural input for enhancing crop production.

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Plant tissue culture: A tool to forestry and fulfilling international targets of the country

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Introduction

Trees are the most multifarious and priceless natural resources. They not only home multitude of birds, animals, insects but are also source of timber, food, medicines and abundant non wood forest produces. Trees acts as instruments for generating oxygen, fresh air, water, capturing and controlling soil erosion, enhancing aesthetic value of the land and providing uncountable tangible and intangible benefits. The array of benefits a tree provides makes it invaluable. Since time immemorial the importance of planting trees has always been recognised and it holds even greater relevance with the needs and damage from the modern lifestyle.

India is bestowed with great riches of natural resources. With only 2.4% of the land area, the country accounts for 46,000 species of plants and 7-8% of the total recorded species around the world (NBA 2018). The extent of Trees Outside Forests (TOF) i.e., all trees growing outside the recorded forest area was reported as 29.29 million hectare i.e., 36.18 percent of total forest and tree cover of the country. The National Forest Policy 1988 mandates 33 percent of the geographic area under forest or tree cover. For this, isolated trees and small patches of trees (less than 1 hectare area) outside the recorded forest area are also assessed (ISFR 2021). Also, India's Intended Nationally Determined Contribution (INDC), promises enhancement of forest covers in order to absorb additional 2.5 to 3 billion tonnes of global warming causing carbon dioxide (CO_2) by 2030.

Globally, raising trees holds importance more than ever before for not only fulfilling the demands of local people but to also achieve long-term ecological security and accomplish environment commitments of the country. Increasing demands for the growing stock brings wide scope of the Plant Tissue culture for production of quality planting material in enhancing the tree cover of the country. Over the last decade, the use of tissue culture techniques for the commercial production of woody plants has evolved from a potential future prospect into a swiftly growing and substantial achievement. This transformation is astonishing, not only in the quantity of plants being generated but also in the diversity of species and varieties currently being cultivated.

Plant tissue culture technique

The ability to regenerate complete plants from minute fragments of tissue, organs, or individual plant cells forms the basis of this novel strategy. The biotechnological approach of Plant Tissue Culture involves

isolation of small fragments of plants (like tissues, organs, cells, or protoplasts) and growing them in artificially created media and conditions for growth and development. Plant tissue culture makes a substantial contribution to the enhancement of commercially important tree species. It also produces secondary metabolites and pharmaceutically intriguing chemicals and improves staple crop plants' nutritional value through plant breeding. Regardless of the season or weather, plant tissue culture could offer high-quality planting material for a variety of fruits, vegetables, decorative plants, and forest tree species all year long. This presents new options for growers, farmers, and nursery operators.

This well established human engineered technique is used for generating numerous identical plantlets through micropropagation which has the potential to act as a valuable instrument for maximizing advancements in tree improvement programs within the shortest timeframe possible. This is achievable due to the capacity of tissue culture to generate a vast number of individuals from a minimal amount of seed or even from tissue derived from exceptional or superior trees through the process of micropropagatio. The resulting progeny or clones possess identical desirable genetic traits as the donor plants and can be mass-produced swiftly. These genetically uniform plants or clones find application in clonal forestry. It has demonstrated its advantages in producing plants that are free from diseases and enhancing plant yields in emerging nations. The process only necessitates a sterile working environment, a greenhouse, skilled personnel, and a nursery.

Requirements of plant tissue culture

Plant Tissue Culture requires the following:

Explants: the section of the plant utilized for culturing is referred to as explants. These may involve small tissues, anthers, root fragments, shoot fragments, leaf sections, petals, etc.

Nutrient media: the artificially created media having essential nutrients including:

Macronutrients - These encompass essential elements such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S) necessary for proper growth and morphogenesis.

Micronutrients - Elements like iron (Fe), manganese (Mn), zinc (Zn), and others, which are equally vital for tissue development.

Carbon or Energy Source like sucrose, among other carbohydrates for providing carbon (C), hydrogen (H), and oxygen (O) the basic building blocks of plants.

Vitamins, amino acids, and other inorganic salts.

Sterile conditions and platform to perform the process like that created with HEPA filters of laminar air flow.

Types of plant tissue culture technique

Based on the explants used there can be following (Figure 2) of tissue cultures described below:.

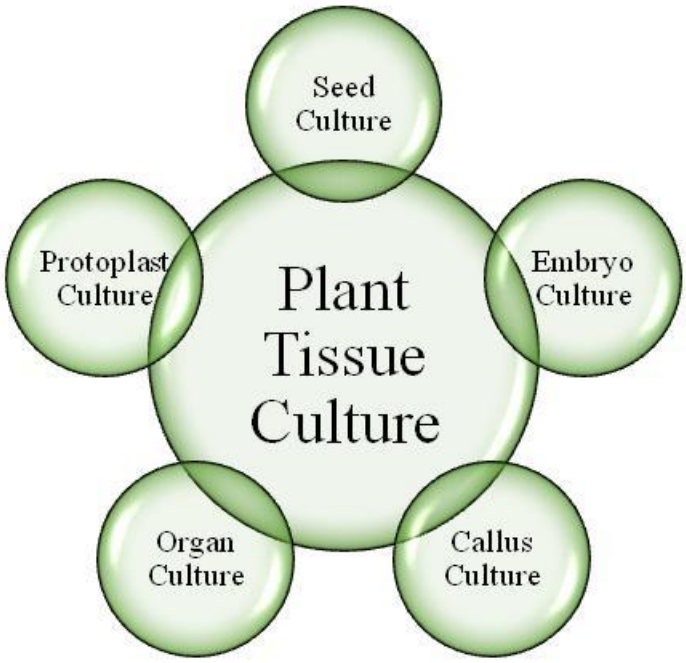

Figure 1: Types of Plant Tissue Culture Techniques

Seed Culture involves obtaining explants from a plant that has been developed in a controlled, in-vitro environment and introducing them into a laboratory setting for proliferation. It's essential to sterilize the explants to prevent tissue damage.

Embryo Culture involves using mature embryos obtained from fully ripened seeds or immature embryos from seeds that have failed to germinate.

Callus Culture involves introduction of rapidly dividing mass of cells grown on a gel-like medium containing agar and specific nutrients necessary for cell growth.

Organ Culture involves using any part of the plant, such as a shoot or leaf, can be used as an explant. This is done with help of various methods including the plasma clot method, raft method, grid method and agar gel method. This approach is utilized to preserve the structure and functions of a plant organ.

Protoplast Culture uses introduction of protoplast from desires plant cell. Protoplasts can be cultured using methods like the hanging-drop method or micro-culture chambers. This encompasses several phases, including cell wall development, cell division, and the regeneration of a whole plant.

Steps involved in tissue culture technique

The process of Plant Tissue Culture involved 5 different steps (Figure 1) which are described in brief below:

Figure 2: Steps of Plant Tissue Culture

Initiation Phase in which the specific tissue of interest is acquired, carefully sterilized to prevent any potential contamination and introduced into the medium containing growth regulators and essential nutrients.

Multiplication Phase involves giving ideal conditions to the introduced sterile explant for cell multiplication. This will generate undifferentiated mass of cells referred to as a callus**.**

Root Formation involves introduction of plant growth hormones in the media to initiate the formation of roots.

Shoot Formation thereby involves introduction of plant growth hormones and thereby monitoring the progress in growth for a week**.**

Acclimatization lastly is transferring the above lab grown plantlets in a greenhouse where it can develop under carefully controlled environmental conditions. Ultimately, it is moved to nurseries, allowing it to thrive in a natural environmental setting.

Advantages & disadvantages of plant tissue culture

Numerous benefits plant tissue culture offers can be enlisted below:

- Rapid plants generation using minimal plant tissue.
- Disease-free plant.
- Year-round cultivation regardless of the season.
- Space efficiency as it requires minimal space for plant cultivation.
- Accelerated variety development with desired characters.

Although the techniques also carry certain drawbacks:

- High costs as tissue culture demands specialized equipment and skilled personnel, resulting in considerable expenses. This financial barrier can restrict access to this technology, particularly for small-scale farmers and horticulturists.
- Limits genetic diversity as the techniques clones that are genetically identical to the parent plant. This at longer run also makes the plants more vulnerable to diseases, pests, and environmental stresses. Also, dependence on a single crop and the potential for monocultures raise the risk of crop failure.
- Contamination risk as despite the stringent sterilization measures there is always a risk of microbial contamination in the tissue culture medium which can jeopardize an entire batch of plants. Maintaining a sterile laboratory environment is

a complex and time-consuming process, requiring expertise and resources that may not be readily available.

- Adaptation challenges as at times tissue-cultured plants may not adapt to local environmental conditions as effectively as their wild counterparts.

Applications of tissue culture technique in forestry

To safeguard forests, the adoption of well-suited genotypes for afforestation and the rapid propagation and planting of forest trees is facilitated by leveraging the advancements in science and technology. Among the various asexual propagation techniques such as cuttings, grafting, and layering, plant tissue culture stands out as an effective and convenient method. It finds extensive use not only in forestry but also in fundamental botany, genetic research, agricultural breeding, and the preservation of various varieties.

Plant tissue culture has several valuable applications in forestry:

Mass Propagation

Tissue culture allows for the rapid and large-scale propagation of tree species. This is particularly useful for producing a high volume of tree seedlings for reforestation and afforestation projects.

Clonal Selection

Foresters can select and clone individual trees with desirable traits, such as disease resistance, fast growth, or timber quality. This helps in creating improved tree varieties.

Conservation of Endangered Species

Tissue culture is employed to conserve and propagate endangered or rare tree species. This can help maintain genetic diversity and prevent the extinction of these species.

Disease-Free Plants

Tissue culture produces disease-free plantlets, which is crucial for preventing the introduction and spread of pathogens in forest ecosystems.

Accelerated Breeding

Tissue culture can expedite the breeding process by allowing for controlled crosses and the production of a large number of offspring.

Genetic Research

It is used in genetic studies to understand and manipulate the genetics of tree species, enabling researchers to develop new varieties with desired characteristics.

Micropropagation of Elite Trees

Elite trees with superior traits can be micropropagated to create large numbers of genetically identical offspring with those desirable traits.

Clonal Forestry

Tissue culture facilitates clonal forestry, which involves the cultivation of genetically uniform tree stands for specific purposes like timber production or conservation.

Environmental Research

Tissue-cultured plants can be used in environmental research to study the effects of environmental stressors on tree growth and development.

Varietal Maintenance

Tissue culture is used to maintain specific varieties or genotypes over time, ensuring a consistent supply of preferred tree types.

Education and Research

Plant tissue culture is a valuable tool for teaching and research in forestry, as it allows for controlled experiments and

demonstrations in a controlled environment.

These applications highlight the significance of plant tissue culture in forestry for both conservation and the sustainable management of forest resources.

Table I. **Some forest tree species that have produced (Updated from Forestry in the Service of Nation: ICFRE Technologies)**

S.No	Species	Economic significance	Developed by
1	*Terminalia arjuna*	High medicinal value, plantation for domestic and commercial utilization.	FRI, Dehradun
2	*Terminalia chubula*	High medicinal value, plantation for domestic and commercial utilization.	FRI, Dehradun
3	*Terminalia barilica*	High medicinal value, plantation for domestic and commercial utilization.	FRI, Dehradun
4	*Eucalyptus species*	Very high medicinal value, widely utilized for producing quality planting material.	FRI, Dehradun
5	*Dalbergia sissoo*	Very high commercial and economic timber value.	FRI, Dehradun
6	*Grewiaoptiva*	Very high commercial and economic timber value.	FRI, Dehradun
7	*Teak*	Very high commercial and economic timber value.	FRI, Dehradun
8	*Dendrocalamus stocksii*	Very high commercial and economic timber value, plantation for domestic and commercial utilization.	IWST, Bangalore & AFRI, Jodhpur.
9	*Commiphora wightii*	Tremendous potential to address livelihood issue.	AFRI, Jodhpur
10	*Anthocephalus chinensis*	Technology can address livelihood issues and generate additional income through mass multiplication of superior germplast.	IFP, Ranchi
11	*Schleicheraoleosa*	Potential to address livelihood issue and increase production and productivity.	FRI, Dehradun
12	*Cylindrocladiumquinqueseptatum*	Productivity enhancement due to early detection of disease of Eucalyptus which then can be controlled in time.	FRI, Dehradun
13	*Ailanthus excelsa*	Potential to address livelihood issue and increase production and productivity, gap between the demand and the supply of fodder in increasing.	AFRI, Jodhpur

The commercial prospect of tissue culture in forestry

Tissue culture offers a promising commercial opportunity in the cultivation of ornamental plants, vegetables, fruit trees, and forest plants, especially when the market value of these products surpasses that of traditional cultivation methods. In contrast to conventional nurseries, this technique has the potential to meet the high demand for these products.Hence, it is imperative to express a need for and promote the establishment of high-quality commercial tissue culture laboratories to augment the production of plant materials through the utilization of advanced biotechnological methods.Around 350 million tissue-cultured plants (TCPs) are annually generated, serving as a significant source of economic sustenance for the nation. In India, there is a current trend of commercial entities advancing their technical proficiency in tissue culture, either independently or in collaboration with foreign partners.This achievement is only attainable because of the substantial export potential associated with tissue culture plants, which is highly regarded.

Plant tissue culture involves the controlled cultivation and replication of plant cells, tissues, and organs in a sterile and carefully managed environment using either solid or liquid mediums. The predominant commercial approach relies on micropropagation, wherein swift multiplication is accomplished through small stem cuttings, axillary buds, and, to a more limited extent, somatic embryos, cell clusters in suspension cultures, and bioreactors.

Future aspects

Over the recent decades, tissue culture techniques have provided fresh perspectives on enhancing plant growth, biological functions, genetic transformation, and the production of secondary metabolites. These methods have the capacity to yield substantial quantities of secondary metabolites and medically valuable compounds from plants that naturally have low concentrations of these substances. The use of sterile plantlets overcomes contamination challenges and reduces the time required for sterilization.The development of tissue culture techniques has been crucial in enabling the introduction of genetic information into plant cells. This breakthrough has paved the way for one of the most promising methods of producing proteins and medicinal substances, including antibodies and vaccines, which involves the use of transgenic plants. These genetically modified plants have been engineered to produce specific proteins or compounds of interest, making them a cost-effective and scalable platform for biopharmaceutical production. This approach has opened up new avenues in biotechnology for the efficient and sustainable manufacturing of crucial medical products.

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