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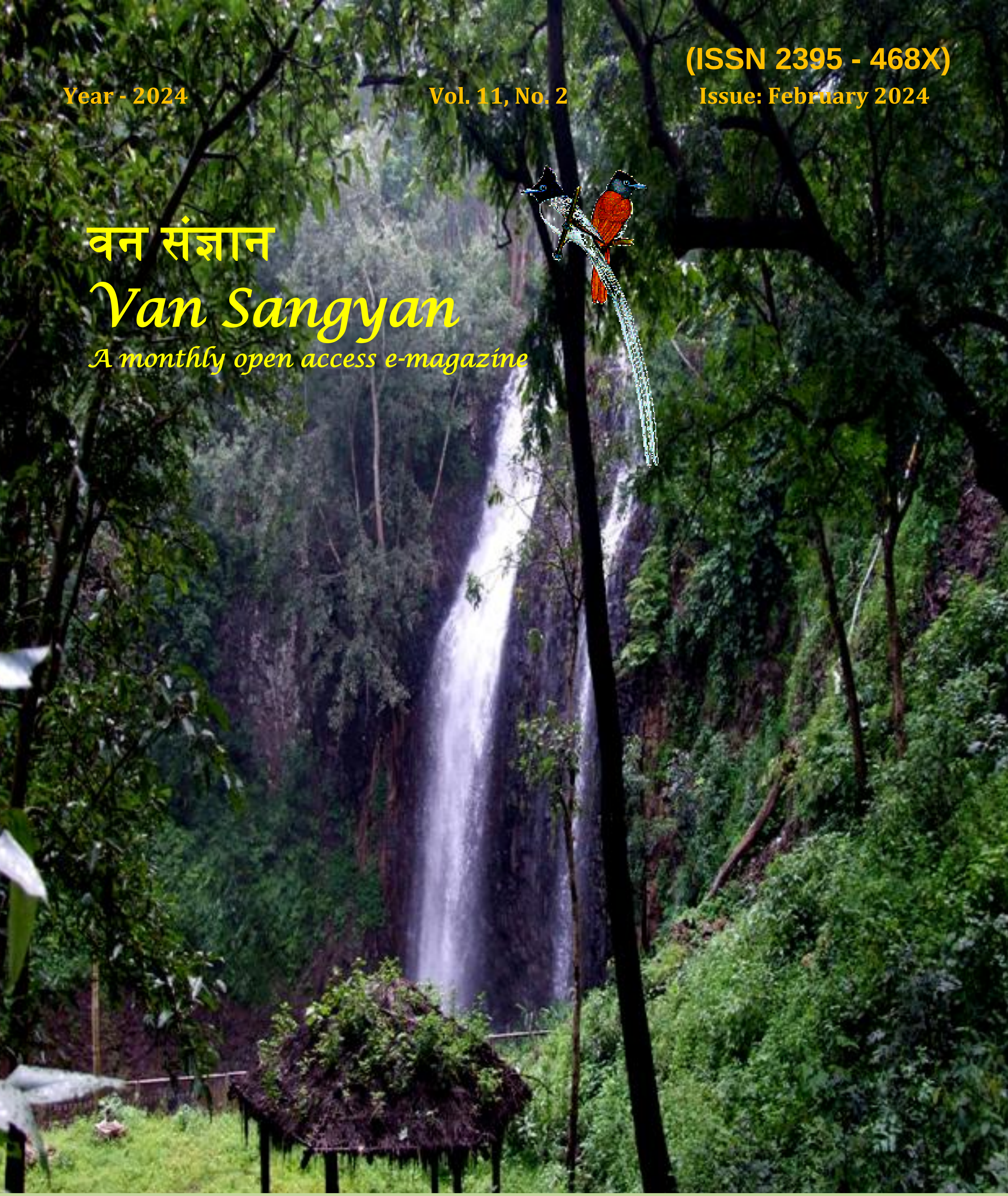

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Van Sangyan

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Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

From the Editor's desk

The Western Himalaya is home to five different kinds of oaks, the most common of which is the ban oak, Quercus leucotrichophora, which is the dominating species up to 2,200 meters. It is as a crucial component of the ecosystem in the temperate western Himalayan region, providing fodder, habitat, and ecological stability. However, its survival is now under severe threat due to various anthropogenic and environmental factors. However, its survival is now under severe threat due to various anthropogenic and environmental factors. Firstly, deforestation and land-use changes have significantly reduced the natural habitat of Ban Oak. Rampant logging and land conversion for agriculture and infrastructure have led to the fragmentation of its habitat, limiting its ability to regenerate and propagate. Additionally, climate change poses a significant challenge to the survival of Ban Oak. Alterations in temperature and precipitation patterns can disrupt its growth and reproduction cycles, leading to diminished populations and genetic diversity. Furthermore, overgrazing by livestock exacerbates the pressure on Ban Oak populations. Uncontrolled grazing prevents saplings from establishing and regenerating, further jeopardizing the long-term survival of this vital fodder resource. Conservation efforts are urgently needed to safeguard the future of Ban Oak in the temperate western Himalayan region.

In line with the above this issue of Van Sangyan contains an article on Ban Oak _ an important fodder tree of temperate western Himalaya facing survival threat. There are also useful articles viz. Celtis australis - A promising multipurpose species of Uttarakhand, Nature's puzzle: Understanding crown shyness in forest canopies, Biochar and its application in forestry, Agroforestry: a sustainable solution for biofuel production in India, Role of industrial wood plantations in the current scenario, Innovative forage crop management: A key to sustainable livestock agriculture, Biological nitrification inhibition through forest tree species and Forest giants under threat: Identifying diseases in key tree species .

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Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad
Chief Editor

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Ban Oak – An important fodder tree of temperate western Himalaya facing survival threat

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Introduction

Quercus leucotrichophora (Family: Fagaceae; English name: Himalayan Oak) locally known as Ban oak or Banj oak is an evergreen broadleaved tree of temperate Western Himalaya growing between 1000–2500m altitude mostly on cooler aspects. It is also known as Hara sona of Himalaya. It is moderate to large sized tree reaching on an average up to 20 m height and 60cm diameter. Its crown takes up round shape, bole remains irregular as well as short; bark is grayish brown with fissures and leaves are coriaceous, dark green serrated, elliptic to lanceolate shaped and slivery grey abaxial surface. On lower altitude of its occurrence (up to 1500 m) it is found mixed in other forests not as a primary species, in mid altitude zone elevation (1500–1800 m) it is mainly found associated with pine forming pine-oak forests and 1800–2200 m elevation it dominates the forests community forming ban oak forests.

Distribution and ecology

Ban oak is found growing mostly on cool aspects with shale, quartzite formation and also prefers clayey soil. Oak is moderate light demander, wind firm species but sensitive to severe frost and fire. New leaves appear during the March April month; male and female catkins appear during April –May month and fruits are formed in November December month which finally ripens in January and February month after 19–21 months after flowering.

Propagation

Ban oak is propagated through seeds. Its acorns are collected in December-January month, dried in shade and directly sown in moist and cool sloppy areas in forests. In nursery, seeds are sown in beds during February March month and once first leaf appears the seedlings are transferred into growing container in nursery and seedlings are planting out in monsoon after 18–20 months after sowing.

Importance of species

Ban oak is very important component of Himalayan ecosystem and farming system owing to its multiple uses. Leaves of the trees are palatable and utilized as fodder through lopping trees to feed livestock during winter and dry season. Its dried branches are used as a fuel wood (calorific value: 4600 Cal/kg) by local people. Ban Oak wood is used to make charcoal of excellent quality. Decomposed leaves of ban oak are collected by people and are utilized as manure in agricultural fields. Besides this, leaves are often mixed with livestock dung and urine for making manure for growing agricultural crops. Wood of ban oak tree is utilized for agricultural implement making like plough, sickle handles etc. Ban oak plays a significant role in conserving water and soil on hilly slopes and recharging natural springs in its vicinity. Oak trees are house for numerous micro as well as macro flora and fauna including epiphytes, ferns and fungus species, thereby play a significant role in sustaining biodiversity. Acorns/seeds of ban oak are food for monkey and Himalayan gray langur, squirrel and bird species etc. Wood logs of ban oak are utilized to grow medicinally important shiitake (*Lentinula edodes*) mushroom. Thus Ban oak is an important species of temperate Western Himalayan forest ecosystem.

Fodder value

Ban oak leaves are extensively utilized for feeding the livestock in western temperate Himalaya. Ban Oak leaves is given for stall feeding cows and other livestock. During dry and winter season when green fodder is in scarcity its leaves are lopped by local people for feeding animals and are either fed as such or by chopping them into smaller pieces. Some people collect ban oak leaves throughout the year for livestock feeding. Besides, this leaves of ban oak are spread under animals as bedding which thereby gets mixed with dung & urine and is utilized for manure making. As per as fodder value of ban oak leaves is concerned it contains average crude protein 9.4%, crude fiber as 38 % and sufficient mineral content (Table 1). Leaves of ban oak are usually mixed other grasses (dried) during winter for feeding livestock. Leaves are not recommended for sole feeding as has tannin content so mixing ban oak leaves with wheat straw and local grass mixed hay is a good option for supplementation to livestock. Also feeding mature leaf has been suggested by researcher as they contain less phenol and tannin content. Feeding of cattle solely on mixed grass hay was lacking in both energy and protein for sustaining even minimum levels of production. Study carried out by researcher have reported that grass hay and mature oak leaves at 36.4:63.6 ratio can increase feed intake, nutrient digestibility and mature oak leaves feeding as high as 63.6 % of DM did not interfere in nutrient utilization and had no apparent toxicity in animals (Paswan and Sahoo, 2012).

Table 1. Fodder quality traits of Ban Oak leaves (Navale, 2017)

S. No	Leaf parameters	Content
1.	Dry Matter	59%
2.	Crude Protein	9.48%
3.	Crude Fiber	38.02%

4.	Ether extract C	3.49%
5.	Total Ash	5.6%
6.	Acid Detergent Fiber	42.37%
7.	Neutral detergent Fiber C	52.13%
8.	Nitrogen free Extract	43.88%
9.	P	0.11%
10.	K	1.30%
11.	Ca	2.85%
12.	Cu	17.11 ppm
13.	Fe	678.42 ppm
14.	Mn	165. 30 ppm
15.	Zn	15.55 ppm

Degradation of Ban oak forests in Himalaya

This important tree species of temperate Western Himalaya is facing stress and survival threat owing to heavy unscientific lopping of foliage, poor regeneration, heavy grazing, invasive alien species, development activities and climate change etc.

- Excessive continuous lopping for foliage and branches for fuel wood and fodder leads to absence acorn/seed formation due to absence of sufficient resource in tree to produce acorns.
- Poor natural regeneration of oak trees due to quick proliferation of alien species like *Eupatorium adenophorum*, *Lantana camara* etc. and grazing of young seedlings leads to poor establishment of species.
- Moreover seed germination of ban oak is facilitated by leaf litter present on forest floor that provides moisture and nutrients to its recalcitrant seeds but practice of removing leaf litter by local people hampers germination and ultimately poor regeneration.
- Besides this, acorn weevil and other insects eat seeds of oak leading to poor regeneration.
- Climate change and invasion of Pine species owing to poor natural regeneration has also led ban oak on danger.

- Road constriction, hydroelectric projects, building constructions also leading to habitat fragmentation of the species leading to poor regeneration and survival of species.

This is high time that we should plan concerted efforts for conservation and restoration of this keystone species of temperate western Himalayan region. Otherwise we are going to lose many flora and fauna of Himalayan ecosystem that are dependent on ban oak for its survival. Soil and water conservation, water springs recharge carbon sequestration will also face threat due to loss of ban oak.

Fig 1 a & b Ban oak tree in Himalaya

Conclusion and way forward for conservation of Ban Oak

Ban oak species is a key species of Western Himalayan temperate forests that's sustains macro as well as micro flora and fauna of forest ecosystem and human life and livestock in Himalaya. Degradation of Ban oak forests and decrease in its population indicates loss of several other species dependent on it. Thereby there is need to plan scientific and concerted steps for restoration of its population and prevent further degradation of the ban oak forests.

Possible steps could be:

1. Lopping frequency and intensity of ban Oak tree should be decreased so that trees can set adequate seeds ensuring its natural regeneration.
2. Grazing in forest should be banned so that young seedlings of the ban oak can be protected till they reach a stage when they are not prone to grazing damage.
3. Large scale introduction of nursery raised quality planting material of ban oak tree into suitable location in forest to enrich stock of ban oak should be carried out and area should

be protected till seedlings are established successfully.

4. Planting of other fodder trees as well as Ban oak on common land, around agricultural fields should be promoted to reduced pressure from ban oak forests.
5. Perennial fodder grasses should be planted on bunds, common land, near agricultural fields to produce sufficient fodder and reduce pressure from ban oak forests.
6. Awareness creation among farmers regarding fodder conservation to store and utilize fodder for long period to avoid damage to oak trees.
7. Most importantly involvement of people at large scale for conservation of ban oak forests and plantation of fodder trees near farm, on bunds and community land is required to protect ban oak trees and forests.

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Celtis australis - A promising multipurpose species of Uttarakhand

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*Celtis australis*is an indigenous multipurpose tree species of western Himalaya grows at 500-2500 m aslwhich belongs to Ulmaceace family and grown for fodder, fuel, timber and various other uses. It is a promising multipurpose tree specieswhich not only provides nutritious fodder for the livestock in North Western Himalaya, but also as fuel wood and small timber for poor farmers, medicines and for other end uses also.

Basic description of the tree species

It is a fast growing moderate-size woody and deciduous perennial plant which can withstands against moderate amount of shade. The crown is somewhat irregular, round, moderate and fast growing and lumbering in nature. Bark is smooth and light grey in color. Theleaves are green, deciduous, alternate, simple, ovate, bowed, pinnate and reticulate in nature. Flowers are inconspicuous and fruits are small dark purple in color, round, fleshy in cluster form and are quitewidespread among birds and other biota.

Phenology

The flowering, fruiting and sprouting of new shoots in celtisaustralisvary significantly with respect of elevation and climatic changes and in addition to this it may also vary from year to year. The young shots appears in month of March to April and older leaves shed in month of December-January.

Propagation

Usually this species can be propagated by seeds; they are sown as soon as they ripe in a cold frame, and then sown in February or March month in a greenhouse (Sheat, 1948). Alsothe stem cuttings of 5-15 cm in length and 1.5-2.0 cm in thickness are used for propagation respectively. In addition the hormonal (IBA) treatment to cuttings is quite helpful for rooting percentage and number of roots per cutting. IBA not only enhanced root formation but also improves the quality of root system too (Butola and Uniyal, 2005).

Celtisaustralis uses

Fodder

This tree species is predominantly grown for fodder purpose. They are lopped during lean periods (October to mid -January) and provides bounteous amount of highly palatable, nutritious fodder during peak periods (Bisht et al., 2000).

Timber

C. australisas timber is proved to be excellent, also it is a good source of paper and pulp (Pearson and Brown, 1932 and Trotter, 1944) and used for making tools and whip handles, cups, wooden sticks, agricultural implements and many more. It can also be carved, and used as a general building material (Bhatt and Verma, 2002). The wood is also used as fuel wood, contains 16.81 KJ/g calorific value, 0.54 g/cc density, 3.4 percent ash, 57.53 percent moisture, 0.40 percent nitrogen, with a Fuel wood Value Index of 464(Purohit and Nautiyal, 1987).

Medicinal

Various parts of this tree is used for medicine. The bark used as paste and applied on bones, pimples, sprains and joint pains (Gaur, 1999). The fruits are used as remedies for amenorrhea, heavy menstrual and intermenstrual bleeding (Duke and Ayensu, 1985 and Chopra et. al., 1986). The Bhil tribe of Madhya Pradesh uses both stems and leaves, they crushed them and give to people tormented with leprosy (Maheshwari et al., 1986). The roots are boiled by tribes of the Western Himalayas and they use them as remedies for colic and other stomach troubles (Karnick and Pathak, 1982 and Chevallier, 1996).

Edible

The oil is extracted from the seed (Chiej, 1984).

Others

A yellow colordye is obtained from the bark (Polunin, 1969).These are widely used by turners (Chiej, 1984), for handles of agricultural implements (Manandhar, 2002). The thin shoots are used for walking sticks (Usher, 1974) and an excellent fuel too (Gamble, 1972).

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Plate 1- *Celtis australis*
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Nature's puzzle: Understanding crown shyness in forest canopies

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Abstract

Crown shyness, a fascinating phenomenon observed in certain tree canopies, has captured the curiosity of scientists and nature enthusiasts alike. This natural occurrence manifests as a distinct pattern of gaps or channels forming between adjacent tree crowns, preventing them from overlapping. This abstract explores the phenomenon of crown shyness, its underlying mechanisms, ecological significance, and potential applications.

Crown shyness is a complex interplay of various factors, including tree species, canopy density, and environmental conditions. While the exact causes are still under investigation, research suggests that physical abrasion between tree branches, photoreceptor sensitivity, and hormonal signaling may contribute to the formation of these distinctive gaps. The resulting crown patterns have been observed in various tree species worldwide, enhancing the aesthetic appeal of forests and facilitating ecological interactions.

Ecologically, crown shyness offers a multitude of benefits. The gaps formed between tree crowns allow increased light penetration to the forest floor, promoting the growth of understory vegetation and creating diverse microhabitats. This phenomenon also aids in wind and pest resistance, as the reduced contact between tree crowns reduces the likelihood of disease transmission and physical damage.

Crown shyness has practical implications beyond its aesthetic and ecological value. Understanding the factors that govern crown shyness could inform forest management practices, including tree planting and spacing, to maximize ecological benefits and enhance timber yields. Additionally, crown shyness has inspired architectural and urban planning concepts, fostering sustainable design approaches that mimic nature's patterns.

Keywords

Crown shyness, photoreceptor sensitivity, microhabitats, hormonal signaling

Introduction

As individual trees pass away or are topped by neighbors throughout the middle to later stages of stand development, gaps form in the forest canopies. Many people believe that as the stand ages, the crowns of nearby trees will expand and fill these spaces (Curtis 1982). The spatial distribution of above-ground biomass within a forest can be referred to as forest structure (Von Gadow and Hui, 2002). In completely stocked stands, crown shyness refers to the empty area between crowns that is unrelated to tree-fall gaps.

Fig.1: A group of trees displaying crown shyness

Crown shyness might just be a result of a conflict between wind-blown trees racing to grow new branches and defend themselves from attacks from their neighbors, according to Putz *et al*. (1984). According to Inés Ibáez, a forest ecologist at the University of Michigan, trees could thereby prevent needless damage. "For plants, producing new tissue is incredibly expensive... It's as if the trees are saying in advance that it is not worthwhile for them to grow here. According to certain theories, the inter digitation of canopy branches causes nearby trees to undergo "reciprocal pruning". Wind-induced collisions between trees cause physical harm in windy locations. A crown shyness response is brought on by the abrasions and collisions Offermans (1986).

The rapid growth of sustainable forest management (SFM) has led to the adoption of a number of frameworks for forest management aimed at preserving biodiversity. At the same time, the value of the ecological services provided by forests has grown. There are significant understanding gaps about the connections between biodiversity and ecosystem services and potential trade-offs in forests, despite the emergence of various programs targeted at their preservation. Due to recent developments, expanding prospects, and significant gaps in forest ecology, more research should be done on the development of SFM practices will heavily rely on ecological functions, biodiversity, and services. Mori *et al*. (2016)

Several intangible benefits of forests, such as regulating local and global climate, safeguarding watersheds, stopping soil erosion, nutrient cycling, etc., go unnoticed by policy makers because they are either impossible to assess or do not register in conventional markets. Prior to the Millennium Ecosystem Assessment (MEA) 2005, the use, non-use, and intrinsic benefits of biodiversity and ecosystems were used as justifications for conservation.

The first species of Australian Eucalyptus to exhibit crown shyness was documented by Jacobs in 1855. Subsequent descriptions of the behavior were made for many species in the tropical Far East (Paijmans 1973, Ng 1977), and black mangrove (Avicennia erminansi) in Costa Rica (Putz *et al*. 1984).

Phenomenon of crown shyness

Crown shyness is most common between trees of the same species (Paijmans 1973), although it can also occur between trees of different species (Ng 1977). Crown shyness even develops between branches inside individual trees. Crown shyness has an unknown origin. Eucalypts are subjected to strong and persistent winds in north-eastern Australia, according to Jacobs (1955).

It is believed that abrasion and death of delicate developing tips were caused by contact between crowns. In the black mangrove, Putz *et al.* (1984) discovered several dead twigs on the branches bordering the openings of the crown shyness as well as a correlation between the breadth of the openings and the distance that neighboring pairs of trees moved when they swung in the wind.

Initially, some researchers pursued the idea that trees were simply unable to fill the voids between their canopies because there was insufficient light—a necessary component for photosynthesis—where their leaves overlapped.

However, Putz's team conducted research in 1984 demonstrating that in some circumstances, crown shyness may simply be the result of a conflict amongst wind-blown trees, each of which is vying to grow additional branches and deflect blows from its neighbors. One of the earliest findings supporting the so-called abrasion hypothesis to explain the treetop patterns was that the more mangroves swung in the wind, the more apart their canopies were from those of their neighbors.

A study led by Michigan Technological University biologist Mark Rudnicki studied the pressures jolting lodgepole pine trees in Alberta, Canada, around 20 years later. They discovered that windy forests with tall, spindly trunks that are all the same height were most prone to crown shyness. The plants interlocked their canopies, filling in the spaces between adjacent crowns when Rudnicki and his team deployed nylon ropes to keep adjoining pines from clashing.

Other researchers have discovered hints that suggest there are more than one ways to overcome shyness, some of which might be less confrontational than these breezy tussles. For instance, Rudnicki claims that some trees may have learned to completely stop growing at their tips after realizing that any further leaves will be raked off.

According to Inés Ibáez, a forest ecologist at the University of Michigan, trees could thereby prevent needless damage. "For plants, producing new tissue is incredibly expensive... It's as if the trees are saying in advance that it is not worthwhile for them to grow here.

Trees that display crown shyness patterns include

Crown shyness is a species-specific condition that mostly affects trees that are the same species. Only a small number of tall tree species participate in this type of canopy disengagement to meet their physiological needs. Regardless of the environment or type of trees Angiosperms including black mangrove (*Avicennia germinans*), Borneo camphor (*Dryobalanops aromatic*), Eucalyptus (*Eucalyptus grandis*), Indonesian kapur (*Dryobalanops lanceolate*) Pitch apple (*Clussia alata*), Sal (*Shorea robusta*), etc, and conifers including lodgepole pine (*pinus contorta*), Japanese larch (*Larix kaempferi*), satka spruce (*Picea sitchensis*) etc. shows crown shyness.

The relation of the blue-green pigment 'phytochrome' (hypothesis)

Trees and plants use phytochromes as photoreceptors to help them detect light. They can be categorized as type I (activated by far-red light) or type II (activated by red light) according on their sensitivity to light in the visible spectrum's far-red and red regions.

Numerous distinctive photoreceptors are known to be involved in neighbor detection. By detecting backscattered far-red (FR) light, plants are able to determine their neighbors' whereabouts. This ability is largely attributed to the activity of phytochrome photoreceptors.

The crucial processes that take place inside the body of a tree or plant, like flowering and the growth of lateral branches are controlled by phytochrome.

As 'red light' is absorbed, tree growth is accelerated. However, if tree crowns come into contact with one another, it reduces the amount of red light that the trees absorb because there is more shade created as a result. Therefore, avoid this tree since it could exhibit crown shyness.

The relation of wind and abrasion with crown shyness (hypothesis)

Pruning is a process that involves removing particular branches, leaves, and buds from trees and other plants. The lateral growth of trees is impacted by pruning, and studies show that until mechanical abrasion, lateral branch growth is mainly unaffected by neighbors. A pair of scissors or other cutting implements can be used artificially to carry out this operation, or it can occur naturally as a result of winds.

Winds cause trees' flexible branches to wander randomly, and if this results in interaction with the crowns of other trees, it leads to needless cutting. Therefore, trimming with the aid of the wind may result in harm to a tree's crucial sections, such as its foliage, which is essential for conducting photosynthesis. As a result, trees may exhibit crown shyness. However, it has already been stated that if crowns are purposefully kept from meeting in the wind, the holes in the canopy are gradually and drastically filled.

M.R. Jacobs, an Australian forester, hypothesized that canopy gaps were caused by trees' growth tips being particularly sensitive to abrasion when he examined the patterns of crown shyness in eucalyptus in 1955. This illustrates how trees may exhibit crown shyness in order to avoid unneeded abrasion with nearby trees.

The camphor connection

Camphor is a substance that is solid and has the chemical formula $C10H16O$. The 'Eucalypt' and 'Dryobalanops' tree genera are the two most well-known tree types that exhibit crown shyness. The 'Camphor link' between these two genres is an intriguing fact. An investigation of the chemical components of the essential oil from the leaves of the eucalyptus globulus was conducted, and it was discovered that camphor is contained in the oil to some extent. Some species of "Dryobalanops," including Dryobalanops keithii, Dryobalanops lanceolata, Dryobalanops oblongifolia, and Dryobalanops rappa, have also been shown to contain camphor crystals.

The science behind crown shyness

The 'ideal' symmetrical shape of a tree's crown may not develop due to competition. Due to this, tree crowns occasionally exhibit a certain amount of "crown shyness," a

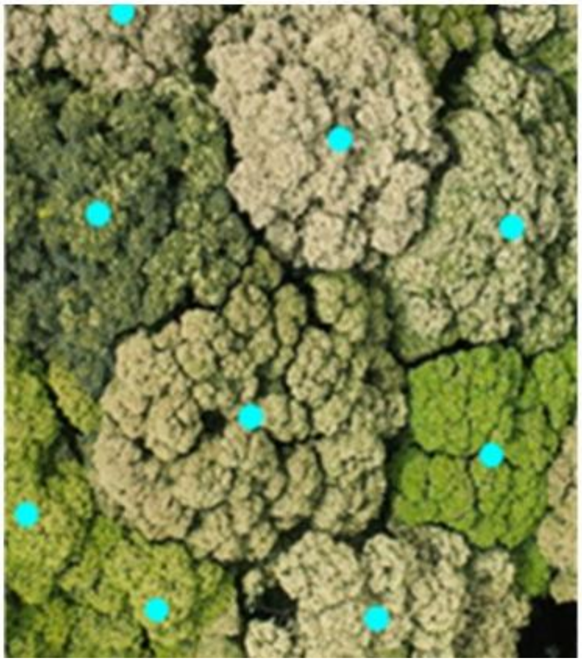

Fig. 2: Orthographic view of canopy shyness

condition in which tree crowns resist complete canopy closure by leaving tiny channel-like spaces between their crowns. For instance, tree crown gaps can be permanently formed by the abrasion of the outer twigs (Putz et al., 1984; Meng *et al.*, 2006; Hajek *et al.*, 2015). However, even benign touch can cause trees to steer branch growth away from neighboring tree crowns (Jaffe *et al.*, 1985).

According to research (Rudnicki *et al.*, 2003; Fish *et al.*, 2006; Goudie *et al.*, 2009), trees with slender stems—those with a large height to diameter ratio—sway more in windy conditions and are therefore more likely to collide with nearby trees. The speed and trajectory of vegetation growth, species population dynamics, and spatial heterogeneity in mature forests can all be impacted by canopy gaps left by tree mortality (Gray *et al.*, 2012).

Trees adjacent to gaps of various widths or in similar thinning treatments experience environmental changes, but these changes are not necessarily consistent with predictable growth. (Harrington and Reukema, 1983; Garber *et al.*, 2011) Rapid exposure in extensively disturbed stands can cause "thinning shock" and growth decreases that can continue up to 10 years.

Alternately, lower soil moisture availability in cracks during the dry summers caused by uptake by neighboring tree roots may also inhibit vegetation development. Because of the region's low precipitation levels during the growing season, soil moisture availability has a significant role in determining the make-up of plant communities and tree growth (Zobel *et al.*, 1976; Littell *et al.*, 2008).

Methodologies and techniques for studying crown shyness

1. Laser scanning equipment can be used to scan trees. Semi-automatically extracted individual tree point clouds are then manually adjusted as necessary. Point clouds of neighboring tree pairs are subjected to a metric that measures the surface complementarity (Sc) of a pair of protein molecules. After that, by computing their shapes, point clouds were used to create 3-D tree crown surfaces. (2002) Zee *et al.*
2. To determine whether stands with crown shyness retain longer crowns to make up for lost leaf area. In stands of varying heights, relative

densities, and site indices, we took measurements of canopy closure (the opposite of crown shyness), crown radius and length, and green litter fall. Canopy closure increased with site index and relative density and declined with stand height. According to Fish et al., green litter fall rose with height and relative density.

3. A spherical densitometer was used to estimate the percentage of canopy opening (Lemmon, 1956). The total percentage of canopy opening was calculated first. Second, the contribution of each of three classes of openings—gaps from large branch falls and tree falls; crown shyness; and other openings—could be estimated by directly observing the canopy, identifying various types of openings, and then referring back to the densitometer. If the overall area of an opening was at least 2 × 2 densiometer points (one grid square), it was classified as a gap and given a gap score.
4. A crown shyness opening had uniform dimensions that were one densitometer point's width by at least two densitometer points' length (the real dimensions were closer to 0.5 to 1.5 meters wide and at least 2 meters long). Small gaps and diffuse lighting through sparse vegetation were included in the miscellaneous category. Every 10 m along transects, readings were taken using the densitometer, with a few deviations to avoid influence from dense understory plants and trees. Each reading represented the average of four replicate observations. An arc sine square root transformation was used to fix the original data's positive skewness before statistical analysis 2016 (Rebertus *et al.*).

Phytochromes and shade-avoidance

Phytochrome is one of the most prevalent photoreceptors, a class of light-sensitive proteins found in plants and trees. Research on numerous species has revealed that plants are capable of modifying their growth as a means of shade avoidance. This photoreceptor is able to detect red light; which sunshine contains in plenty. This mechanism makes sense since when crowding happens; the outermost branches of the trees would receive less light because the branches of other trees cast shade.

The impact that shade has on the trees' trunks as well as their tips may be essential. What may develop here would be constrained by a highly matted canopy that would shade out sunlight from the forest floor. It's possible that trees who display crown shyness help the forest floor by promoting their own growth.

Potential threats to crown shyness

Human activities

Deforestation, logging, and land development are significant threats to crown shyness. When trees are cut down or removed for various purposes, the natural spacing and arrangement of trees can be disrupted, leading to the loss of crown shyness.

Climate change

Climate change can impact crown shyness by altering weather patterns, temperatures, and precipitation levels. Extreme weather events such as storms, droughts, or heavy rainfall can damage or uproot trees, potentially disrupting the crown shyness pattern.

Invasive species

Invasive plant species can outcompete native trees and disrupt their growth patterns. If invasive species invade an area with crown shyness, they may alter the natural arrangement of trees, reducing crown shyness over time.

Disease and pests

Tree diseases and pests can weaken and kill trees, leading to gaps in the canopy. This can affect crown shyness by altering the spacing between trees or by causing the death of one or more trees within the stand.

Air pollution

Air pollutants, such as sulfur dioxide and nitrogen oxides, can harm trees and reduce their vitality. Weakened trees may have altered growth patterns or become more susceptible to diseases and pests, which can disrupt crown shyness.

Soil Erosion

Soil erosion caused by factors like improper land management, deforestation, or urban development can destabilize tree roots and lead to the loss of trees. This can change the canopy structure and affect crown shyness.

Fire

Forest fires can be devastating to trees, potentially destroying large portions of a forest. In the aftermath of a fire, regrowth may not follow the same crown shyness patterns as the original forest.

Natural succession

Over time, as forests mature and go through natural successional stages, the canopy structure can change. This can result in alterations to crown shyness as different tree species replace others or as trees grow taller and close the gaps in the canopy.

Conclusion

Crown shyness creates an impressive puzzle-like structure of complementary tree crowns in forest canopies**.** The crown complementarity of pairs of trees and that pairs of slender trees grow more complementary crowns, suggesting that adjacent trees may adapt the shape of their crown as a result of physical touch.

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Biochar and its application in forestry

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Introduction

The process of pyrolysis, which involves heating organic material like plant remains without oxygen, produces biochar (Spokas et al. 2012). Biochar can be produced from a variety of organic materials, including grasses, crop leftovers, and trees. Given the longevity of biochar, applying it to soil to store carbon (C) has been proposed as one potential method of lowering atmospheric CO2 concentrations [Woolf et al. 2010]. Recently, biochar has been applied often to arable land both for soil amendment and C storage purposes in order to increase agricultural productivity (Ohtsuka *et al*. 2021).

The main component of biochar is carbon, which makes up a sizeable amount of its weight and typically ranges from about 50% to almost 90%. For a number of reasons, biochar's high carbon concentration is crucial to its ability to sequester carbon. The first benefit is that it makes biochar a reliable source of carbon. When incorporated into soil, biochar functions as a sink, efficiently collecting and holding carbon (C) over time and preventing its release as CO2 [Li and Chan 2022; Li and Tasnady 2023]. Additionally, the high levels of C that biochar contain enable higher soil C saturation levels.

According to several studies, biochar is a potential method for securing carbon (C), producing energy, increasing soil productivity, and improving soil and environmental quality. Land application of biochar has been shown to increase crop production through improved nutrient availability and soil physical, chemical, and biological properties and reduce loss of nutrients, sediment, and pollutants. Biochar can permanently sequester carbon in the soil and reduce net emissions of greenhouse gases.

The pyrolysis conditions and feedstock source have a significant impact on the characteristics of biochar. In comparison to manure-based biochar, wood biochar often has higher total carbon (C), lower ash content, lower total N, P, K, S, Ca, Mg, Al and Cu contents, lower potential cation exchange capacity (CEC), and exchangeable cations.

Biochar applications

The application of biochar paly a major role in soil improvement, soil nutrient and fertility, carbon sequestration, plant growth etc.,

Soil improvement

The addition of biochar in the soil mixture can increase net soil surface area, improve soil aeration, and enhance soil bulk density, porosity, and packing. By improving soil aggregate stability, soil preparation workability, water infiltration, and water holding capacity, biochar application also directly alters the interactions between soil and water. The movement of water, heat, and gases in soils as well as the improvement of soil quality can be attributed to a decrease in bulk density and an increase in soil porosity). Due to biochar's huge surface area and low bulk density caused by its wide pore size distribution, the physical characteristics of soil have changed.

Applying biochar to soil can change its pH level. Due to the alkaline character of many biochars, the positive effect is particularly obvious for acidic soils.

Soil nutrition and fertility

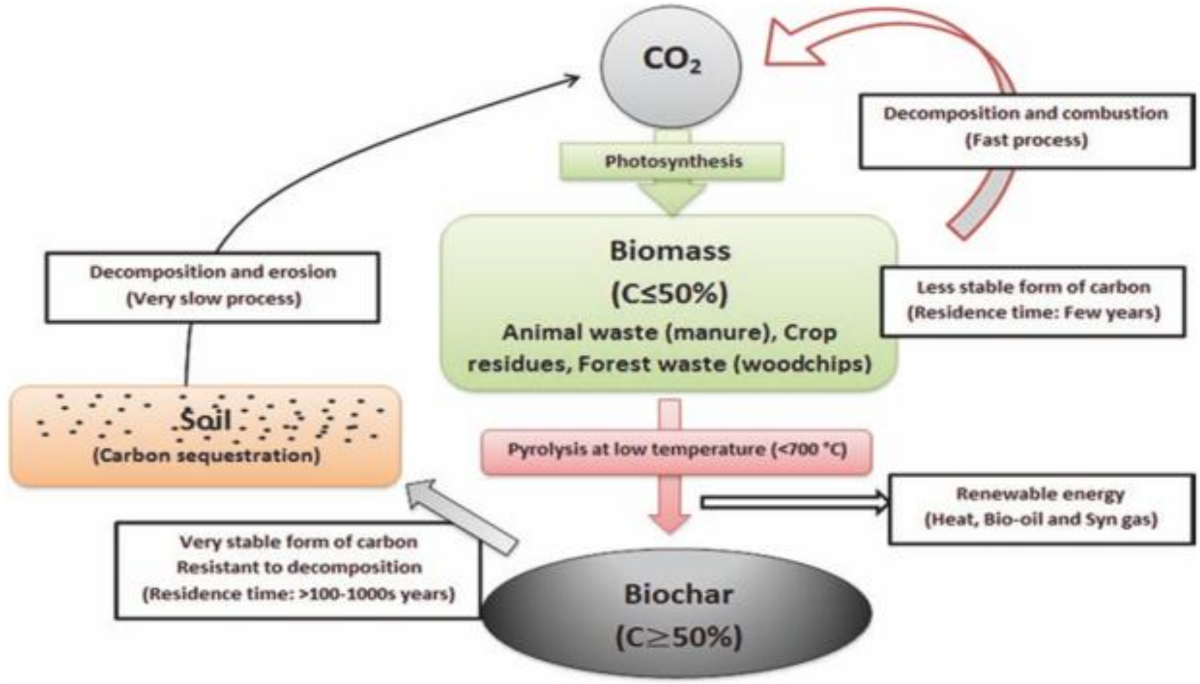
Carbon and organic materials are abundant in biochar. The introduction of biochar into the soil can reduce the net mineralization of nitrogen, NO2 emission, and leaching of NO3-. It has been suggested that adding biochar to soil can boost biological N fixation while reducing inorganic N leaching, N2O emissions, and NH3 volatilization. Incorporating biochar into soil improves nutrient cycling and mediates interactions between biochar and plant roots, which in turn affect root development and plant performance as a whole.

Plant growth

The following elements may have contributed to the amendment of biochar to the nutrient-deficient soils and the better plant growth as a result: nutrients provided by biochar; improved fertilizer use efficiency, increased CEC, soil pH, moisture retention and nutrient retention and bioavailability; decreased soil tensile strength and improved soil structure and induced favorable rhizosphere environment for earthworm population and microbiota.

Carbon sequestration

Biochar plays a significant role in carbon sequestration, which refers to the long-term storage of carbon dioxide (CO2) from the atmosphere. When biochar is applied to the soil, it helps to capture and store carbon, thereby reducing the amount of CO2 in the atmosphere



Process of carbon sequestration by biochar (Gupta *et al.*, 2020)

Conclusion

By absorbing and storing carbon in the soil, biochar is an essential component of carbon sequestration. Long-term carbon storage, lower greenhouse gas emissions, greater soil fertility, lessened soil erosion, and increased soil microbial activity are just a few of the advantages it provides. The possibilities of biochar in carbon sequestration and its involvement in resolving environmental issues are still being investigated by science.

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Agroforestry: A sustainable solution for biofuel production in India

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Introduction

India, currently the ninth largest economy globally, has experienced a remarkable real GDP growth of 8.7% over the past five years. To sustain a growth rate of 9% and to meet the energy demands of a rapidly developing nation, India is faced with the challenge of increasing its primary energy supply by three to four times. To sustain a growth rate of 9 %and to meet the energy needs of the country, India needs to increase primary energy supply by 3 to 4 times. India is currently the fourth largest consumer of crude oil and natural gas in the world. It is worth noting that out of the total consumption of petroleum products in India; more than 75% of the requirement is met through imports. The transportation sector is the largest consumer of petroleum energy, accounting for 70% of total consumption. As a result, a significant portion (37%) of foreign currency reserves is allocated towards paying the import bill for crude oil. However, it is important to note that the transportation sector's heavy reliance on petroleum energy is also a major contributor to air pollution. Biofuels have gained significant attention as a potential solution to the challenges posed by rising fuel prices, increasing energy demands, and the urgent need to reduce greenhouse gas emissions. However, one crucial concern that remains is the availability of an adequate supply of raw materials.

In order to meet the ambitious target of achieving a 20% mandatory blending ratio by 2017, as outlined in the National Biofuel Policy of 2009, a staggering amount of approximately 19 million metric tons (Mt) of biodiesel would be required. This demand poses a significant challenge when we consider that the current biofuel plantations cover only 0.5 million hectares (M ha) of land (Raju *et al.*, 2012).

As the demand for biofuels continues to grow at an annual rate of 7.5% in India, finding sustainable solutions becomes crucial. Simultaneously, the availability of wasteland, spanning approximately 43.15 million hectares, presents an opportunity to integrate perennial woody biofuel crops with traditional agriculture crops through agroforestry. This approach offers a promising path to meet the country's energy demands without compromising food production. By harnessing the potential of agroforestry, India can achieve a harmonious balance between energy security and environmental sustainability.

Biofuels are renewable liquid fuels derived from biological sources, and they have emerged as viable alternatives to conventional oil-based fuels in the energy sector. In India, the utilization of food crops such as corn, sweet sorghum, and soybean for biodiesel production is not feasible due to their importance as food sources. As a result, the focus has shifted towards non-edible oils extracted from the seeds of various tree species, some of which have traditionally been used as fuel sources in rural areas. These tree-borne oilseeds (TBOs) are cultivated in different agro-climatic conditions across the country, both in forested and non-forested areas, as well as in wastelands, deserts, and hilly regions. India possesses a vast potential for cultivating oilseed-producing trees, which can be grown and established on unused or underutilized lands, making them a valuable resource for biofuel production.

Indian scenario

India has taken a step forward by adopting bio-diesel and ethanol as alternative fuels to blend with traditional petro-diesel and petrol. This move comes as a response to the country's heavy reliance on oil, which currently accounts for 95% of transportation energy, and the ever-growing demand for transport fuel. In line with the findings of the third assessment of the Intergovernmental Panel on Climate Change (IPCC), the global demand for oil is projected to increase by a staggering 1.68% from 75 million barrels per day in 2002 to 120 million barrels per day by 2030, representing a tenfold rise. India took initiative for use of Bio-diesel and ethanol for blending with petro-diesel and petrol. In India, oil provides energy for 95% of transportation and the demand for transport fuel continues to rise. As per the third assessment of IPCC, the global oil demand will rise by 1.68% from 75 MB/day in the year 2002 to 120 MB/day in 2030 i.e. a tenfold increase. Energy input in agriculture is also increasing. Part of this energy should come from bio-based fuel, which is short term renewable

Potential value of TBOs

India is home to a diverse range of non-edible tree borne oilseeds (TBOs), with approximately 150 different species found within its borders. These TBOs play a significant role in various industries, particularly in the production of biodiesel. Some of the important TBOs used in India are Neem (*Azadirachta indica*), Karanj (*Pongamia pinnata*), Mahua (*Madhuca indica*), Jatropha (*Jatropha curcas*), Kusum (*Schleichera oleosa*), Pilu (*Salvadora oleoides*), Bhikal (*Prinsepia utilis*), Undi (Calophyllum inophyllum), Thumba (Citrullus colocynanthis), Sal (Shorea robusta) and Jojoba (*Simmondsia chinensis*). Two prominent TBOs in India are *Jatropha curcas* and *Pongamia pinnata*. The cultivation of *Jatropha* and *Pongamia* is feasible across a wide range of soil and climatic conditions, making them adaptable to various regions in India. These species have proven to be exceptionally well-suited for biodiesel production, thanks to their resilient nature, ease of cultivation, and ability to thrive in diverse agro-climatic conditions. Moreover, their oil possesses the ideal characteristics for biodiesel manufacturing. Furthermore, the production and utilization of biodiesel derived from these TBOs can significantly reduce the country's dependence on fossil fuels, mitigating the environmental impact associated with traditional energy sources.

National policy on bio-fuel

The union cabinet approved the National Policy on biofuels and its implementation on 24.12.2009. It also approved setting up of a National Biofuel Coordination Committee chaired by the Prime Minister to provide policy guidance and coordination. The Ministry of New and Renewable Energy has been designated as the coordinating Ministry for biofuel development and utilization, while specific roles have been assigned to other ministries concerned (Chandel*et al.*, (2017).

National mission on oil seeds

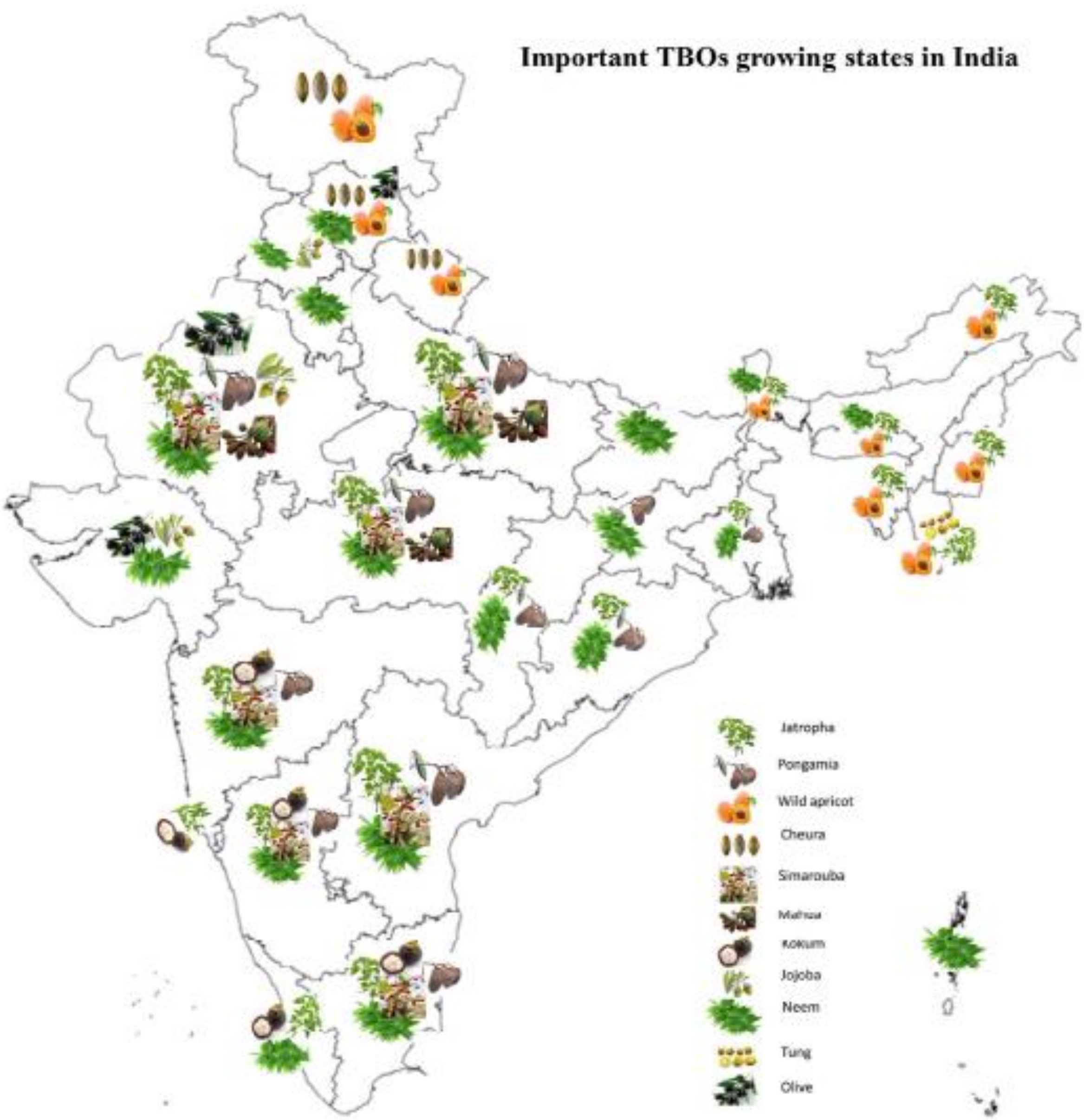
In the XIIth Plan, the Government of India introduced Mini Mission III as part of the National Mission on Oil Seeds and Oil Palm (NMOOP), which is being implemented by the Department of Agriculture & Cooperation. The primary objective of Mini Mission III is to promote the cultivation and utilization of 11 tree-borne oilseeds, namely *Simarouba*, Neem, Jojoba, Karanja, Mahua, wild Apricot, Jatropha, Cheura, Kokum, Tung, and Olive. The country has enormous potential of oilseeds producing trees which can be grown and established in the wastelandand varied agro-climatic conditions. But it is not being utilized fully due to lack of awareness of their uses, collection and marketing etc. Besides, lack of proper facility for storage, seed collection, long gestation period, fruiting/maturity season coinciding with rain etc. are main constraints limiting to the collection and utilization of above TBOs.

Important tree borne oilseeds for oil and biofuel growing in India

S No:	Botanical name	Family	Oil content in seed (%)
1	*Jatropha curcas*	Euphorbiaceae	30-40
2	*Pongamia pinnata* (Karanj)	Fabaceae	27-39
3	*Prunus armeniaca* (Wild Apricot)	Rosaceae	46
4	*Diploknema butyracea* (Cheura)	Sapotaceae	42-47
5	*Simarouba glauca* (Simarouba)	Simroubaceae	60-70
6	*Madhuca indica* (Mahua)	Sapotaceae	33-43
7	*Garcinia indica* (Kokum)	Clusioideae	33-43
8	*Simmondsia chinensis* (Jojoba)	Simmondsiaceae	50
9	*Azadirachta indica* (Neem)	Meliaceae	30-50
10	*Aleurites fordii* (Tung)	Euphorbiaceae	30-40
11	*Olea europaea* (Olive)	Oleaceae	45-70

Source: Dhyani*et al.*, (2015). Tree borne oilseeds for oil and biofuel

Cultivation of Tree Borne Oilseeds across different Agro-climatic zones of India



Source: Dhyani *et al*., (2015). Tree borne oilseeds for oil and biofuel

Seeds of *Jatropa*

Seeds of *Pongamia*

Seeds of Wild Apricot

Seeds of Cheura

Seeds of *Simarouba*

Seeds of Mahua

Seeds of Kokum

Seeds of Jojoba

Seeds of Neem

Seeds of Tung

Seeds of Olive

Source: Dhyani *et al.*, (2015). Tree borne oilseeds for oil and biofuel

Studies on agroforestry practices for biofuel

Suvera*et al.,* (2015) conducted a study on intercropping four species of *Ocimum* under a silvi-medicinal system with *Pongamia pinnata*. The results showed that the average oil yield of *Ocimum* spp. was significantly higher in the silvi-medicinal systems (50.75 kg/ha) compared to sole cropping (45.41 kg/ha).

Vishwanath *et al.,* (2014) conducted a study to evaluate the yield of Soybean as an intercrop in the presence of seven different biofuel tree species. They found that the highest yield of Soybean was observed under the agroforestry system with *Madhuca latifolia*, with a yield of 1577 kg/ha. This yield was comparable to the yield obtained with *Calophyllum inophyllum*, which was 1541 kg/ha.

Singh *et al.*, (2007) conducted a study and discovered that the varieties Dh 86 (1.85 t/ha) and ICGV 93468 (1.84 t/ha) of Groundnut exhibited a substantial increase in pod yield when grown in a *Jatropha*-based agroforestry system during the summer season.

Puri and Bangarwa (1992) conducted a study in the semi-arid regions of Haryana to examine the impact of *Azadirachta indica*, *Prosopis cineraria*, *Dalbergia sissoo*, and *Acacia nilotica* on the yield of irrigated Wheat crop. The findings revealed that there was no significant difference in Wheat yield under the agroforestry system when *A. indica* and *P. cineraria* were used. However, the study did find that the use of *D. sissoo* and *A. nilotica* resulted in a reduction in Wheat yield.

Banarjee*et al.,* (2013) conducted a study to compare the yield of Pigeon pea when grown under two different Tree-Based Organic (TBO) systems: Neem (*Azadirachta indica*) and Karanj (*Pongamia pinnata*). They observed that the yield of Pigeon pea was higher when grown under the Karanja plantation, with a yield of 1.51 t ha^{-1}, compared to the Neem plantation, which had a yield of 1.40 t ha^{-1}.

Economics of the system

Prathyusa*et al.,* (2013) found maximum BC ratio (2.88) when sweet corn was intercropped under *Pongamia+ Maize*based agri-silviculture system.

Solanki *et al.,* (2014) recorded higher BC ratio (1: 1 .67 and 1:1.71) of the system, when Basil was grown under *Sapota-Jatropha* based three tier agroforestry system.

Conclusion

Agroforestry presents a viable option for establishing a sustainable production system for biofuel supplies in India. To achieve this, a well-defined policy framework, along with improved planting materials and sustainable agronomic practices, is necessary. By considering the synergy between biofuel production and food security, India can pave the way for a successful biofuel program that meets current and future demands while ensuring economic returns for farmers. With the right policy decisions and scientific advancements, India can harness the potential of agroforestry and lead the way in sustainable biofuel production.

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Role of industrial wood plantations in the current scenario

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Abstract

This article discusses the pivotal role of Industrial Wood Plantations to address the surging demand for wood products due to population growth and industrialization. With a demand for 153 million m^3 of wood and only 60 million m^3 produced domestically, the reliance on imports is evident. Forecasts show increasing wood demand, notably in the furniture industry (from 9.47 to 13.34 million m^3 by 2030) and wood-based industries (from 15 to over 57 million m^3 by 2030). The article also explores the contributions of Forest Development Corporations to meet this demand. Despite challenges, industrial wood plantations provide essential employment opportunities, particularly in high-unemployment areas. Moreover, they act as safety nets for rural communities by offering access to resources like fuelwood and non-timber forest products.

Key words: Industrial wood plantations, wood demand, and rural development.

Introduction

Industrial Wood Plantations can be defined as "any tract of land planted mainly for timber producing species, including rubber, or non-timber species such as rattan and bamboo, primarily to supply the raw material requirements of existing or proposed wood processing plants and related industries"**.**

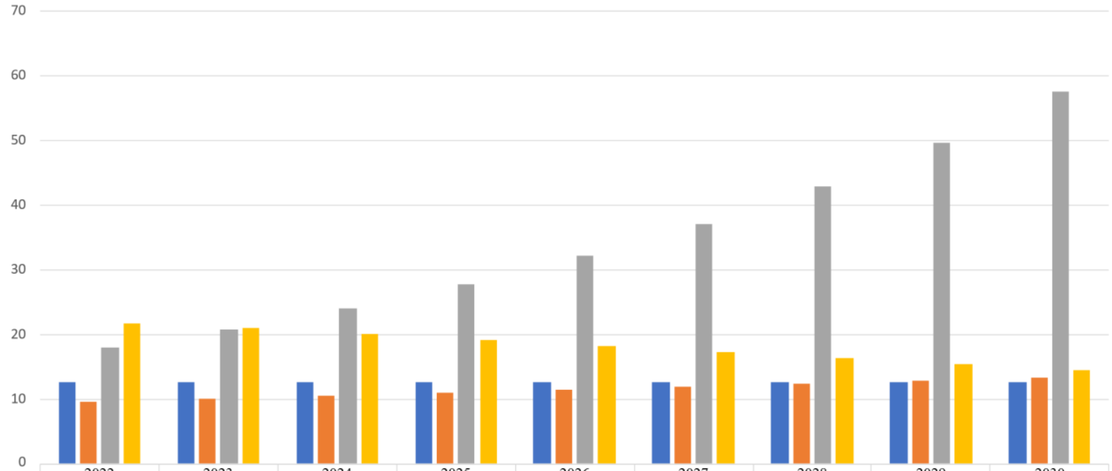
India holds a prominent position in wood production and utilization in Asia, driven by factors such as population growth, industrialization, and technological advancements, which have generated substantial demand for wood products and led to significant imports. The heightened demand is a consequence of India's forests exhibiting low productivity and legal constraints on accessing wood from natural forests. Consequently, there is a growing emphasis on the development of agro- and farm forestry systems to fulfil raw material requirements for both domestic and industrial purposes. Industrial plantations, with shorter rotations, prevent this decline in density, enabling them to achieve the status of a forest, as defined, much earlier than their counterparts on forest land. The establishment of industrial wood plantations serves the purpose of providing a sustainable and well-managed source of wood for industrial needs.

Need for industrial wood plantations

In 2020, wood-based industries in India required 153 million m^3 of woods, but the domestic market could only supply 60 million m^3due to the country's low wood productivity (0.7 m^3 ha^{-1} $year^{-1}$). This shortfall necessitates India to heavily depend on imported raw materials to meet its industrial demands. Furthermore, the

National Forest Policy of 1988 advised wood-based industries to generate their own resources through contract farming and industrial agroforestry.

Roundwood demand forecasts by wood –based sector in India, 2021 - 2030 (million cubic meter Round Wood equivalent)



	2022	2023	2024	2025	2026	2027	2028	2029	2030
Pulp & Paper	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Furniture	9.47	9.95	10.44	10.92	11.4	11.89	12.37	12.86	13.34
Plywood	17.88	20.69	23.94	27.7	32.06	37.1	42.93	49.68	57.49
Construction	21.79	20.88	19.96	19.05	18.14	17.22	16.31	15.39	14.48

Source: Kant and Nautiyal, 2021 ■ Pulp & Paper ■ Furniture ■ Plywood ■ Construction

Demand forecast of wood

The furniture industry is expected to experience a gradual rise in the demand for round wood, projecting an increase from 9.47 million m^3in 2021 to around 13.34 million $m^3$by 2030. In contrast, the demand for wood in the plywood and other wood-based industries is set to surge significantly, escalating from 15 million m^3in 2021 to surpass 57 million $m^3$by the year 2030.

Role of Forest Development Corporations

In response to the NCA 1972 Interim Report, Indian State Governments established Forest Development Corporations (FDCs) with a multifaceted commercial approach. These FDCs cultivate industrial plantations, including Teak, Eucalyptus, and Bamboo, to enhance forest resource production, restore degraded areas, manage timber and non-timber forest product trade, oversee forest-based industries, support farmers in marketing, and provide consultation for bio-aesthetic plantations.

Industrial wood plantations enhance local livelihoods and improve employment

Industrial wood plantations play a vital role in meeting the global demand for industrial wood products. These establishments, along with sawmills, provide employment, especially in areas facing high unemployment and limited economic growth. However, they suffer from drawbacks such as poor working conditions, low wages, and a lack of formal contracts, leading to noticeable gender disparities, mainly with men occupying most roles, and only a few women primarily working in nurseries. Despite these issues, plantations contribute economically to rural development, offering job opportunities for local communities. Typically, casual workers view plantation jobs as a reliable source of income in the absence of long-term employment options. Additionally, plantation development offers substantial non-wage benefits, like access to fuelwood (an important domestic energy source), non-timber forest products, livestock shade, and other environmental advantages. As a result, plantations serve as a safety net for these impoverished rural communities.

Conclusion

Industrial Wood Plantations in India have emerged as a critical response to the surging demand for wood products, driven by population growth, industrialization, and technological progress. With India's natural forests facing low productivity and legal restrictions on wood access, the development of these plantations has become imperative to meet the raw material needs of the nation's wood-based industries. Shorter rotations in industrial plantations prevent the decline in planting density and expedite their recognition as forests. These plantations fulfill the role of providing a sustainable and well-managed source of wood for industrial purposes. Despite challenges, such as poor working conditions and gender disparities, industrial wood plantations significantly contribute to local employment and act as a safety net for impoverished rural communities.

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Innovative forage crop management: A key to sustainable livestock agriculture

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Introduction

Livestock husbandry is an important sector of our economy and a major component of the National Food Security system. Livestock production is the backbone of Indian agriculture and a source of employment and ultimate livelihood for 70% of the population in rural areas. Shift in the lifestyle of people in feeding habits towards milk products, meat and eggs resulted increase in the demand for livestock products. Although we are Largest producer of milk, but productivity is very low and the reasons behind low productivity of Livestock are inadequate availability of quality fodder, unavailability of fodder throughout the year and poor genetic constitution and diseases. Forage crops are the important component of the livestock based farming system. Balanced nutrition to livestock through feed and fodder has been become possible in selected pockets of the country, where intensive fodder production systems under improved package of practices are practiced. Forages constitute the base of a complete food chain and are the source of protein and fat *i.e.* meat, egg, milk and other dairy products that become available to human beings through intermediaries like cattle, sheep, goats, poultry etc. Since feeding alone accounts for 60-70% of the total cost of milk production, availability of adequate nutritious fodder coming from cheaper sources assumes greater importance. Out of total Indian geographical area of about 328 million hectares, only 161.3 million hectares (roughly 52.7 percent) is arable. Examining the land resources available for fodder and forage crops, it is estimated that the average cultivated area devoted to fodder production is only about 4.6% of the total area. In India where over 75% farmers are small and marginal holders, livestock is the main source of livelihood for a majority of the rural population.

Forage resource development

The forage resource development is a more complex issue than food and commercial crops. Lack of momentum in fodder development in the country owes much also to poor organizational structure. Keeping in view the huge livestock population and their nutritional security, the area under fodder cultivation should not be less than 10% of the gross cropped area.

Indian grasslands are also most neglected and abused ecosystems in the country. Indian grasslands/grazing lands have been observed as fragile eco-systems and ranked them as class IV and V in their land capability classification. The carrying capacity of these areas is 0.20 to 1.47 adult cattle units (ACU)/ha, but the present stocking rates are much higher. In semi-arid areas, the present stocking rates are 1 to 51 ACU/ha against the carrying capacity of 1 ACU/ha, while in the arid areas, the stocking rates are 1 to 4 ACU/ha against the carrying capacity of 0.2-0.5 ACU/ha. Thus overgrazing has caused the near complete loss of edible forage species. A holistic approach is required for grassland development. If grasslands are removed from a village, it disturbs the whole village, its economy, social aspects and may lead to migration of people. Therefore, keeping grassland intact, progressive, prosperous and well harmonized with agriculture systems and development programs is of utmost importantance, particularly in India.

Choice of suitable forage crops and their variety:

Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage (cut green and fed fresh), silage (preserved under anaerobic condition) and hay (dehydrated green fodder).

Leguminous fodders

The leguminous fodders have special significance because of high herbage protein and partial independence from soil for their nitrogen needs.

Non-leguminous fodders

Non-leguminous fodders provide energy-rich herbage to livestock.

Crop and its variety should be selected according to soil type, area and situation.

For irrigated and arable land conditions: Bajra × Napier hybrids, guinea grass, rye grass, setaria, maize, sorghum, oat, cowpea, berseem, lucerne, etc.

For rainfed and non-arable land: Perennial grasses like Tall fescue, Orchard grass, *Brachiaria*spp., *Paspalam*spp., *Chrysopogon*spp., *Bothriocloa*spp., *Setaria*spp., Guinea grass, etc and Perennial legumes like red clover, white clover and *Stylosanthes etc.*

The important high yielding cultivated forage crop varieties under different situations are enlisted as under;

Crop and Variety	Areas of adaptation	Green forage (q/ha)
I Cultivated Fodder Cereals		
Sorghum (*Sorghum bicolor* (L) Moench)		
Pusa Chari-6 & 9	Whole of India	400-450
HC-136	Whole of India	400-500
M.P. Chari	North India	400-500
Meethi Sudan (SSG-59-3)	Whole of India (Multicut)	500-550
Jawahar Chari-6	M.P.	350-450
Jawahar Chari-69	M.P. (Multicut)	350-450
HC-308	Whole India	350-550

PCH 106	Whole India	650-900
Pantchari 3 (UPFS-23)	U.P.	350-450
MFSH-3	Whole India	500-850
Bajra (*Pennisetum glaucum* (L) Leek.)		
Giant Bajra	Entire bajra growing tract	350-400
K-677	Entire bajra growing tract	400-500
Raj Bajra Chari-2	Entire Bjara growing tract	300-450
L-72	Entire bajra growing tract	400-550
Fooder cumbu-8 (TNSC-1)	Entire Bajra growing tract	270-400
Maize (*Zea mays* L.)		
African tall	Whole of India	500-600
Vijay composite	Whole of India	350-450
Jawahar	Whole of India	350-450
Moti composite	Whole of India	350-425
Manjari Composite	Whole of India	400-450
Oats (*Avenasativa* L.)		
Kent	Whole of India	450-500
OS-6	Whole of India	400-500
UPO-212	Whole of India	370-520
OL-125	Whole of India	350-480
UPO-94	Whole of India (Multicut)	450-500
JHO-822	Central India	450-550
JHO-851 (Multicut)	Whole of India	500-550
II Cultivated Fodder Legumes		
Cowpea (*Vigna Unguiculata* (L) Walp.)		
NP-3 (EC-4216)	Northern, Western and Central India	300-350

UPC-287	Whole of India	350-400
UPC-5286	Whole of India	350-450
UPC 8705	Whole of India	300-420
C-30	Whole of India	300-350
Shweta (No.998)	Whole of India	300-350
BundelLobia 1 (IFC-8401)	Whole of India	250-300
Guar (*Cyamopsis tetragonoloba* (L) Taub.)		
HFG 156	Guar growing area of India	200-250
FS-277	Guar growing area of India	175-250
Bundel Guar-1(IGFRI 212-1)	Guar growing area of India	220-350
Bundel Guar-2 (IGFRI 2395-2)	Guar growing area of India	280-400
HFG-119	Guar growing area of India	250-300
Berseem (*Trifolium alexandrinum* L)		
Mescavi	Northern and Central India	800-900
Wardan (S-99-1)	All India	900-1500
JB-2	Northern and Central India	900-1000
BB 2 (JHB 146)	North West and Central zone	580-850
BL-2	Northern India	650-900
UPB-103	Northern, Central and part of South India	1000-1150
Lucerne (*Medicago sativa* L)		
Type-9	Whole of India	900-1000
Anand-2	Gujrat, Rajasthan, Haryana, M.P. & U.P.	850-900
RL 88	Whole of India	700-1000
SS-627	Haryana, Punjab, Delhi, U.P., Rajasthan, H.P. & M.P.	800-950

III Cultivated fodder -perennial grasses

Napier-Bajra hybrid (*Pennisetum purpureum* x *P. glaucum*)

Pusa Giant	Whole of India and tropics	1000-1300
Swetika-1 (IGFRI-3)	U.P., M.P., NE hills, Punjab & hills of North India	1100-1200
IGFRI-6	U.P., H.P., NE hills, Punjab and hills of	1200-1300
North India (intercropping)		
Yeshwant (RBN-9)	Whole of India	1300-1400

Guinea grass (*Panicum maximum*) Jacq.

PGG-1	North-West states	900-1100
PGG-3	Northern, North-West and Central India	800-1000
PGG-9	Northern, North-West and Central India	900-1100

Cropping systems

Cropping systems should be selected in such a way that it should also help in stability and sustainability of soil fertility in long run, minimize harbouring of insect-pest and diseases. Potential intensive cropping system according to agro-climatic zones are as under;

North Zone

1. Maize + Cowpea – Sorghum + Cowpea 2 cuts) – Berseem + Mustard.
2. Sudan grass + Cowpea – Maize + Cowpea – Turnip – Oats (two cuts).
3. Hybrid Napier or Setaria inter-planted with cowpea in summer and Berseem in winter (9 -10 cuts/year).
4. Teosinte + Cowpea (two cuts) – Carrot – Oats + Mustard/Senji (two cuts).

Western and Central Zone

1. Bajra + Guar (Clusterbean) (2 cuts) – Annual Lucerne (6 cuts).
2. MP Chari + Cowpea (2 cuts) – Maize + Cowpea - Teosinte + Cowpea (2 cuts).
3. Hybrid Napier or Guinea or Setaria grass inter-planted with Cowpea in summer + Berseem in winter (8-9 cuts/year).
4. Hybrid Napier or Guinea or Setaria grass interplanted with Lucerne (8-9 cuts/ year).

Southern zone

1. Sorghum + Cowpea (3 cuts) – Maize + Cowpea – Maize + Cowpea
2. Hybrid Napier or Guinea or Setaria grass inter-planted with Lucerne (8-9 cuts/year)
3. Hybrid Napier + Subabul / Sesbania (9-11 cuts/year).
4. Sudan grass + Cowpea (3 cuts) – Sorghum+ Cowpea (3 cuts).
5. Para grass + Centro (Centrosema pubescens) (9-11 cuts/year).

Eastern zone

1. Maize + Cowpea – Teosinte + Rice bean (2 cuts) – Berseem + Mustard (3 cuts).

2. M.P. Chari + Cowpea – Dinanath grass (2 cuts) – Berseem + Mustard (3 cuts).
3. Para grass + Centrosemapubescens (8-9 cuts/year).
4. Hybrid Napier or Setaria grass inter-planted with Subabul or Common Sesban (Sesbaniasesban) (9-10 cuts/year).

Package of practices of important forage crops

Crop	Sowing time	Seed rate (kg/ha)	Spacing and depth
Sorghum	March-July	25-35	30x10 cm, 3 cm
Maize	April - July	40-50	30x15 cm, 3-4 cm
Pearlmillet	March-July	12-15	25x10 cm, 2 cm
Cowpea	March-July	20-25	30x 10 cm, 3 cm
Cluster bean	April - July	25-40	30-45 cm R to R
Berseem	October	25	25 cm R to R or broadcasting
Lucerne	Mid of October	12-15	25 cm R to R, 2 cm
Lathyrus	October to November	50	30-35 cm R to R , 4 cm
Oat	Mid October to last November	80-100	20-25 cm cm R to R for low tillering& 25-30 cm R to R for high tillering varieties, 4 cm depth
Barley	October to November	80-100	20-25 cm R to R, 4 cm
Berseem	October	25	25 cm R to R or broadcasting
Lucerne	Mid of October	12-15	25 cm R to R, 2 cm
Lathyrus	October to November	50	30-35 cm R to R , 4 cm
NB Hybrid	March to August	20000 to 35000 rooted slips	100x50 to 75x50 cm
Guinea grass	March to August	20000 to 40000 rooted slips	100x50 to 50x50 cm

Crop	FYM (t/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	N top dressing (kg/ha)
Sorghum (S)	25	30	40	20	30 kg N/ha 30 DAS
Sorghum (M)	25	30	40	20	30 kg N/ha 30 DAS, 30 kg N/ha just after cutting
Maize	25	30	40	20	30 kg N/ha 30 DAS
Pearlmillet	25	25	20	12.5	25 kg N/ha 30 DAS
Cowpea	25	25	40	20	-
Cluster bean		15	90	20	
Berseem	-	20	80-90	30-40	-
Lucerne	-	20	60-75	40	-
Lathyrus	-	20	40	-	-
Oat (one cut)	15	60	40	-	20 kg N after Ist irrigation
Oat (two cut)	15	80	40	-	40 kg N after Ist cut
Oat (multi cut)	15	100-120	40	40	40 kg N after each cut
Barley	-	45	30	20	15 kg N after Ist irrigation
NB Hybrid	15-25	40	50	50	30 kg N after each cut
Guinea grass	15-25	50	50	50	30 kg N after each cut

Crop	**Irrigation No./ scheduling**
Maize	It requires 5-6 irrigations at 10-12 days interval during summer season and 1-2 during rainy season. In excess rainfall areas, proper drainage facility should be assured.
Sorghum	Rainy season (July) sown crop may also require 2 irrigations depending upon distribution of rains. For summer sown crop, 5-6 irrigations are required due to high ET demand.
BN hybrid	The crop should be planted in well moist soil condition. During monsoon seasons, the irrigation is rarely needed in event of long monsoon failure. The crop needs regular irrigation at an interval of 15-18 days in March to May, at 10-12 days interval in summer months.
Berseem	October to February: 14-16 days interval (Clay and clay loam soil), 12-14 days interval (Loamy soil) October to February: 10-12 days interval (Clay and clay loan soil), 8-10 days interval (Loamy soil)
Lucerne	15-20/ At early stage:7-10 days interval. Later on: 25-30 days interval During summer: 15-20 days interval.
Oat	First: 20-25 DAS, 4-5 (Single cut) & 7-8 (Double cut)

Herbicide based weed management strategies for fodder crops

Crop	Strategies
Cowpea	Pre-plant incorporation of Trifluralin (0.75 kg with 600 litre of water/ha) herbicide.
Guar	Pre-plant incorporation of Nitralin (0.75 kg /ha) herbicide.
Berseem	Dipping the seed in 5-10% solution of table salt for five minutes, light weight weed seeds float while heavy weight forage seeds will settle down at the bottom. Use stale seed bed technique: Pre-sown irrigation followed by spraying of paraquat herbicide for newly germinated weeds. Pre-plant incorporation of EPTC (1.5 kg /ha) herbicide. Pre-emergence application of Butachlor (2.0 kg/ha), Pendimethalin (0.75 kg/ha) Post emergence (3-4 trifoliate leaf stage) application of MCPB (0.50 kg/ha) herbicide for control of broad leaf weeds. Note: EPTC should not be used in fields where a trizine herbicide was applied in the previous season
Lucerne	Dipping the seed in 5-10% solution of table salt for five minutes, light weight weed seeds float while heavy weight forage seeds will settle down at the bottom. Use stale seed bed technique: Pre-sown irrigation followed by spraying of paraquat herbicide for newly germinated weeds. Pre-plant incorporation of Fluchloralin (1.0 kg/ha), benefin (0.75-1.5 kg/ha herbicide. Pre-emergence application of Pendimethalin (0.5-1.0 kg/ha)andoxadiozon (0.5 kg/ha) herbicide. Post emergence (3-4 trifoliate leaf stage) application of 2, 4-DB (0.50-0.75 kg/ha) herbicide for control of broad leaf weeds. Note:
Sorghum	Broadcast/ cross sowing of cowpea (25 kg/ha) Pre-emergence and post emergence (at initial growth of forage) application of Atrazine (0.50-0.75 kg/ha), pre-emergence application of Pendimethalin (1.0 kg/ha).
Maize	Intercropping with cowpea (25 kg/ha) Pre-emergence application of Atrazine (0.75 kg/ha), Pendimethalin (1.0 kg/ha) with 600 litre of water after sowing on same day or positively by next day before the emergence of seedlings of the crop.
Pearlmillet	Pre-emergence application of Atrazine (0.50 kg/ha) with 600 litre of water after sowing on same day or positively by next day before the emergence of seedlings of the crop.
Oat	Pre-emergence application of Linuran (0.5 kg/ha) Post-emengence application of 2,4- D sodium salt (0.75 kg/ha)

Harvesting schedule of different fodder crops is summarized below;

Crop	Stage of harvest	Time of harvesting
Sorghum (Single cut)	After flowering and up to milking stage	75-80 days after sowing *Note:* To overcome the possibility of HCN poisoning, the crop should be properly irrigated during summer and harvested only after 40-45 days of growth.
Sorghum (Multi cut)	-	2 months after sowing and subsequent cuts 35-40 days after the previous cut *Note:* To overcome the possibility of HCN poisoning, the crop should be properly irrigated during summer and harvested only after 40-45 days of growth.
Maize	Cob formation to milk stage	60-70 days after sowing
Bajra (Single cut)	Boot leaf stage to early flowering	60-75 days after sowing
Bajra (Multi cut)	-	Ist cut 55-60 days after sowing and subsequent cuts 35-40 days after the previous cut
Cowpea	At 50 % flowering	50-60 days after sowing As mixed crop at the time of companion crop
Guar	-	55 days after sowing
Berseem	-	1^{st} cut: 50 – 55 days after sowing & subsequent 25-30 days (5-6 cuts)
Lucerne	-	1^{st} cut: 65-80 days after sowing & subsequent 25-30 days (7-8 cuts)
Lathyrus	50 % flowering	65-70 days after sowing
Oat (single cut)	50 % flowering stage	60 days after sowing
Oat(multi cut)	-	Double cut 1^{st} : 60 DAS & II cut at 50 % flowering

		Multi cut 1st: 60 DAS, II cut 45 days and III cut at 50 % flowering
Berseem	-	1st cut: 50 – 55 days after sowing & subsequent 25-30 days (5-6 cuts)
NB hybrid and Guinea grass	-	Ist 75 days after planting, subsequent at 30 days interval

Varieties released / identified recently by AICRP / AICRP forage centers at national and state level

Crop	Variety	Institution	Area of adoption
*Dichanthium*sp	Marvel-09-4	MPKV, Rahuri	Guj, UP, MP, MH
	JHD-2013-2	IGFRI, Jhansi	Pb, Raj
	Phule Marvel-06-40	MPKV, Rahuri	Maharashtra
	PhuleGovardhan	MPKV, Rahuri	Maharashtra
Cenchrus sp.	RCC-10-6	MPKV, Rahuri	Pb, Raj, Guj, UP, MH
	TNCS 265	TNAU, Coimbatore	Kar, TN, AP, TL
	IGFRI-96-706	IGFRI, Jhansi	Rajasthan
	IG-67-365	IGFRI, Jhansi	GUJ, MH, MP, UP
	GAAG-1	AAU, Anand	Gujarat
	RCCB-2	SKRAU, Bikaner	Rajasthan
Pennisetum hybrid	VTPH-3	IGFRI, Jhansi	Pb, Har, Guj, MH, HP, Assam
Bajra Napier hybrid	PBN 342	PAU, Ludhiana	Pb, Har, Raj, Odh, Assam, TN, Kar
	PBN-351	PAU, Ludhiana	MH, Guj, UP, MP, CG
	TNCN 1280	TNAU, Coimbatore	Pb, Har, Raj, MH, Guj, UP, MP, CG

	BNH-14	BAIF, Urulikanchan	Pb, Har, Raj, Kar, TN, AP, TL, Kerala
	BNH-11	BAIF, Urulikanchan	Pb, Har, Raj, Kar, TN, AP, TL, Kerala MH, Guj, UP, MP, CG
	BNH-10	BAIF, Urulikanchan	All India except Hill
	CO (BN) 5	TNAU, Coimbatore	All India
	PhuleGunwant	MPKV, Rahuri	Maharashtra
Hedge Lucerne	TND 1308	TNAU, Coimbatore	Pb, Raj, MH, Guj, UP, TL, Kar, Kerala, TN,WB
	TSLH-1	PJTSAU, Hyderabad	MH, Guj, UP
Clitoriaternatea	JGCT-2013-3	IGFRI, Jhansi	MH, Raj, Pb, Har, UP, MP, Guj
Vicia sativa	JVS-1	JNKVV, Jabalpur	MP, UP, CG, MH
Forage Oat	OL 1760	PAU, Ludhiana	Kar, TN, AP, TL
	OL-1769-1	PAU, Ludhiana	UP, MH, Guj, CG, MP
	OL-1802-1	PAU, Ludhiana	Raj, Har, Pb, UK, UP
	SKO-225	SKUAST-K, Srinagar	J&K, HP, UK
	OS-424	CCS HAU, Hisar	J&K, HP, UK
	JHO 2012-2	IGFRI, Jhansi	Kar, TN, AP, TL
	HFO-427	CCS HAU, Hisar	Kar, TN, AP, TL, Kerala
	JHO-2015-1	IGFRI, Jhansi	J&K, HP,
	OL-1869-1	PAU, Ludhiana	Raj, Har, Pb, UK, UP, MH, Guj, MP, CG
	HFO-607	CCS HAU, Hisar	Raj, har, Pb, UK, UP
	OL-1861	PAU, Ludhiana	All India except hill zone

	JHO-2010-1	IGFRI, Jhansi	Andhra Pradesh, Karnataka, TN
	OS-377	HAU, Hisar	UP, Maharashtra, Gujarat, MP, CG
	JO-03-93	JNKVV, Jabalpur	MP, Gujarat, Maharashtra, UP
	JO-03-91	JNKVV, Jabalpur	MP, Gujarat, Maharashtra and UP
	SKO-96	SKUAST, Srinagar	HP, J&K
	UPO-06-1	GBPUA&T, Pantnagar	Uttarakhand
	OL-10	PAU, Ludhiana	Punjab
	Pant forage oat 3	GBPUAT, Pantnagar	Uttarakhand
	Pant forage oat 4	GBPUAT, Pantnagar	Uttarakhand
	NDO-711	NDUAT, Faizabad	Uttar Pradesh
	UPO-06-2	GBPUA&T, Pantnagar	Uttarakhand
	JHO 2009-1	IGFRI, Jhansi	Central zone
	OS-403	HAU, Hisar	NE, NW, South zone
	OS 405	CCS HAU, Hisar	Central Zone of India
	RO-11-1	MPKV, Rahuri	All India (except hill zone)
	OL 1802	PAU, Ludhiana	Central zone
	OL 1804	PAU, Ludhiana	North East Zone
Forage Cowpea	CO 9	TNAU, Coimbatore	Tamil Nadu
	TNFC 0926	TNAU, Coimbatore	NEZ
	Aiswarya	KAU	Southern Kerala
	IL 1177	IGFRI, Jhansi	Jharkhand, Odhisha, WB, UP

	MFC 09-1	UAS, Mandya	Karnataka
	Vijaya	PJTSAU, Hyderabad	Telangana
Forage Rice bean	KRB-19	BCKVV, Kalyani	North eastern region
	Shyamalima	AAU, Jorhat	Assam
	JRBJ05-2	JNKVV, Jabalpur	MP, Chhatishgarh, & NEZ
Forage Lathyrus	Madhuri	AAU, Jorhat	Assam
Guinea Grass	JHGG 08-1	IGFRI, Jhansi	All India
	RSDGG-1	IGFRI, Jhansi	All India
	TNGG-062	TNAU, Coimbatore	All India
	CO (GG) 3	TNAU, Coimbatore	All India
Forage Maize	TSFM-15-5	PJTSAU, Hyderabad	Kar, TN, AP, TL, Pudducherry
Fodder Bajra	TSFB-15-4	PJTSAU, Hyderabad	Kar, TN, AP, TL
	TSFB-15-8	PJTSAU, Hyderabad	Kar, TN, AP, TL
	RBB-1	SKRAU, Bikaner	Rajasthan
	PAC-981	Advanta Private Ltd.	Punjab, Haryana, Rajasthan, Gujarat, MP, Maharashtra, UP
	Motibajra	PJTSAU, Hyderabad	Telangana
	APFB-09-1	PJTSAU, Hyderabad	Telangana
	Raj Bajra-1(RBB-1)	SKRAU, Bikaner	Rajasthan
Setaria Grass	S-25	CSKHPKV, Palampur	HP, UK
	S-18	HPKV, Palampur	HP and Uttrakhand

Tall fescue	Hima-14	HPKV, Palampur	HP, Uttarakhand, J& K
Sewan grass	RLSB 11-50	SKRAU, Bikaner	Rajasthan
Lolium (annual rye grass)	PBRG-2	PAU, Ludhiana	HP, UK, J&K, Pb
	Palam Rye Grass-1	CSKHPKV, Palampur	HP, UK, J&K, Pb
Lucerne	TNLC-14	TNAU, Coimbatore	Kar, TN, AP, TL
	Alamdar 51	M/S KhojaHabibMamad, Kutchh	Kar, TN, AP, TL
	TNLC 15 as Co-4	TNAU, Coimbatore	Kar, TN, AP, TL
	Anand Lucerne-4	AAU, Anand	Punjab, Rajasthan
	Lucerne CO-2	TNAU, Coimbatore	Tamil Nadu
	RRB 07-1	SKRAU, Bikaner	Punjab, Rajasthan
Berseem Single cut	JSBC-1	IGFRI, Jhansi	MH, Raj, Pb, Har, UP, MP
Berseem	JB-05-9	JNKVV, Jabalpur	UK, Har, Pb, UP, Raj
	HB-2	HAU, Hisar	Haryana

Fodder production in fruit orchards through Horti-pasture

India has the largest potential for production of quality tropical, sub tropical & temperate horticultural crops. We are bestowed with a variety of agro-climatic conditions ranging from tropical, sub-tropical, sub temperate, temperate and cold arid. Each agro-climatic region has its own potential to grow specific fruit, providing an opportunity to grow a variety of fruits during the major part of the year. Use of forage crops (perennial grass/legume mixtures) in the interspaces of fruit orchards offers a huge potential as a sustainable orchard floor management approach, combined with grazing by sheep for the improvement of physical, chemical and biological properties of orchard soils and augmenting forage resource availability. Establishment and upscaling of hortipastoral models should be replicated at farmers' fields. There is a need for development of recommendations/advisories for managing animal, forage crops, and fruit trees. This will require greater knowledge regarding three-way interactions between livestock, pasture and fruit trees. To encourage more farmers/orchardists and educated youth in the animal husbandry and horticulture sector, hortipastoral models need to be developed along with introduction of fodder conservation techniques.

Fodder Production from permanent pasture/ grazing lands/forests

Major threats to forage crop genetic resources includes conversion of natural grasslands and pastures to agricultural lands, pasture degradation and deforestation, diversion of grasslands and pastures to developmental projects, improper grazing management and rural/urban encroachment need to be checked. Appropriate strategies are needed for effective utilization of grasslands based on their carrying capacity and nutritive status.Involvement of the locals and end-users for grasslands and natural pastures through participatory management needs to be emphasizedon the lines of the Joint Forest Management. Suitable grasses and legume mixtures need to be introduced in grasslands to increase their production potential and carrying capacity.Restoration, protection, conservation and development and sustainable utilization of these rangelands grasslands are very important for sustaining livestock but no focus has been given on conservation and improvement of these grasslands and rangelands.

Establishment of Silvipastures

Silvipasture can enhance average dry fodder biomass production from 1.25 – 4.50 tonnes per hectare (t/ha) per year on natural grassland to 4.50 – 8.70 t/haper year (Chinnaondi 2014). The average animal carrying capacity can be increased up to 50% in comparison to natural grazing land during rainfed season by adopting silvipastural models.Trees in silvipastures supply fodder during lean period thereby it can reduce feeding cost thus ensures round the year fodder supply.In addition to producing round the year fodder silvipastures also supply fuel wood, timber, non timber forest products; sequester atmospheric carbon dioxide; conserve soil and water; improves soil fertility too. Therefore, silvipastures can be established in the degraded forest lands or other wastelands which will be a win-win situation as on the one side it will reclaim the wasteland and on the other side it will provide nutritious fodder for livestock. Moreover, tree leaf fodder quality does not get impacted significantly by seasons as in case of forage crops and grasses.

Alternative fodder resources

Alternative sourceof fodder species like beetroot, turnip, rapeseed, vetch, peas, raddish, azolla etc. can be grown easily in J & K. Less commonly used fodder species which are having good fodder value can be utilized in J & K. Rapeseed (*Brassica napus*); Kale (*Brassica oleracea* cv acomphala), Swedes (*Brassica napobrrasica*), Turnip (*Brassica rapa*), Raddish (*Raphanus sativus*), Beet (*Beta vulgaris*), Vetch (*Viciasativus*), Peas (*Pisumsativum*) and *Azolla* spp. leaves can provide 2.5 to 5 t DM/ha. Aquatic plants like water hyacinth, aquatic spinach and leaves of lotus plant, lemna, water chestnut, hydrilla, pistia, aquatic weeds can be utilized as unconventional fodder.

Azolla as alternate fodder crop in Jammu Division

In, subtropical areas of Jammu division*Azolla* farming can be taken up to reduce the cost on concentrate as *Azolla* provide good nutritious protein rich biomass for livestock. *Azolla*cultivation is an inexpensive as it can be multiplied in natural water bodies for production of biomass. *Azolla* is very rich in proteins, essential amino acids, vitamins (vitamin A, vitamin B12, Beta Carotene), and minerals including calcium, phosphorous, potassium, ferrous, copper, magnesium. On a dry weight basis, Azolla has 25-35% protein, 10-15% mineral content, and 7-10% comprising a combination of amino acids, bio-active substances and biopolymers. During lean/ drought period it provides sufficient quantity of nutrients and acts as a feed resource. Azolla is a highly productive plant. It doubles its biomass in 3–10 days, depending on conditions and it can yield up to 37.8 t fresh weight/ha (2.78 t DM/ha dry weight).

Azolla production unit

Hydroponic fodder production

Hydroponics is a way of rapid quality fodder production. Hydroponic growing systems produce a greater yield over a shorter period of time in a smaller area than traditionally-grown crops. Hydroponic fodder systems are usually used to sprout cereal grains, such as barley, oats, wheat, sorghum and corn or legumes, such as alfalfa, clover or cowpeas. But now less expensive and sustainable technologies are available which can be used for hydroponic fodder production.

Hydroponic structure consists of a framework of shelves on which metal or plastic trays are stacked. After soaking overnight, a layer of seeds is spread over the base of the trays. During the growing period, the seeds are kept moist, but not saturated. They are supplied with moisture and nutrients, usually via drip or spray irrigation. Seeds will usually sprout within 24 hours and in 5 to 8 days have produced a 6 to 8 inch high grass mat. Peri-urban small farms, land less animal farms and steep hill farms having no agricultural land but possess small pig, poultry and/or cow units can benefit from either of the two or combining the hydroponic fodder-cum-sprouted grain technologies. Hydroponic fodder cannot substitute green fodder and hay completely, as it lacks in fibre content. But it is definitely a better substitute for packaged feeds.

Moringa as an alternate fodder source in Jammu Division

Moringa oleifera is an important alternative source for substituting commercial rations for livestock. It is a fast growing indigenous tree of India that can be propagated easily with both sexual and asexual means. It can thrive in low soil nutrients & water and produce sufficient amount of biomass in dry periods. *Moringa* leaves are highly palatable, digestible and nutritious as they posses 21.53% crude protein, 24.07% acid detergent fiber (ADF) and 17.55% neutral detergent fiber (ADF). The sub tropical zone of the UT i.e. Jammu division is well suited for the cultivation of *Moringa*. Planting of *Moringa* at ICAR-IGFRI at 50x50 cm spacing has been found to yield 80-130 tonnes green forage/ha in 4 cuts at 45 days harvest intervals in 2nd year of planting. This indicated that moringa has huge potential that can be exploited for sustaining livestock production in the UT.

Moringa –A nutritious fodder

Sugar beet / Fodder beet

Fodder beet is an important energy supplements for small and large both category of animal.

Fodder beets contain about 16-22 % dry matter and provide about 4000 kcal/ kg (dry matter) gross energy N digestibility in ruminants is about 85 %. The crude protein content ranges between 7-8% on dry matter basis. Fodder beet can be cultivated in most of the parts of the state except high hills and its duration is 140-150 days

Sugar beet / Fodder beet

Fodder conservation technologies

Traditionally fodder conservation has been only with the dry fodder in the form of hay making and heaping. However, the lack of scientific hay making has often limited keeping quality of hay making and heaping. Recently there is greater emphasis on conserving green fodder popularly known as “Silage”. While the hay making is possible with the dry fodders, green fodders are required for silage making.

Silage

The basic principle of silage making is to convert the sugars in the ensiled fodder into lactic acid; this reduces the pH of the silage to about 4.0 or lower, depending on the type of process. Silage making may be recommended in Jammu and Kashmir. However, its success will depend on surplus forage production, unreliable rainfall pattern, requirement for labour (cutting, raking, collecting, chopping, pit construction and cleaning, ensiling) and materials (polythene, molasses). Several green crops and grasses may be used for silage making *viz.* maize, sorghum, bajranapier hybrid grass, guinea grass, setaria, pineapple stover, etc.

Hay/ Bales

Although it is common practice, necessary training is needed to ensure long keeping quality of the hay material. Further the dry fodder being voluminous in nature often needs larger space and pose problems in transportation. Hence, pressing dry fodder into bales to reduce keeping space and ease transportation has been found to be more necessary in recent times. The basic principle of hay making is to reduce the moisture concentration in the green forages sufficiently as to permit their storage without spoilage or further nutrient losses. The moisture concentration in hay must be less than 15% at storage time. Hence, crops with thin stems and many leaves are better suited for hay making as they dry faster than those having thick and pithy stems and small leaves.

Feed Block

Bale making or feed block making could be good strategy for reducing the cost involved in transportation of fodder from one place to another and saving the space for keeping the fodder. The mechanization aspect may also be thought of in terms of harvesting with weed cutters and chaffing of fodder with power operated chaff cutters, which reduce the reliance on manual labour and also help in saving time on these activities. It will also help in supplying fodder during the calamities as well as lean season.

Tree leaves conservation

Willow, mulberry, *Grewia*tree leaves can make into silage and dry hay.

Reduction of wastages by chaffing

Minimize the wastage is important as it is reported that 15-20% of the straw offered to livestock is usually refused by them when it was fed unchaffed. Therefore, chaffing is essential to minimize the wastage.

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Biological nitrification inhibition through forest tree species

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Introduction

Soil being one of the complex habitats on the earth, hides many secrets from us. Even with the rapid advancement in science and technology, we are currently unable to completely understand the vital processes taking below our feet. Nature maintains a balance between different components and processes and whenever there is an imbalance, nature has its own regulation mechanism to reimpose the equilibrium. Conversion of ammoniacal form of nitrogen to the nitrate form is known as nitrification. Even though the process looks simpler, it involves a complex set of microorganisms, enzymes and intermediary products. The end product of nitrification, nitrate, is the major form of nitrogen (N) uptake by crop plants. Nitrogen is the essential component of amino acids, proteins, enzymes, DNA, RNA and chlorophyll etc.

In soil, nitrification is mainly carried out by ammonia oxidizing archaea in low N environment and ammonia oxidizing bacteria in high N environment. In soil, at first the ammoniacal N will be converted to hydroxyl amine by ammonia monooxygenase (AMO) enzyme and then to nitrite by hydroxyl amino-oxidoreductase (HAO) enzyme. *Nitrosomonas*, *Nitrosolobus* and *Nitrosospira* are the ammonia oxidizing bacteria involved in this process. The nitrite form is toxic to plants and it is simultaneously converted to nitrate by nitrite oxidoreductase enzyme. This second step is crucial and is carried out in soil by *Nitrobacter*, *Nitrospina* and *Nitrococcus* bacteria (Subbarao *et al*., 2012).

The fate of ammoniacal and nitrate forms of N in soil is different. The movement of ammoniacal N in the soil is restricted due to the cation exchange capacity of the soil. However, nitrate being an anion, is repelled by the negatively charged clay matrix and freely diffuses in the soil solution. Thus, the nitrate is easily lost from the soil system through leaching. The nitrate lost through runoff and leaching results in eutrophication and groundwater pollution. Also, the presence of nitrate in the soil is the prerequisite for denitrification, which is a gaseous loss of N in the form of N_2 and N_2O from the soil. Nitrous oxide, being a greenhouse gas contributes to global warming and climate change. The denitrification is carried out by facultative anaerobes like *Bacillus spp*., *Psuedomonas spp*. and *Klebsiella spp*. particularly under a poorly aerated environment. Thus, the nitrification process is a necessary evil. It will be beneficial only when the plant is present in the system and the nitrification rate matches with plant nitrogen demand.

In the disturbed ecosystem the N cycle opens up and leakage of N takes place through denitrification, leaching and volatilization which creates a nitrogen cascade in the atmosphere. This whole nitrogen cascade will be catalyzed when external nitrogen is applied through fertilizers or manures. To tackle this, synthetic nitrification inhibitors like N serve, AM, ATC and DCD are used. However, their practical utility is limited due to the availability and cost involved. Nature being the best teacher has its own mechanism to regulate nitrification in the soil. Control of nitrification prevents leakage of nitrogen from the soil system. Undisturbed natural ecosystems can conserve nitrogen within the system which leads to N buildup. N conserving mechanisms like the uptake of the organic form of N, release of polyphenols from leaf litter which resists mineralization of N and suppression of nitrification are the different strategies by forest tree species to regulate the N cycling in the soil. Even though nitrification is known to be restricted in the undisturbed natural ecosystem, the mechanisms are not well understood (Subbarao *et al*., 2015). The immediate vicinity of the plant root, surrounded by soil, which is influenced by root activity, is known as the rhizosphere. The rhizosphere is the zone of high biological activity mainly due to plant rhizodeposition. Plants can regulate the microenvironment in the soil through rhizodeposition. The chemicals released through rhizodeposition can influence the nitrification process. The controlling of the nitrification process by plants through their root exudates is known as biological nitrification inhibition (BNI) (Subbarao *et al*., 2006).

Plants with BNI capacity

The plants tolerating the nitrogen limited environment show the ability to regulate nitrification in the soil through rhizodeposition. The BNI phenomenon is widely reported in perennial grasses of tropical savannas like *Bracharia spp*., *Hyparrhenia spp*.and *Andropogan spp*. Even cultivated plant species such as rice and sorghum also possess this inhibitory action (Subbarao *et al*., 2012). *Bracharia humidicola* through root exudation of brachialactone (2-phenyl propanoids, methyl p-coumarate, methyl ferulate) inhibits the nitrification process in the soil. Sorgoleone, methyl 3-4 hydroxyphenyl propionate (MHPP) and sakuranetin in sorghum are known to control the nitrification process in the soil. 1,9 decanediol in rice and karanjin in pongamia have an influence on nitrification in the soil. Biological nitrification inhibition is also reported in some weed species like wild radish, brome grass, wild oats and annual ryegrass.

Tree species with BNI capacity

Though the research on BNI in forest tree species is limited, few temperate forest tree species are reported to possess the BNI capacity. In forest tree species, control of nitrification occurs through the production of terpenoids, phenolics, alkaloids and other species-specific secondary metabolites. These compounds are produced by the decomposition of litter and root exudation. Temperate trees like *Quercus spp*. and *Pinus spp*. releases caffeic acid, ferulic acid and chlorogenic acid and strongly inhibits the growth of *Nitrosomonas* in soil. However, species like *Picea abies* and *Abies nordmanniana* are known to inhibit the growth of *Nitrobacter* in the soil (Laffite *et al.*, 2020). Thus, these tree species maintain very low levels of nitrate in the soil solution and therefore put a brake on N loss by leaching or denitrification. The reciprocal soil core transplantation technique is used in studying the BNI property of tree species (Florio *et al.*, 2021). Bioluminant strain of *Nitrosomonas europea* is also a promising tool to detect BNI in plants. As BNI is frequently recorded in tropical grass species, some tropical tree species could be expected to be possessing BNI capacity (Lata et al., 2022).

Mechanism of inhibition

Compounds responsible for BNI are known to inhibit the activity of ammonia monooxygenase and hydroxylamine oxidoreductase enzyme activities along with the interruption of electron transfer pathway in cytochrome. Plants like rice and sorghum are known to alter the community structure of both ammonia oxidizing archaea (AOA) and ammonia oxidizing bacteria (AOB). However, in some temperate tree species, *Nitrobacter* population was found to be affected rather than AOA and AOB. The nitrogen immobilization by soil microorganisms limits the substrate availability for nitrifiers and might also have a role to play in BNI.

Utilization of BNI in forest tree species

- BNI capacity of tree species and grasses has to be considered in mixed plantations, Silvopasture and Agri silvicultural system
- Leaves of tree species possessing BNI capacity can be used as a source of green manuring which will improve the use efficiency of nitrogen.
- The use of tree species having BNI capacity as fodder helps to control nitrification from urine and dung of animals which might control the nitrate leaching and denitrification.
- Quality of manure can be enhanced by using leaves of trees possessing BNI capacity
- Identification of genes responsible for BNI will be useful as the gene pool for future exploration of this phenomenon in food crops.

Future prospects

The identification of the BNI capacity of the tree species is the major challenge. The research in this regard is limited. Several tree species might have BNI capacity and be left undetected. Thus, the reporting of BNI in the plants is a major task. The stability of compounds responsible for BNI in the soil also needs attention, as long-term BNI may affect overall plant growth and affect biodiversity. Implication of nitrification inhibition on plant physiology and soil biodiversity also requires attention.

Conclusion

Nitrification makes nitrogen loss from the soil system easier through leaching and denitrification. Undisturbed natural ecosystems like forests can conserve that N within the system by releasing different compounds, that inhibit the activity of specific enzymes and the growth of specific microbes involved in the nitrification process. Temperate forest tree species like oak and pine have biological nitrification inhibition capacity. The research on BNI of forest tree species, especially in tropical forest is limited and need attention for its broader ecological implication.

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Forest giants under threat: Identifying diseases in key tree species

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Introduction

A plant is deemed sick when it cannot function normally. Environment and infections are the main sources of disease in trees. The pathogens that cause disease in trees include viruses, bacteria, fungus, nematodes, organisms that resemble mycoplasma, and parasitic higher plants. Pathogens that cause fungus are most common. They are the culprits behind seed rots, seedling damping-off, root rots, leaf illnesses, cankers, vascular wilts, diebacks, galls and tumours, trunk rots, and degradation in older trees. Unfavorable weather conditions and environmental elements can directly harm trees and make them more vulnerable to insect assault. Examples include temperature and moisture extremes, strong winds, and ice.

Other industries, including those involved in energy, agriculture, education, water resources, industry, infrastructure development, biofuels, changes in population composition, and rapid economic growth, have an impact on the forestry sector. It is crucial to safeguard these priceless resources from threats like fire, pollution, invading species, insects, and illnesses. One of the main goals of forestry is environmental sustainability, and this includes safeguarding forests against biotic and abiotic threats. Protecting the health of the forest involves its conservation or development as well as the prevention of damage from anthropogenic or natural causes.

Forest pathology

The study of biotic and abiotic conditions that affect a forest ecosystem's health, especially fungal pathogens and the insects that carry them, is known as forest pathology. It is a branch of plant pathology and forestry. The larger strategy for protecting forests includes forest pathology.Robert Harting, who worked in forest pathology and was born in 1935, is remembered for penning two significant works in German: (1) Important Diseases of Forest Trees (1874), (2) Text Book on Tree Diseases (1882).He is referred to as the "Father of Forest Pathology." Forest pathology is an awesome field because it allows you to get into everything from molecular biology to climate change, including mycology, soils, plant anatomy and physiology, biochemistry, meteorology, silviculture, forest ecology, and more.

Forest disease effects

Forest tree diseases can have negative impacts that are overt or covert. These are listed below in no particular sequence according to priority:

- Mortality: Any illness that kills trees.

- Destruction of already-formed wood, which generally refers to losses caused by heartrots that kill or ruin wood. Therefore, the degradation of live trees is a sort of loss that is unique from all others.
- Decreased height and/or diameter growth, which results in volume loss, is a reduction in growth increment.
- Delayed regeneration causes years to pass before a new crop may be planted.
- Stocking flaws such too few stems, inconsistent spacing, or stand holes. Site is not fully occupied, which prevents it from producing to its full capacity.
- Degeneration of species composition: illness of desirable species allowing weed or inferior species to take over the area as a volunteer.
- Site deterioration, including leaching, compaction, and soil erosion.
- Deterioration of wood quality due to early stages of decay, stains, fractures, excessive knots, pitch pockets, and other disease-related reactions. Despite no change in production volume, product values have declined.

The majority of these eight different impact kinds are not too difficult to mentally picture. Except for death, they are challenging to ocularly observe in the field and very challenging to measure or otherwise assess quantitatively. Furthermore, it goes without saying that a given disease may cause multiple types of loss.

Diseases of some important tree crops

S.No.	Disease	Causal organism	Symptom
		Neem (*Azadirachta indica*)	
1.	**Web blight**	*Rhizoctonia solani*	Greyish brown patches start to appear; they grow in size as the fungus's hyphae spread and eventually envelop the entire leaf blade. The fungal hyphae connect the diseased neighbouring leaves as if they were trapped in a spider's web, giving web blight its name.
2.	**Leaf spot**	*Cercospora meliae*	The fungus produces leaf spots that spread quickly and cover huge leaf surfaces. The diseased leaves look blighted and eventually fall off the plant. Seedlings with severe infection exhibit premature defoliation.
3.	**Root rot**	*Ganoderma lucidum*	One or two branches of the trees will begin to show yellowing and drooping leaves, which will be followed by drying of the branches. The fungus spreads widely from the bark and

			results in spongy white rot of the sap wood.
Eucalyptus (*Eucalyptus spp.*)			
1.	**Leaf spot**	*Colletotrichum eucalypti*	A little black spot with dark borders. Young shoots were affected by the virus, which caused developing point symptoms of dieback.
2.	**Leaf blight**	*Alternaria alternata*	The majority of the leaf is covered with a brown soak, which causes the lamina to completely dry out. Concentric rings are present in the devastated region.
3.	**Stem canker**	*Diaporthe cubensis*	Little black cankerous growth that spread to cover the majority of the branch. Branch drying after infection.
4.	**Pink disease**	*Erythricium salmonicolor*	The cobweb stage is the initial indication of infection and involves the rapid spread of white, sparse mycelium throughout stem surfaces.
Teak (*Tectona grandis*)			
1.	**Leaf Rust**	*Olivea tectonae*	Infected leaves prematurely drop off, which slows down the growth of the plant. In young plantations and nursery areas, the illness is widespread.
2.	**Leaf Blight**	*Rhizoctonia solani*	The affected plants display water-soaked, greyish brown patches that quickly spread and cover most or all of the lamina. Because infected tissues are lost during intense rains, blighted leaves frequently have holes in the afflicted area.

Objectives of diseases management

To avoid or reduce losses while maintaining tree quality is the main goal of disease control. Rarely is complete disease control attained, let alone attempted. The focus of management efforts is frequently on eradicating or lowering disease to the level of a manageable annoyance. Most of the time, managing forest diseases needs long-term preventive measures that take into account the stand as a whole rather than just one or two infected individuals. Management strategies must be financially viable; costs cannot be higher than anticipated gains. Numerous constraints, such as the following, impede direct management of disease in the forest:

- The enormous areas concerned
- The difficulty in reaching numerous stands.
- The prolonged tree life cycle.
- The comparatively low values per acre or per tree.

Forest disease control

The most basic concept of forest protection is that it is considerably more effective to stop the harm before it begins than to try to stop an insect or disease pest attack or continued development of the pest problem. In the end, using forest management techniques wisely produces more durable and cost-effective results than using more direct forms of protection. The majority of forest disease control is accomplished through changing the way that forests are managed. Typical techniques for forestry management include:

- Rotational decay reduction
- Taking precautions to avoid fires when logging
- Disease control using partial cutting techniques and stand improvement activities.
- Utilizing controlled burning
- Maintaining high stand densities where necessary.
- Recovering to lessen losses

Conclusion

Disease is particularly prone to affect planted stands. As plantations get older and more planting is done, the effect of disease will become more significant. Most stands reach their critical age between the ages of 20 and 40, at which time they place the highest demands on the site. Early growth that is vigorous does not guarantee long-term development that is satisfactory. Avoidance is the main strategy for disease control in plantations. It is crucial to choose a location with ideal growing circumstances before choosing a species appropriate for that location. The planting stock must be disease-free. Large tracts of evenly-aged trees as well as pure stands are more vulnerable than mixed stands. Maintaining stand vigour also requires proper spacing, thinning and weed management.

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