# Research Trends in Forestry Sciences

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# Adoption of Sustainable Agroforestry Practices in Sub Saharan Africa


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# Chapter - 1

## Adoption of Sustainable Agroforestry Practices in Sub Saharan Africa

**Benjamin Mutuku Kinyili and Ezekiel Ndunda**

### Abstract

Adoption of agricultural innovations is essential for improvement of livelihoods of smallholder farmers, especially in developing countries where agricultural development lags the rest of the world. As a result, different agroforestry practices have been adopted and currently being practiced in the Sub Saharan Africa. The economic and policy issues of achieving optimum adoption, however, remain blurred relative to the determinants of adoption of agroforestry practices in the Sub Saharan Africa. Based on the critical review, synthesis and analyses of agroforestry studies, several pertinent issues related to agroforestry development have been discussed under technical, economic, social, institutional and research issues. Further, the factors that influence adoption of agroforestry systems among smallholder farmers in Sub Saharan Africa are discussed under socio-economic, institutional, marketing and technological factors. There are constraints to scaling-up agroforestry of which this chapter highlights lack of appreciation of the advantages accrued from agroforestry, low or negative return to investments, emphasis on practicing commercial agriculture, outdated land tenure systems, policy challenges, poor adoption of certified seeds/seedlings, and insufficient access to extension services. The study recommends that national governments in the Sub Saharan Africa region should lead the development and guide and monitor the implementation of innovative national policies, strategies and action plans for agroforestry systems, if possible, through multi-stakeholder approach.

**Keywords:** Agroforestry, agroforestry policies and strategies, agroforestry adoption, Sub Saharan Africa

### 1. Introduction

Agricultural production in Sub Saharan Africa (SSA) countries is largely dominated by smallholders with little access to agricultural technologies. Thus agricultural technology adoption remains a key to achieving agrarian development in many parts of the SSA which has suffered decadal long food insecurity, low farm productivity and low livelihood status. There have been several attempts to make accessible a number of agricultural technologies, such as agroforestry, accessible to the farmers due to their livelihood benefits. Agroforestry is the deliberated consortia of trees with crop plants and/or livestock, in determined space arrangements and sequences, presenting varied interactions among their components (Tiwari *et al.*, 2017). The practice includes attempted integration and management of a consortia of forest and agricultural resources on the same landscape, where farmers grow trees on their farms, pasturelands and homesteads. Agroforestry has been implicated in positive development for livelihoods (Lentz *et al.*, 2015). These include availability of suite of products for utilization including energy in the form of firewood, building materials in the form of posts and timber, food such as fruits, medicine etc. (Wulan *et al.*, 2008; Kimaro *et al.*, 2019). As a result, adoption of agroforestry is currently on the uptrend.

In recent years there have been continued campaign and increasing interest in adopting and promoting agroforestry at the global, regional and local scale especially for the smallholder farmers (Simelton *et al.*, 2017; Fleming *et al.*, 2019). Subsequently several international bodies including the United Nations and World Bank, governments and Non-Governmental Organizations (NGOs) have advocated for its global adoption (Cuperus *et al.*, 2018; Quandt *et al.*, 2019). Consequently, between the year 2010 to 2017 there were approximately 300 to 350 million people who had adopted agroforestry (Atangana *et al.*, 2013; Abbas *et al.*, 2017). Most of the new adopters of agroforestry reside in the tropical region of the world where conditions are favourable (Tscharntke *et al.*, 2011; Atangana *et al.*, 2014).

In the Sub Saharan in Africa, agroforestry has gained increased recognition and subsequent adoption by smallholder farmers, where a number of smallholder farmers practice several forms of such poorly developed forms of agroforestry (Mbow *et al.*, 2014). Although the contribution of trees cover from such poorly developed systems rarely meet the minimum threshold of forest resource demand (Awodoyin *et al.*, 2015), agroforestry has largely improved the resilience of households towards negative impacts of climate variability including wild fires, drought, flash floods, extreme temperatures and variation in rainy periods (Buyinza *et al.*, 2020). However, such synergies are possible if aspects affecting adoption of agroforestry, improved qualitative data and supportive policy environments allow or the successful scaling-up of agroforestry systems in Africa. Most importantly, it is worthy to note that the full potential of agroforestry to respond to poverty and food insecurity and global climate change cannot be fully realized until the constraints and various challenges to scaling-up agroforestry are addressed and ultimately resolved. It becomes imperative for countries in SSA to develop, formulate policies and implement national agroforestry strategies, so that agroforestry adoption is considered a part of the national development agenda.

## 2. Factors influencing the adoption of agroforestry among smallholder farmers in Africa

Analysis of agroforestry adoption have a tendency to tag along the immeasurable narrative on adoption of agricultural production or conventional agricultural crops (Mattia and Lovell, 2016). A number of features of agroforestry nevertheless, make investigation of its adoption exceptional and justifiable of its own review and subsequent studies. Among farmers, the decisions on whether to adopt or not to adopt agroforestry system often the result of matching projected benefits and cost of adopting the technology (Do *et al.*, 2020). Therefore an understanding the factors that influence the choice to adopt agroforestry is important both for economists studying the determinants of adoption and the producers and promoters of agricultural productivity. Basically, the extant literature highlight two major driving factors behind successful agroforestry adoption: availability and affordability of new agricultural technologies and farmers' expectations of long-term profitability promised by the new technology.

Based on extensive review of available literature, there is no clear line separating the categorization of these factors. Categorization can be done to suit the technology being studied, to meet the preference of the researcher, or based on prevailing issues for which the researcher is investigating. Overwhelmingly, the determinants of agroforestry adoption has been previously classified into three categories namely: economic, social and institutional (Mercer and Pattanayak, 2003). The economic factors may include consideration such farm size, cost of adoption, income, expected benefits from the adoption and the off-farm income among others. The social factors include gender related aspects, age of farmers, and level of education. The institutional factors include access to support from the institutions. Meanwhile, other groups categorize the factors into: farmer characteristics, farm structure, institutional characteristics and managerial structure (Kafle and Shah, 2012). Similar lack of clarity has seen these factors grouped into informational, economic and ecological (Jerop *et al.*, 2018), not to forget the classification under human capital, production, policy and natural resource characteristics (Worku, 2019).

## 2.1 Socio-economic factors

One of the most extensively studied conditions that influence agroforestry is socio-economic factors, due to its influence on human environment and the condition under which people live (Curry *et al.*, 2019; Fleming *et al.*, 2019). Due to poor socio-economic status of households in the Sub Saharan Africa, many studies point to socio-economic conditions as bearing the greatest potential and barrier to agroforestry adoption in the region (Singh, 2017; Magugu *et al.*, 2018). There are also other studies that link socio-economic proxies such as level of household food security, gender, age, levels of education, income level, occupation etc. are the main determinants of agroforestry adoption (Oino and Mugure, 2013; Rotich *et al.*, 2017). In Gutu District, Zimbabwe, the ability or inability to meet the cost of pesticides, seeds and other inputs necessary for adopting agroforestry relied on household income (Chitakira and Torquebiau, 2010).

Factors related to the characteristics of farmers are conglomerated under the social and economic or socio-economic factors. Socio-economic factors or characteristics influence farmers' ability to attain the necessary human ability, willingness and technical know-how of adopting a technology (Curry *et al.*, 2019; Fleming *et al.*, 2019). These factors also drive the farmers' decision to adopt new or emerging agricultural technologies. Most of the socio-economic studies on adoption attempt to decipher the issue through the lens of social specific factors like gender, age, marital status, levels of education of the farmer, household heads, religious factors etc. (Chimoita *et al.*, 2019). Other authors look at the socio-economic factors through economic aspects of the farmers such as income levels, land size, working experience, farm income among others (Kinyangi, 2014). Yet others studies include individual farmer's demographic factors which buttress proxies such as level of household size, family size and land size as part of socio-economic factors (Oino and Mugure, 2013; Rotich *et al.*, 2017). Therefore, a proper analysis of socio-economic factors should be broadened to cover much of these variables.

Gender issue is one of the most widely studied aspect of socio-economic factors with regard to adoption of agroforestry owing to the differential gender roles in most of the developing countries especially in SSA (Flarian *et al.*, 2018; Sofoluwe, 2020). These studies highlight the different roles men and women play in technology adoption. There are plethora of studies reporting that gender roles play a very significant role on adoption of agroforestry which bring out differences in roles, opportunities, decision making and control over productive agricultural resources (Chima and Rahman; Adekunle *et al.*, 2016). In Sub Saharan Africa, gender affects technology adoption since the head of the household is the primary decision maker and control over vital production resources than women due to socio-cultural values and norms (Gebre *et al.*, 2019; Changalima *et al.*, 2020). There are also isolated studies where there was no significant gender role in adoption of improved technologies (Arimi and Olajide, 2016).

In terms of age, it is usually expected that older farmers have more experience, but younger farmers being more innovative (Ogada *et al.*, 2014). Older farmers are also assumed to have more experience, resources, or authority to enable them try out new technology, but exhibit a stronger belief in traditional methods which sometimes hinder their likeliness of adoption (Maro *et al.*, 2013). It has also been asserted that younger farmers are typically less risk-averse and are more willing to try new technologies. For instance, it has been shown that adoption of genetically modified seeds increased with age for younger farmers as they gain experience and increase their stock of human capital but declines with age for those farmers closer to retirement (Awotide *et al.*, 2016). Given the age of farmers, differences may exist depending on how experience is captured so that as farmers grow older, there is an increase in risk aversion and decreased interest in long-term investment in the farm (Mottaleb, 2018). In contrast, while younger farmers are more ambitious, energetic and put more efforts in searching and trying out new technologies, they sometimes lack resources to access and therefore adopt the technologies (Kharumnuid *et al.*, 2018). Nevertheless, the role of age of the farmer in adoption of certified Agroforestry seedlings and tree site matching is not known.

Education level of a farmer increases adoption behavior such as the ability to obtain, process and use information relevant to the adoption of a new technology (Muzari *et al.*, 2012; Pamuk *et al.*, 2014). This is because higher education influences respondents' attitudes and thoughts making them more open, rational and able to analyze the benefits of the new technology (Akudugu *et al.*, 2012). More educated farmers tend to have greater access to diverse information sources compared to smallholder subsistence farmers who depend on fewer sources. Besides, household head's level of education was found to enhance awareness and decision-making, which was likely to increase the probability of adoption of seedlings technology (Baglan *et al.*, 2020). Higher educational attainment influences respondents' attitude and thoughts making them more open, rational and able to analyze the benefits of the new technology, this facilitates the introduction of Agroforestry which eventually influence the adoption process (Fu *et al.*, 2018). Thus various studies confirmed that level of education of the farmer has a significant positive influence on adoption of technologies (Amare and Shiferaw, 2017). On the other hand, some authors have reported insignificant or negative effect of education on the rate of agroforestry adoption (Chimoita *et al.*, 2019; de Oca Munguia and Llewellyn, 2020). Since the above empirical evidence has shown mixed results on the influence of education in adoption of new technology, more studies are needed for specific context.

Household size have often been viewed as a reflection of labour supply for agricultural activities and the household's ability to supply surplus labour to non-farm activities and income that is received could be invested into farm activities (Prokopy *et al.*, 2008). It may determine adoption process in that, a larger household have the capacity to relax the labour constraints required during introduction of new technology (Fu *et al.*, 2018). However, the proportion of dependents or active members may mare this assumption and produces mixed results if not measured well. Again, there are lack of empirical studies especially in Kenya on how household size as a socio-economic factor influenced the adoption of agroforestry in the household.

Farmers with high farm income are likely to invest in technologies and if the cost is affordable, more farmers will be willing to take up that particular technology. Some studies have found out that off farm income has a positive relation but not statistically significant (Ghimire and Huang, 2016; Brookes and Barfoot, 2018). Off farm income/employment can affect adoption of technology either positively or negatively. Farmers involved in off farm activities tend to spend less time on the farm and as such lose touch with what is happening in the field of agriculture consequently missing out on innovations (Verkaart *et al.*, 2017).

## 2.2 Institutional factors

In order to adopt agricultural production technologies such as agroforestry, there is need for input support which may be in the form of fertilizers, pesticides, herbicides, lime and finances for irrigation systems (Binam *et al.*, 2017; Lillesø *et al.*, 2018). The institutional factors include availability of credit, the availability and quality of information on the technologies, accessibility of markets for products and inputs factors, the land tenure system, and the availability of adequate infrastructure, extension support (Liu *et al.*, 2018). The potential effects of institutional factors in influencing adoption of seed technologies appear to be massive (Métouolé Méda *et al.*, 2018). However, many smallholder farmers rarely get the support needed to successfully adopt the technology (Sanou *et al.*, 2017). In several countries especially those in Africa, provision of agricultural services to rural smallholder farmers still rely on government goodwill (Miller *et al.*, 2017).

The effectiveness of institutional support systems towards adoption of smallholder's tree nursery establishment are quantified based on leverage required to achieve food security, and create wealth for the households (Ashiagbor *et al.*, 2018). For better assessment of the agroforestry adoption, challenges faced by farmers, support systems and impact of trees on individual household farmers should be considered (Alavalapati *et al.*, 2001). Nevertheless, the support system provided in adoption of the tree nursery is not clearly understood in several smallholders farming systems mainly in the developing countries of Africa, including Kenya (Ajayi and Place, 2012; Bernier *et al.*, 2015). Additional, few evidence have been adduced to support the role of public extension services on the adoption of agroforestry.

However, many smallholder farmers rarely get the support needed to successfully adopt the technology (Sanou *et al.*, 2017). In several countries especially those in Africa, the provision of agricultural services to smallholder farmers is still largely in the hands of the government sector (Dumont *et al.*, 2017; Miller *et al.*, 2017). Furthermore, inadequate support programmes, high degree of bureaucracy and poor working conditions of field staff are commonly cited as major constraints (Lillesø *et al.*, 2017; Benjamin, 2018). Institutional support has had an impact of adoption of agroforestry among the rural populations (Rosenstock *et al.*, 2018; Makate *et al.*, 2019). Nevertheless, the support system provided in adoption of agroforestry is not clearly understood in several smallholders farming systems mainly in the developing countries of the Sub Saharan Africa. Furthermore, there is less emphasis on how institutional factors affect adoption of agroforestry. This is particularly lacking in the Sub Saharan Africa. Therefore, the contribution of institutional factors on adoption of agroforestry needs to be understood in the local context to better understand the barriers to adoption to boost Agroforestry production.

The analyses of institutional factors and adoption identify access to extension services and markets as significant determinants of technology adoption (Altalb *et al.*, 2015). Farmers who had contact with extension agents were more likely to adopt farming technologies. Similarly, extension visits can help to reinforce the message and enhance the accuracy of the implementation of the technology package (Wang *et al.*, 2020). Several authors have reported a positive relationship between extension services and technology adoption (Wossen *et al.*, 2017; Shita *et al.*, 2018; Manda *et al.*, 2020) while others have stated that the influence of agricultural extension agents can counter balance the negative effect of lack of motivation for adoption (Ugochukwu and Phillips, 2018). Farmers are usually informed about the existence as well as the effective use and benefit of new technology through extension agents (Walisinghe *et al.*, 2017).

Extension agent acts as a link between the innovators of the technology and users of that technology. This helps to reduce transaction cost incurred when passing the information on the new technology into a large heterogeneous population of farmers (Pan *et al.*, 2018). Extension agents usually target specific farmers who are recognized as peers exerting a direct or indirect influence on the whole population of farmers in their respective areas (Wang *et al.*, 2020). Many authors have reported a positive relationship between extension services and technology adoption. In fact, the influence of extension agents can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies.

Credit facility, particularly institutional credit facility also affects the adoption pattern of Agroforestry by the farmers. Farmers who got credit facility were found to have a significant effect on the likelihood of adoption of improved Agroforestry (Okuthe *et al.*, 2013). Generally, some technologies are capital intensive requiring credit which may not be accessible to farmers thus constraining adoption. Credit access is another institutional factor that encourage smallholder farmers to adopt Agroforestry (Akudugu *et al.*, 2012). It is believed that credit access promotes the adoption of risky and capital-intensive technologies through relaxation of the liquidity constraint of inadequate finance (Obisesan *et al.*, 2016). This is because with an option of borrowing, a household can do away with risk reducing but inefficient income diversification strategies and concentrate on more risky but efficient investments. There are negative aspects that affect access like gender bias where female-headed households are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates. There is therefore need for policy makers to improve current smallholder credit systems to ensure that a wider spectrum of smallholders is able to have access to credit, more especially female-headed households. This may, in certain cases, necessitate designing credit packages that are tailored to meet the needs of specific target groups (Métouolé Méda *et al.*, 2018). For instance, in Kenya, the government has started a program that offer free interest loans to youths and women (UWEZO fund) and without collateral (Micheni, 2020) to empower women and enable them to adopt agricultural technologies hence enhancing economic growth.

Smallholder farmers within a social group or non-formal organizations easily share their agricultural experience with other members and learn from each other the benefits and usage of new agricultural technologies they have come into contact with (Ainembabazi *et al.*, 2017; Manda *et al.*, 2020). Institutional factors in the form of social networks and groups are essential for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and easily pick up from each other (Mottaleb, 2018; Dyck and Silvestre, 2019). It has indeed been established that farmers who engaged more in community or farmer-based organizations were more likely to take part in Agroforestry adoption (Weyori *et al.*, 2018).

Access to information regarding a new Agroforestry is another institutional factor that may influences Agroforestry adoption (Simtowe *et al.*, 2019). Acquisition of information about new Agroforestry enables farmers to learn the existence as well as the effective use of innovations (Rehman *et al.*, 2016). Farmers are rational and will only adopt a technology they have information about the technology or have heard about (Udimal *et al.*, 2017). Access to information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time (Simtowe *et al.*, 2016). However, access to information about a technology does not necessarily mean it will be adopted by all farmers. It is therefore important to ensure that access to information is reliable, consistent and accurate, which can only be ensured that there is appropriate data availed based on research studies.

## 2.3 Marketing factors

Market participation of farmers is both a cause and a consequence of economic development (Heiman *et al.*, 2020). It is a major pathway for rural people in assuring better income and improving food security. The existence of markets and improved market access are important for smallholder farmers since it can draw agricultural and economic development (de Janvry *et al.*, 2016). Improved access to markets has paramount importance in increasing smallholder market participation and the extent to which they can be influenced in their decision to adopt, *ceteris paribus* (Khai and Dung, 2020).

Fundamentally, most of the smallholder farmers are in remote areas with poor transport and market infrastructures, causing high transaction cost. In addition, they lack reliable market information as well as information on potential exchange partners (Magruder, 2018). Due to their small surpluses in production, smallholders are also generally exposed to a higher degree of risk and transaction costs (Maertens and Barrett, 2013). Most rural farmers sell their produce mainly at their farm gate and in village markets. Their decisions on the amount of output to sell are mainly influenced by marketing information, produce prices, and distance to the market (Muzari *et al.*, 2012). However, one drawback regarding smallholder farmers is that they lack marketing knowledge and as a result, most of the crops are sold with lower prices at their farm gate or in local markets (Mariano *et al.*, 2012). Limited access to guaranteed markets for their produce and for the acquisition of inputs is another major problem the smallholders confront (Hailu *et al.*, 2014).

Marketing as a factor that affect farmers decision is important since it makes farmers be able to deliver the produce to the final consumer (Kyaw *et al.*, 2018). Agricultural marketing is the performance of all business activities involved in the flow of goods and services from the point of initial agricultural production until they are in the hands of the ultimate consumer. Access to markets and particularly in closer proximity is associated with a high likelihood adoption of technologies (Janssen *et al.*, 2020). In many places, a lack of infrastructure drives a wedge between the prices that farmers receive for their output and the market price, lowering the benefits from technology adoption. Where infrastructure is weak, local prices are driven by local supply, which may undermine farmers' incentives to maximize output if higher output leads to lower prices. But investment in infrastructure is a public good, which results in under-investment since those making the investment will not capture all the benefits.

Individual farmers' lack of market power, in combination with the lack of competition among input suppliers and among output intermediaries, leads to capture of much of the profit from improved technologies by market actors other than the farmer. This can lower technology adoption. By raising the fixed cost of distribution, poor infrastructure increases the market power of intermediaries. The result is a vicious cycle with low take-up, resulting in few traders with market power, which lowers profits for farmers and further depresses take-up. Weak contracting environments exacerbate many of the constraints imposed by input and output market inefficiencies by making it difficult to enforce superior arrangement. The lack of market-led community commercialization approach has led to agroforestry extension and research emphasize, increasing production levels of trees and crops. But these efforts have been undertaken with little regard for demand and price. Research work has shown that market conditions and institutions play a critical role in farmer adoption of agroforestry. For example, it was found out that when the price of maize in Zambia decreased, farmers were more likely to use improved fallows to reduce the area under maize cultivation, allowing them to increase the production of higher value cash crops on other fields (Franzel *et al.,* 2002b). Further, the price of fuelwood had a strong effect on the popularity of agroforestry in Kenya (Franzel *et al.*, 2002a).

## 2.4 Technological factors

Agroforestry refers to the machinery, tools, and manpower available for use to ease manpower and increase efficiency on farms (Shita *et al.*, 2018). Currently, agricultural machinery such as those for irrigation, land tillage, planting seeds/seedlings, protecting these very crops from pests and weeds, harvesting, and sorting and packaging are key in every stage of the agricultural production process (Magruder, 2018). Farmers need to know the existence of technology, its benefits, and its usage for them to adopt it. Agroforestry is considered as one of the most impactful and revolutionary area in the modern technology era, which is driven by the basic need for food production (Michler *et al.*, 2019). These advancements have opened a century in which powered machines do the job formerly performed by human workforce or animals such as horses and oxen. These machines in return have greatly increased farm output, reduced farm input costs and dramatically changed the way people produce food worldwide (Rehman *et al.*, 2016). A good example of such agricultural machinery in the modern time is the use of tractor, knapsack sprayer and weeding machines. Even more surprising is that current technology involves the use of drones, satellites, airplanes, and helicopters (Aryal *et al.*, 2019). Farmers' perception and understanding about the performance of new agricultural technologies significantly influences their decision to accept new innovations.

The small-scale farmer's choice and decision to adopt any modern Agroforestry requires different types and forms of information and knowledge about the technologies available because, for any technology adoption decision making process to be concluded, access and availability of viable information is very critical. First, the farmers must appreciate that the technologies exist; second the farmer know that the technologies are beneficial if adopted and lastly, the farmer must understand how to apply the knowledge about the technology effectively on his farm during the adoption process. The three stages require access to credible information to guide the adoption decision making process. Therefore, there must be a smooth flow and access to information from the available information sources to the farmers through effective and efficient communication channels.

Smallholder farmers contribute to food security, equitable distribution of income, and linkage creation for economic growth (Alavion *et al.*, 2017). Farmers involved in traditional food crops generally depend on informal markets due to weak or lack of linkages with formal markets (Habineza *et al.*, 2020). Nonetheless, the participation rate of smallholder farmers in the market remains low due to various constraints including physical access to markets and lack of market information (Bisimungu and Kabunga, 2016). Fundamentally, most of the smallholder farmers are in remote areas with poor transport and market infrastructures, causing high transaction cost. In addition, they lack reliable market information as well as information on potential exchange partners (Magruder, 2018). Due to their small surpluses in production, smallholders are also generally exposed to a higher degree of risk and transaction costs. Most rural farmers sell their produce mainly at their farm gate and in village markets. Their decisions on the amount of output to sell are mainly influenced by marketing information, produce prices, and distance to the market (Muzari *et al.*, 2012). However, one drawback regarding smallholder farmers is that they lack marketing knowledge and as a result, most of the crops are sold with lower prices at their farm gate or in local markets (Mariano *et al.*, 2012). Limited access to guaranteed markets for their produce and for the acquisition of inputs is another major problem the smallholders confront (Hailu *et al.*, 2014). Therefore, studying the market participation of farmers can provide useful implications for countries in similar circumstances and characteristics.

## 3. Constraints to scaling-up agroforestry

Several studies have been conducted in Africa solely on adoption or scaling-up or development of traditional and modern agroforestry technologies, practices, methods and systems. A number of factors have been identified as challenges or constraints. Some key factors that constraint the scaling-up of agroforestry are discussed as follows:

### 3.1 Lack of appreciation of the advantages accrued from Agroforestry

Academia, farmers, extension staff, NGOs, the private sector and governments (policymakers) have a common tendency to over-rely on conventional agriculture systems (monoculture cropping) to the detriment of traditional and modern agroforestry systems. The public sector extension services lack sufficient on the relevant skills, knowledge and understanding of agroforestry technologies (Coe *et al.*, 2014). As a result, the multiple functions and multiple benefits of agroforestry systems are not well understood. The ranking of agriculture's contribution to the GDP and the exclusion of the potential financial and economic value of agroforestry in the system of national accounts favour agriculture over agroforestry, unless there is a paradigm shift.

### 3.2 Low or negative return to investments on agroforestry

The turnaround period for most agriculture crops is shorter and return on investment is quicker, while investing in agroforestry may come with disadvantages. However, this argument can be countered by the fact that horticultural crops in conventional (especially fruit trees) and timber species in plantation forestry systems also take extended periods before they reach the market (Rashid *et al.*, 2013). But still government policies favour more investment in those sectors than agroforestry. This is more a matter of understanding on the resource economics of the products provided by these sectors. Clearly, the net present value of agroforestry trees compared to establishment costs is superior to agricultural crops. The cost of the long-term environmental damage caused by agriculture crops due to tillage, application of inorganic chemical fertilizers and excessive use of water is unbelievable. Further, market information systems in most SSA countries do not include agroforestry trees (Meijer *et al.*, 2015).

### 3.3 Emphasis on practicing commercial agriculture

The policy and legislative framework in SSA countries supports agriculture and discourage farmers from adopting agroforestry (Msuya and Kideghesho, 2012). These policies continue to discourage the development and scaling-up of agroforestry Development finance is targeted at mainstream agriculture development, and the credit facilities in place to support agriculture have negative consequences on the scaling-up and development of any form of viable agroforestry. Favourable credit terms granted for large-scale monoculture systems are hardly ever offered to agroforestry initiatives. Hence, by excluding agroforestry in the benefit package, the system is discouraged. In several SSA countries, agriculture input subsidies are rarely provided and thus become a disincentive for farmers to adopt and practice agroforestry (Ajayi *et al.*, 2009).

### 3.4 Policy challenges

Overarching legislation and multiple legal restrictions on multifunctional land management and complex taxation policies may hinder the development of agroforestry in SSA (Place, 2009). The agriculture sector is so developed that the policies and legislation are suited to industrial agriculture (characterized by monoculture establishments). Between 2001 and 2010, beginning with intercropping systems, all agroforestry systems progressively became eligible for subsidies established by the policy, and now all agricultural lands are eligible, regardless of the degree of tree cover. This reform can be adopted by SSA countries to promote the development and scaling-up of agroforestry.

National forest policies and forestry programs rarely support agroforestry in most African states. However, the most critical preconditions for the advancement of agroforestry could be an enabling policy environment that favours smallholder rural development and appropriate institutional support for agroforestry. At the local level, challenges of policy and institutional frameworks include:

1) **Local policies:** Some local customary practices and institutions prevailing in the sub-region, especially incidence of bush fires and browsing by livestock during the dry season and absence of perennial private right over land, limit the widespread uptake of some agroforestry technologies.
2) The animals destroy the trees after planting either by browsing the leaves and removing the biomass or by physically trampling over the plants.
3) Community's institutional regulations for fruit collection as well as land and tree tenure affect the individual farmer's decision to invest in establishing an indigenous fruit tree orchard.

### 3.5 Lack of certified seedlings

Quality seeds/seedlings means seeds/seedlings security and seeds/seedlings security guarantees food security. In other words, good quality seeds/seedlings and germplasm, which is pure to type and free from contamination, are vital for any meaningful progress in promoting and scaling-up agroforestry systems in SSA (Njuguna *et al.*, 2020). Currently, one of the hindrances to the advancement of some agroforestry systems, technologies, practices or methods, as they are called, is the unavailability of land access to good quality tree seeds/seedlings. It is well acknowledged that in mainstream agriculture, a number of establishments (government agencies and the private sector) and national programmes for quality seeds/seedlings multiplication and distribution exist. However, there is little or no institutional structure or national programme to produce quality seeds/seedlings for agroforestry. The lack of quality tree seedlings of superior genotypes is a major hurdle to the expansion of agroforestry systems in Africa. Recent studies suggest that currently there are few incentives for private sector investment in this area.

### 3.6 Insufficient extension work

The existing government extension service in SSA is relatively strong in agricultural extension and not in agroforestry extension for various reasons, including the heavy investment and support offered to the former. Large-scale agriculture has expanded both in the public and private sectors since the early 1960s as earlier highlighted. Even mainstream forestry has learnt a lot of technologies from horticulture, which is a sub-sector of agriculture. The issue of poor extension service is compounded by the fact that agroforestry, by its nature, is a knowledge-intensive practice, which means that agroforestry technologies require skilled, knowledgeable and diligent extension workers to spread the knowledge and skills to farmers. National agriculture and forestry extension systems in African countries seem to be the major barriers to scaling-up agroforestry.

## 4. Key policy agenda need for agroforestry in Sub Saharan Africa

National governments in the SSA region should lead the development and guide and monitor the implementation of innovative national policies, strategies and action plans for agroforestry systems if possible through multi-stakeholder participation. The strategies that are being suggested should be guided by a situational analysis; a policy framework; analyses of strengths, weaknesses, opportunities and threats (SWOT); analyses of political, economic, social, technological, environmental and legal (PESTLE); and a clear vision, mission, transformational mission, strategic framework, risk management matrix, goals, objectives and priority actions as well as budget, ending with a comprehensive monitoring and evaluation framework.

It is critically important to always ensure that research studies, focusing on policy issues surrounding agroforestry systems and linking them to farmers and implementing agency/implementing partner/executing agency, are carried out to inform the national policy direction. National policies should be evidence-based and research agenda should be policy driven.

Institutional issues need to be addressed at three levels.

1) **Micro-level interventions:** Such as fruit trees or alley cropping, should emphasize short-term benefits, relative ease of management and project implementation at the individual or farm level.

2) **Middle-level interventions:** Such as community nurseries or woodlots, may emphasize short-or long-term benefits. Such projects should involve implementation by groups or associations. They are likely to require more specialized and intensive management and to combine economic returns to the group with social service and/or environmental benefits to the community as a whole.

3) **Macro-level interventions:** Such as windbreaks or forest plantations, emphasize long-term benefits and may be most appropriately implemented through the public sector. These projects are likely to involve the most specialized and intensive management requirements.

## 5. Conclusions

Based on the foregoing review, the following conclusions are presented to enhance the development of both traditional and modern agroforestry systems and technologies in the Sub Saharan Africa.

1) Transition from traditional to modern farming systems is imperative. Research indicates that agroforestry is widespread through Africa, since the concept of combining trees and shrubs with field crops and/or livestock on one piece of land is central to many traditional farming systems on the continent. Unsustainable development has led to diminishing natural resources, including land degradation, deforestation and water scarcity. Therefore, traditional and cultural livelihood strategies are no longer sustainable. For example, rapid and alarming population growth, youth bulge as it relates to the sustainable livelihoods needs, has rendered such traditional systems unsustainable and ineffective. As a result, Sub Saharan African farmers need to adopt an integrated approach to farming and develop and implement new, innovative and more effective farming systems to maximize productivity and production while ensuring environmental protection.

2) A great potential for agroforestry exists in Sub Saharan Africa. In general, natural forests and woodlands in the region have been degraded to the extent that the demand for wood and non-wood forest products can no longer be met from the remaining natural forest resources. The substantial demand for wood and non-wood forest products comes from agricultural, peri-urban and urban areas. Forest products that are in high demand include fuelwood and charcoal, which can be produced through appropriate agroforestry systems by smallholder farmers and even households.

3) Incorporation of agroforestry activities in national agricultural policies will bring about the desired success. National agricultural policies and extension services/in Africa should infuse elements of agroforestry and/or community forestry based on the needs of the communities (households) and adaptability of tree/shrub species to various ecological regions. Research should form an integral part of the projects to ensure that social/cultural, economic/financial and ecological/environmental considerations are at the heart of the agriculture extension programme.

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# Chapter - 2
# Assessment of Carbon Sequestration Potential of Some Selected Urban Tree Species

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# Chapter - 2

## Assessment of Carbon Sequestration Potential of Some Selected Urban Tree Species

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**Abstract**

Tree species carbon assessment and quantification remain the only opportunity to determine the position of forest in climate change amelioration potentials. Forest biomass constitutes the largest terrestrial carbon sink and accounts for approximately 90% of all living terrestrial biomass. The aim of this study is to assess tree species carbon sequestration potentials of selected urban tree species. The study was carried out in Adekunle Ajasin University Campus, Akungba Akoko, Ondo State, Nigeria. All trees species ≥10 cm Diameter at Breast Height (Dbh) within the area were identified and their Dbh measured as well as other variables for volume computation such as height, diameters at the base, middle and top. Also, for density assessment; stem core samples were collected. Again, the coordinate of individual tree was recorded using a Global Positioning System (GPS) receiver. A total of 124 individual trees were encountered with varying growth variables as well as carbon values. The study area contains some indigenous and exotic tree species such as *Acacia auriculiformis, Terminalia mantaly, Gmelina arborea* and *Tectona grandis* etc. but *Acacia auriculiformis* had the highest frequency. The tree species with highest carbon sequestration was *Gmelina arborea* as recorded for this study. The total carbon and carbon dioxide sequestered in the study area were reported as 47.94 kg and 176.03 kg respectively.

**Keywords:** Assessment, quantification, mitigation, amelioration, estimation

### Introduction

Carbon emission and reflection is one of the most important and pressing environmental issues due to climate change in the world today [1]. Expansions of urban areas are steadily throughout the entire world [2] and it is expected that about sixty percent (60%) of the world population will inhabit in cities by 2030 [3]. Unfortunately, urbanization will therefore increase the source of carbon emissions in the world. As a result, urban trees become more important for human to enjoy their living space.

Several studies around the world such as North America, China, and Australia as well as United Kingdom and Germany recently had reported that trees in urban environments can remove carbon dioxide from the atmosphere through photosynthesis which results in tree growth in both directions (horizontal and vertical) [4, 5]. This accumulation of resources stores excess as biomass/carbon in various components of the tree such as roots, stems and branches etc. Incidentally, urban trees reduce building energy due to cooling through their shade and climate amelioration effects, thereby reducing carbon dioxide emissions [6]. It is noteworthy that the strength of urban tree carbon sequestration depends on different factors such as species, health and growth variables as well as their overall living conditions [7, 8]. Also, the mortality or longevity of urban trees can be influenced by site condition(s) and other policies such as land use, natural disturbance (e.g. pests, fire and desert encroachment, etc.), as well as human activities and urban development [8]. Comparably, urban tree growth is influenced by genetics make up, climate and competition amongst other [9].

Trees/forest in the urban centres provides several ecosystem services ranging from atmospheric cooling to carbon emission [10]. Although, this importance has not been documented extensively but European Union Biodiversity Strategy 2014 mandated her member states to asses and map their forest ecosystem services in the year 2020 [11]. Some European cities have begun to formulate carbon dioxide mitigation policies such as; city of Bolzano and Italy. These cities have been designated to become carbon monoxide neutral by 2030 [12]. Consequently, many countries are on the quest to assess their forest carbon emission and sequestration by using developed allometric equations both regionally or local as well as other forest inventory methods to provide reliable, consistent and scientifically proven forest biomass/carbon estimate for reporting. The assessment of carbon in tree or forest ecosystem gives an estimate of carbon emitted into the atmosphere when this particular tree/forest is deforested or harvested. Consequently, the aim of this study is to assess carbon sequestration potentials of some selected urban tree species.

**Study area**

This study was conducted in Adekunle Ajasin University Campus, Akungba Akoko, Ondo State, Nigeria. It is situated in Akoko South West Local Government Area of Ondo State and lies between latitudes 7$^o$ 28" 9.15' to 7$^o$ 29" 15.18’ North of the equator and longitudes 5$^o$ 44" 15.96' to 5$^o$ 46" 14.78’ East of Greenwich Meridian. Akungba town is bordered with Supare-Akoko in the West, Iwaro-Oka in the East, Ikare-Akoko in the North and in the South with Oba-Akoko [13].

The study area falls in rainforest ecological zone but gradually becoming derived savannah due to anthropogenic activities causing climate change effects [13]. The area is characterized by two distinct seasons; the raining season, which occur between April and September and the dry season, which falls between September and March. It has meant annual rainfall of 1250 mm and the average temperature ranges between 18 °C and 35 °C.

**Methods**

Stem of living trees grows both horizontally and vertically. Biomass accumulation also occurs in trees in both directions. The horizontal growth was measured by the diameters and the vertical growth was measured by the total tree height. Newton's formula was used to estimate the total tree volumes for this study (Equation 1).

$$\text{Volume} = \frac{\pi h}{24}(D_b^2 + 4D_m^2 + D_t^2) \text{ ------------------------------- Equation 1}$$

Where:

Volume = Volume of the stem

$\prod$ = 3.142

h = Tree total Height

$D_b$ = Diameter at the base

$D_m$ = Diameter at the middle

$D_t$ = Diameter at the top.

**Density**

A non-destructive sampling method was adopted in this present study to estimate the stem biomass. The length of the stem core extracted using the increment borer was accurately measured in centimeter using ruler. Core diameter was measured for randomly selected core samples and the average taken since only one increment borer with one extraction tube was used for the study. The core samples obtained were oven-dried at 75 ºC and measured at one (1) hour interval until a constant weight was achieved. The density estimation was therefore done by converting the volume and dry weight of a core sample extracted to the stem density. Both Equations 2 and 3 were used to estimate tree core volume and tree density respectively.

$$V_s = \frac{\pi d_s^2}{4} l \text{ ------------------------------------------------------------ Equation 2}$$

Where;

$d_s$= Diameter of the core sample (cm).

$l$ = Core sample length (cm).

$V_s$= Volume of the core sample (m).

$$\text{Density} = \frac{\text{Dry weight}}{\text{Core volume}}$$ ---------------------------------------- Equation 3

Where:

Density = Tree density.

Dry weight = Core sample dry weight.

Core volume = Core sample volume.

**Estimation of biomass**

Biomass of each tree was estimated using the volume and density as estimated from respective tree and Equation 4 was employed to estimate biomass.

$$\text{Biomass} = \text{Density} \times \text{Volume}$$ ---------------------------------Equation 4

Where:

Density = Value obtained in equation 3.

Volume = Value obtained in equation 1.

**Estimation of carbon**

Tree biomass obtained in equation 4 was used to estimate carbon stock for each tree. The standard multiple factor of 0.5 was used for conversion of biomass to carbon (Equation 5) [14].

$$\text{Carbon} = 0.5 \times \text{Biomas}$$ ---------------------------------------- Equation 5

Where:

Biomass = Value obtained in equation 4.

**Estimation of carbon dioxide**

To convert carbon to carbon dioxide, the carbon values are multiplied by the ratio of the molecular weight of carbon dioxide to that of carbon (44/12) [15]. The value(s) obtained in equation 5 was used to convert carbon to carbon dioxide ($CO_2$) using Equation 6.

$$CO_2 = 3.67 \times \text{carbon}$$ ------------------------------------------ Equation 6

Where:

Carbon = value obtained in equation 5.

**Results and Discussions**

The result of this study showed 124 individual trees in 18 tree species. The tree species with highest frequency is *Acacia auriculiformis* with 31 individuals followed by *Terminalia mantaly* with 22 individual and some species was encountered once e.g. *Ficus exasperata*, *Hura crepitans, Piliostigma thonningii, Pinus caribaea, Vitex doniana,* etc.

The highest carbon and carbon dioxide were recorded from *Gmelina arborea* with 25.41kg carbons and 93.03kg carbon dioxide respectively followed by *Acacia auriculiformis* with carbon and carbon dioxide of 4.65kg and 17.05kg respectively. The lowest carbon and carbon dioxide were recorded for *Piliostigma thonningii* with 0.04kg and 0.17kg respectively (Table 1).

This result of the carbon and carbon dioxide of *Gmelina arborea from* 21 individual trees is consistent with the result of [16] who reported 262.6kg of carbon from 212 individual trees. The total carbon sequestered by *Acacia auriculiformis* (4.65kg), *Albizia lebbeck* (0.63kg), *Tectona grandis* (2.28kg) reported in this study was lower than the values reported by [17] which are: 22.891kg for *Acacia auriculiformis*, 15.169kg for *Albizia lebbeck* and 26.071kg for *Tectona grandis* in a research conducted in Jadavpur University, Kolkata, Indian. This may be due to ecological and characteristic of tree as well as condition of tree stocks. The trees waypoint (coordinate) is presented in the appendix 1.

**Table 1:** Summary of Species, Family and their Carbon Sequestered

| S/N | Tree Species | Family | No of individual | Carbon (kg) | $CO_2$ (kg) |
|---|---|---|---|---|---|
| 1. | *Acacia auriculiformis* | *Fabaceae* | 31 | 4.65 | 17.05 |
| 2. | *Albizia lebbeck* | *Fabaceae* | 3 | 0.63 | 2.37 |
| 3. | *Azadirachta indica* | *Meliceae* | 5 | 2.05 | 7.60 |
| 4. | *Delonix regia* | *Fabaceae* | 6 | 1.68 | 6.18 |
| 5. | *Eucalyptus camaldulensis* | *Myrtaceae* | 6 | 1.02 | 3.90 |
| 6. | *Ficus benjamina* | *Moraceae* | 1 | 0.08 | 0.29 |
| 7. | *Ficus exasperate* | *Moraceae* | 1 | 0.66 | 2.41 |
| 8. | *Gmelina arborea* | *Lamiaceae* | 21 | 25.41 | 93.03 |
| 9. | *Hildegardia barteri* | *Malvaceae* | 2 | 0.20 | 0.70 |
| 10. | *Hura crepitans* | *Euphorbiaceae* | 1 | 0.01 | 0.33 |

| | | | | | |
|---|---|---|---|---|---|
| 11. | *Leucaena leucocephala* | *Fabaceae* | 10 | 1.10 | 4.10 |
| 12. | *Mangifera indica* | *Anacardiaceae* | 4 | 3.64 | 13.44 |
| 13. | *Piliostigma thonningii* | *Fabaceae* | 1 | 0.05 | 0.17 |
| 14. | *Pinus caribaea* | *Pinaceae* | 1 | 0.05 | 0.19 |
| 15. | *Tectona grandis* | *Lamiaceae* | 3 | 2.28 | 8.37 |
| 16. | *Terminalia catappa* | *Combretaceae* | 5 | 1.00 | 3.60 |
| 17. | *Terminalia mantaly* | *Combretaceae* | 22 | 3.08 | 11.00 |
| 18. | *Vitex doniana* | *Verbenaceae* | 1 | 0.35 | 1.30 |
| | Total | | 124 | 47.94 | 176.03 |

## Conclusions and Recommendations

Basically, every tree generates a different amount of carbon sequestration based on the tree characteristics including tree diameter and tree height. The total amount of carbon and carbon dioxide sequestered by the 124 trees encountered was 47.94kg and 176.03kg respectively.

This study had equipped forester as well as urban planner the types of tree with high sequestered carbon and this will in turn inform the choice of tree to be planted in urban area. These species (*Gmelina arborea*, *Acacia auriculiformis* and *Mangifera indica*) could be recommended for planting in any University campus for better sequestration and assimilation of carbon to enrich the quality of ecosystem services within campus community.

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# Appendix 1

**Table 2:** Coordinates of individual tree species and carbon sequestered

| SN | Tree species | Latitude (X) | Longitude(Y) | Carbon(kg) |
|---|---|---|---|---|
| 1 | *Acacia auriculiformis* | 7.48005 | 5.73855 | 17.050 |
| 2 | *Albizia lebbeck* | 7.48085 | 5.74085 | 2.370 |
| 3 | *Azadirachta indica* | 7.47974 | 5.73900 | 7.600 |
| 4 | *Delonix regia* | 7.48062 | 5.73892 | 6.180 |
| 5 | *Eucalyptus camaldulensis* | 7.47954 | 5.73951 | 3.900 |
| 6 | *Ficus benjamina* | 7.47957 | 5.73107 | 0.290 |
| 7 | *Ficus exasperate* | 7.47991 | 5.74019 | 2.410 |
| 8 | *Gmelina arborea* | 7.48101 | 5.74066 | 93.030 |
| 9 | *Hildegardia barteri* | 7.48083 | 5.73944 | 0.700 |
| 10 | *Hura crepitans* | 7.48049 | 5.73969 | 0.330 |
| 11 | *Leucaena leucocephala* | 7.48144 | 5.73912 | 4.100 |
| 12 | *Mangifera indica* | 7.47988 | 5.73997 | 13.440 |
| 13 | *Piliostigma thoniyil* | 7.48048 | 5.73963 | 0.170 |
| 14 | *Pinus caribaea* | 7.48010 | 5.73851 | 0.190 |
| 15 | *Tectona grandis* | 7.47980 | 5.73758 | 8.370 |
| 16 | *Terminalia catappa* | 7.47990 | 5.73993 | 3.600 |
| 17 | *Terminalia mantaly* | 7.48071 | 5.74035 | 11.000 |
| 18 | *Vitex doniana* | 7.48083 | 5.73767 | 1.300 |

# Chapter - 3

# Mahavilvam, *Naringi crenulata* (Roxb.): A Lesser Known Medicinal Tree


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# Chapter - 3

## Mahavilvam, *Naringi crenulata* (Roxb.): A Lesser Known Medicinal Tree

**K. Indhumathi, M. Chandrasekaran, K. Sakthivel, J. Auxcilia and L. Srimathi Priya**

**Abstract**

*Naringi crenulata* (Roxb.) Nicolson belongs to the family Rutaceae is a wild relative of *Citrus* species. It is distributed in India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Indo-China, South-west China, Bhutan, Thailand, Java. In Tamil it is called as 'Maha vilvam' and is considered holy by disciples of Lord Shiva. *Naringi crenulata* is a rich source of many important phytochemicals such as Arbutin, Naringetol, Hesperetin, Tanakamine, Impuritine etc. which has been reported by various workers. Mahavilvam is one such plant being used by healers traditionally. The different parts of the plant like root, stem, bark, leaves and fruits were used to cure different ailments and diseases. It has its key role in traditional as well as modern medicine systems. *Naringi crenulata* has been used in traditional medicine for ages in various countries. Root extracts are used for treating snake bites, vomiting and dysentery. Leaves are used for cold, cough, digestive problems. Bark in various forms is used for treating acne, cold cough and throat infection. Fruits are used for antidote to insect poison and intestinal worms and for liver diseases. Its antioxidant property, antifungal, hepatoprotective, aphrodisiac, anti-inflammatory and anticancer activity has been scientifically proven under *in vitro* conditions. *Naringi crenulata* also has insecticidal activities. Reports are found that it has applications in cosmetic industry.

**Keywords:** Mahavilvam, *Naringi crenulata*, medicinal tree, traditional medicine, insecticidal

### 1. Introduction

*Naringi crenulata* (Roxb.) Nicolson belongs to the family Rutaceae is a wild relative of *Citrus* species. It is often but erroneously considered as wood apple (*Limonia acidissima*). It is native to northern India, northern and central of Myanmar and Northern Thailand [1]. It is distributed in India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Indo-China, South-west China, Bhutan, Thailand, Java. In India it is found in South Indian states Andhra Pradesh, Telangana, Karnataka and Kerela [2]. It is commonly known as Elephant Nettle. In Tamil it is called as ‘Maha vilvam’ and is considered holy by disciples of Lord Shiva.

The vernacular names in Indian languages are:

| | |
|---|---|
| Tamil | : Maghavilvam |
| Hindi | : Beli |
| Kannada | : Nayi Bella, Nayi Bullali, Kadubilvapatre |
| Telugu | : Torri-Velaga, Kukka Valaga |
| Oria | : Benta, Bhenta, Baintha, Ranabele |
| Malayalam | : Dadhiphala, Kattunarakam, Mahavilvam, Malanarakam, Manmadhan, Narinarakam, Serakuttunarakam, Vilathi |

## 2. Botanical description

The vegetative and floral parts are the key parameters used in the proper identification. Mahavilvam, *Naringi crenulata* is a long term small to medium size deciduous tree which shed leaves in March and April. Hard pointed spines are found on branches and stem. The trees reach a height of 5m and have a breast height girth of 23 cm. the growth rate is high in moist areas [1]. The bark is yellowish grey, smooth, corky. Leaves are imparipinnate, alternate and estipulate [3]. The rachis is winged, wings obovate-oblong, glabrous and punctuate. The leaflets are 3-11, opposite, sessile. Flowers are bisexual, white in axillary racemes and appears in April and May. Sepals four, free or united at base, petals four, free. Fruits are berry, sub globose, bluish black with 1-4 seeds. Seeds are dull yellow and smooth [4].

**Basionym:** *Limonia crenulata* Roxb.

**Synonym:** *Hesperethusa crenulata*.

The article is presented with the aim to focus light on this religiously, ornamentally and medicinally important but less recognized tree species.

## 3. Phytochemistry

In the process of tapping the traditional medicinal plants into the modern medicinal pool the botanicals and the medicinal products or principles derived need to be evaluated. Many workers emphasize that in the pharmacognostic evaluation of medicinal plants both analysis of chemical constituents and biological assays are inevitable [5, 6]. Therefore, the investigations of micromorphological, phytochemical physicochemical characterization of various parts of *Naringi crenulata* are a need of hour. The presence of chemical constituents *viz.* alkaloids, steroids, phenolic compounds, saponins and flavonoids from ethanolic extract of *Naringi crenulata is* presented in Table 1.

**Table 1:** Chemical constituents in leaf and bark of *Naringi crenulate* [7, 8]

| S. No. | Chemical constituent | Leaf | Bark |
|---|---|---|---|
| 1. | Alkaloids | 198.46 µg | 221.23 µg |
| 2. | Saponin | 98.01 µg | 194.91 µg |
| 3. | Phenolic compound | 108.12 µg | 88.92 µg |
| 4. | Steroids | 281.02 µg | 247.77 µg |
| 5. | Flavonoids | 251.19 µg | 150.79 µg |
| 6. | Vitamin E | 0.68% | - |
| 7. | Vitamin C | 10.17% | - |

Recent studies have shown that it has significant content of various chemicals of phytochemical importance (Table 2).

**Table 2:** Phytochemicals in various parts of *Naringi crenulata*

| S. No. | Phyto-Chemical Compounds | Part | Reference |
|---|---|---|---|
| 1. | Quinoline | Bark | 9 |
| 2. | Hydroxyquinoline | Root | 9 |
| 3. | Suberosin | Root | 10 |
| 4. | Suberenol | Root | 10 |
| 5. | Epoxysuberosin | Root | 10 |
| 6. | Arbutin | Bark | 11 |
| 7. | Caryophyllene | Leaf | 12 |
| 8. | Propane | Leaf | 12 |
| 9. | Triethoxybutane | Leaf | 12 |
| 10. | Diethoxy methyl octane | Leaf | 12 |
| 11. | Cyclohexane | Leaf | 12 |
| 12. | Sumatriptan | Leaf | 12 |
| 13. | Dimethylsilyloxytridecane | Bark | 12 |
| 14. | Isoquinolin-6-ol | Bark | 12 |
| 15. | Hexadecanol | Bark | 12 |
| 16. | Dinitrophenyl hydrazine | Bark | 12 |
| 17. | Pentadecanoic Acid | Leaf | 13 |

| | | | |
|---|---|---|---|
| 18. | Octadecadienoic Acid | Leaf | 13 |
| 19. | Dimethoxy methyl dihydroisoquinoline | Leaf | 14 |
| 20. | Dimethyl Benzo quinoline | Leaf | 14 |
| 21. | Dihydroneopterin | Leaf | 14 |
| 22. | Naringetol 3 | Leaf | 14 |
| 23. | Hesperetin | Leaf | 14 |
| 24. | Hesperetin 7-rhamnoglucoside | Leaf | 14 |
| 25. | Methyl limonilate | Leaf | 14 |
| 26. | Tanakamine | Leaf | 14 |
| 27. | Tanariflavanone | Leaf | 14 |
| 28. | Chloroquine | Leaf | 14 |
| 29. | Impuritine | Leaf | 14 |

## 4. Medicinal properties

*Naringi crenulata* is a very important medicinal plant whose medicinal properties need to be scientifically proved and documented for better and resourceful utilization for the benefit of human health (Figure 1).

### 4.1 Applications of *Naringi crenulata* in traditional medicinal systems

From time immemorial herbs are used for curing human ailments. They are being conserved in name of sacredness by the native people as they know their importance medicinally. Mahavilvam is one such plant being used by healers traditionally. The different parts of the plant like root, stem, bark, leaves and fruits were used to cure different ailments and diseases. *Naringi crenulata* has been used in traditional medicine for ages in various countries. In South India studies has been conducted on the traditional usage of various parts of it. It has recorded the Traditional Aboriginal Knowledge (TAK) of in Western Ghats of India [15]. The report presents the versatile medicinal properties of *Naringi crenulata* among the tribal community. Root extracts are used for treating snake bites, vomiting and dysentery. Leaves are used for cold, cough, digestive problems. Bark in various forms is used for treating acne, cold cough and throat infection. Fruits are used for antidote to insect poison and intestinal worms and for liver diseases.

Root extract of *Naringi crenulata* is used in treatment of and dysentery. It is also used for snake bite treatment. The stem powder is used in curing acne. Fever can be arrested by the intake of root powder. It also has antipyretic and anti-aging properties. When its juice is applied the sprain is being alleviated. Goggling of root juice reduces throat pain. Leaf decoction is used against cold and cough. As a paste with milk, leaf cures digestive disorders and epilepsy. Hair growth is improved by external application of fresh leaf. Chewing of leaves is a treatment in infertility for ladies. The fruit has the anthelmintic property. Eczema and scabies are treated with *Naringi crenulata* and *Phyllanthus reticulatus* [16]. The following table gives a collective information on the traditional usage of *Naringi crenulata* in treatment of human health.

**Table 3:** Parts of Mahavilvam used as drug /medicine

| S. No. | Application Method | Mode of Consumption | Source of the Tree | Curing Diseases | References |
|---|---|---|---|---|---|
| 1. | Internal | Extract | Root | Vomiting and dysentery | [17] |
| 2. | Internal | Extract | Root | snake bite body pain colic | [18, 19, 20] |
| 3. | Internal | Powder | Stem | Acne body pain fever sprain | [16] |
| 4. | Topical | Powder | Bark | Antipyretic, fever, pitta anti-aging | [11, 21] |
| 5. | Internal | Juice | Bark | Sprain | |
| 6. | Topical | Juice | Bark | Throat infection | |
| 7. | Internal | Extract | Bark | Anticancerous, antitumor | |
| 8. | Internal | Tieing a piece with other herbs | Bark | Amulet | |
| 9. | External | Juice | Bark | Analgesic | |
| 10. | Internal | Decoction | Leaves | Cold, cough | [11] |
| 11. | Internal | Paste orally with milk | Leaves | Mental disorders, digestive disorders, epilepsy | |
| 12. | Internal | Extract | Leaves | Anticancerous, anti-diabetic | |
| 13. | Internal | Extract | Leaves | Heart and liver related disease | |
| 14. | Internal | Fresh leaf chewing | Leaves | Skin disorder | [15] |
| 15. | Internal | Fresh leaf Extract | Leaves | Hair growth | [22] |
| 16. | External | Fresh leaf | Leaves | Removes sterility | |
| 17. | Internal | Decoction | Fruits | Antidote to insect poison and intestinal worms | [15] |
| 18. | Internal | Decoction | Fruits | liver related disease | |

## 4.2 Applications of *Naringi crenulata* in modern medicine

In recent decades the traditional medicinal science involving plant sources is evolving in a remarkable manner as herbs are potential source of effective drugs. An obvious proof being, 25% of pharmaceutical prescriptions in the United States have a minimum of one ingredient from plant source. About 120 products were derived from traditional knowledge in the 20th century [8]. Plant derived drugs are gaining momentum due to the additional advantage of plant source and lesser side effects. The medicinal properties and biological activities of mahavilvam have been documented against various diseases like cancer, hepatoprotectivity, aphrodisiac activity and also on different kinds of inflammatory problems (Table 4).

**Table 4:** Medicinal properties of *Naringi crenulata*

| S. No. | Medicinal Property | Part | References |
|---|---|---|---|
| 1. | Antioxidant property | Leaf, Bark, Root | [23, 24, 25] |
| 2. | Antifungal activity | Leaf | [23, 26, 27] |
| 3. | Hepatoprotective activity | Leaf, Bark | [28] |
| 4. | Aphrodisiac activity | Leaf, Bark | [30] |
| 5. | Anti-inflammatory activity | Leaf, Bark | [29] |
| 6. | Anticancer activity | Leaf, Bark | [14, 30] |
| 7. | Anti diabetic property | Leaf | [32] |
| 8. | Insecticidal activity | Leaf | [13, 33] |

## 5. Antimicrobial activity

Antibacterial and antifungal activities of ethanolic extract of Naringi crenulata leaves showed significant activity against two bacterial strains- *Bacillus subtilis*, *Klebsiella pneumoniae* and two fungal strains *Aspergillus niger*, *Mucor* sp. [34] Striking evidences of antimicrobial and antioxidant activities of leaf and bark extracts were reported [23]. The bark extract of *Naringi crenulata* showed activity against three bacteria *Escherichia coli, Salmonella typhi* and *Staphylococcus aureus*. *Salmonella typhi* and *Staphylococcus aureus* were inhibited by leaf extracts. Different solvent extracts from *Naringi crenulata* showed antimicrobial activities against certain microorganisms *viz. Bacillus pumilus, Bacillus subtilis, Candida albicans*, *Mycobacterium* species and *Staphylococcus aureus* [27]. It was reported that, based on *in vitro* antibacterial activity of leaf extracts of *Naringi crenulata* in various solvents, it could be a potential source of traditional medicine for infections caused by *Escherichia coli*, *Klebsiella pneumonia, Staphylococcus aureus* and *Bacillus subtilis* [35]. According to them there were nine major compounds as per thin layer chromatogram which may be behind the antimicrobial activity of *Naringi crenulata.* It needed a further purification of compounds and further investigation on this aspect. It was supported that the bioactive compounds in *Naringi crenulata* may be the reason behind its effective antimicrobial activity [36].

## 6. Antioxidant activity

Extracts of leaf and bark *Naringi crenulata* showed highest antioxidant activity at highest concentration of 10 mg/ml various types of antioxidant assays carried out. The lowest $IC_{50}$ was recorded by leaf extracts of *Naringi crenulata* [23]. The antioxidant activity of the methanolic extracts of *in vivo* and *in vitro* plant parts of *Naringi crenulata* was determined on the basis of their scavenging activity of the stable 2, 2-diphenyl-2-picryl hydrazyl (DPPH) free radical. The high antioxidant capacity observed for methanolic extract of *Naringi crenulata* suggested that this plant could be used as an additive in the pharmaceutical industry providing good protection against oxidative damage [24]. The antioxidant activities of both the water extract and the ethanol extract from the stem barks of *Naringi crenulata* recorded excellent antioxidant properties in ethanolic extracts than the water extracts [25]. There needs to be a further investigation to tap the potential of *Naringi crenulata* as a source of antioxidant properties.

## 1. Anti-Inflammatory property

Opioids, non-steroidal anti-inflammation drugs (NSAIDS) and corticosteroids are being used for inflammation healing which have a risk of gastrointestinal irritation [37], liver damage [38] and renal damage [39]. The efficacy of leaf and bark extract of *Naringi crenulata* as anti-inflammatory drugs which is being used by Indian medical practitioners for alleviation of pains and inflammation [8]. Use of medicines from traditional sources reduces the chances of side effects and makes the treatments more reliable.

## 2. Insecticidal properties of *Naringi crenulata*

Crop cultivation has always a serious threat from the insect pest which affects the vigour and health of the plants in field. Environmentally safe methods for insect and disease control can be derived from plants which are rich source of new chemicals with efficient insecticidal properties [40]. Botanicals in the form of powders, extracts, essential oils of medicinal plants are tested for their insecticidal activity. Botanicals and plant products are excellent alternate strategy for efficient pest management without disturbing the ecological balance [41]. They may be used as fumigants, repellents, antifeedant, anti-ovipositions and insect growth regulators [16, 42, 43, 44, 45, 46, 47]. Chemical constituents in the form of alkaloids, flavonoids, quinines, steroids, terpenoids and glycosides in *Naringi crenulata* have mosquitocidal activity. *Naringi crenulata* plant extract produced more than 90% mortality of larva of *Culex quinquefasciatus*. The larvicidal activity was due to 9,12-Octadecadienoic Acid (Z,Z). Alkynes, alcohols, phenols and carboxylic acids are found during the FT-IR analysis [13]. Hence *Naringi crenulata* is an effective and efficient alternate for the existing synthetic chemical insecticides as they are target specific, biodegradable and low toxicity to non-target organisms.

### 3. Application of *Naringi crenulata* in cosmetic uses

The fruit is exported from India to the Arabian coasts, where it is used as a condiment with fish, meat, etc., being powdered along with the spices commonly used in cooking. Krajee in Thai or Tanaka in Burmese, has been continuously use as a folk remedy for cosmetic propose. Similar to our usage of sandalwood by grinding on a stone with little moisture, it is used traditionally as a natural skin conditioner especially as facial cosmetics in Myanmar and some part of Northern Thailand [33]. The stem wood powered by grinding the stem on the flat round stone moist with water has been used as a natural skin conditioner especially as facial cosmetics in Myanmar. Burmese women paint their faces yellow with the powder in cycle, which functions on skin cooling, sunscreen preventing sunburn in addition to its efficacy of long time used proven on anti-ageing, prevention of acne and providing soft and fresh skin texture [33]. This botanical cosmetic has long been claimed for skin whitening effect with a proved safety application of the stem bark [48]. *Naringi crenulata* leaf is exhibited as the potential source of arbutin and kojic acid. Arbutin is a proven skin whitening agent and is present in bark and stem wood. The sun protection efficacy of thanaka was evaluated. Liquid foundation containing thanaka powder was therefore developed and further monitored on the stability [49]. The novel natural sunscreen product is promising for the cosmetic consumer and industry. The enormity of *Naringi crenulata* in cosmetic industry needs to be explored further for better utilization.

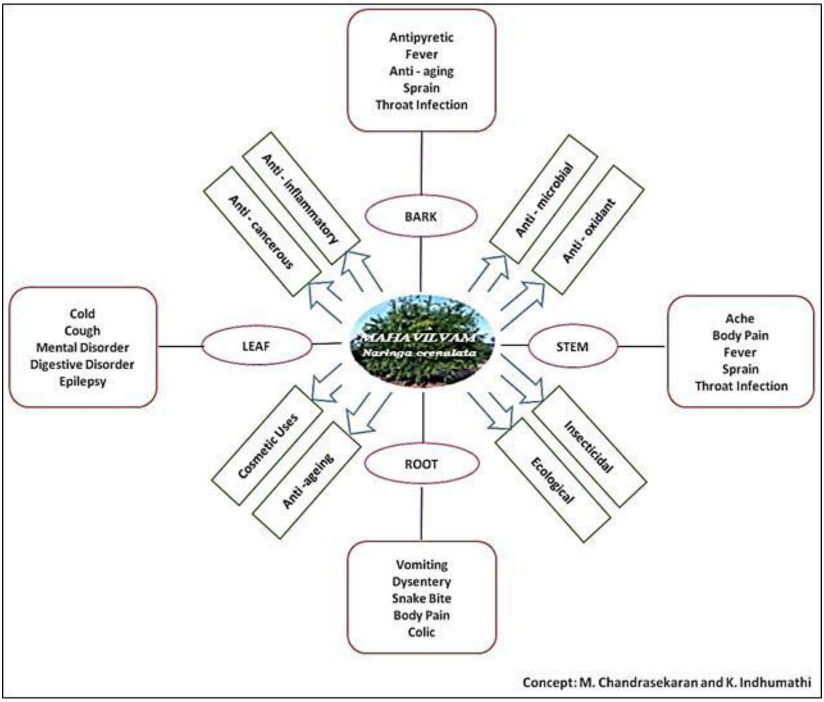


**Fig 1:** Mahavilvam-An Ethnobotanical Bowl of Medicinal, Insecticidal and Cosmetic Values

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# Chapter - 4
# Forest Tree Harvesting Losses and Its Reduction Strategies


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# Chapter - 4

## Forest Tree Harvesting Losses and Its Reduction Strategies

**Upendra Aryal and Bhawana Rijal**


### Abstract

Conventional timber harvesting has been practiced in many countries without taking different forest management regimes and ownership in consideration. Conventional tools and unskilled workers in forest harvesting and timber conversion are resulting huge damage to tree itself, its timber, and residual stand. This chapter explores on possible places of timber losses during forest tree harvesting and timber conversion process. It compares the timber losses during forest tree harvesting in two different stages of forest tree harvesting and processing i.e. tree felling and sawing stages. This chapter also explains about the major timber losses reduction strategies in different stages of timber conversion. In addition, reduced impact logging (RIL) method is the best solution for long-term enhancement of forest resources and timber losses control strategy. In conclusion, conventional logging practices with subsequent regeneration felling are resulting in higher timber losses and other damages on the stand. Reducing harvesting losses using different timber losses reduction strategies could increase outturn timber recovery. It also results higher economic potential of forest, reduce forest degradation and thus enhance climate change mitigation benefits.


**Keywords:** Harvesting tools, reduced impact logging, reduction strategies, tree harvesting losses

### 1. Introduction

In tropical forests, only option to achieve speedy enhancements in long-term forest production is well-planned harvesting operations and stand improvement treatments through sustainable forest management [1]. In both forest tree felling [2] and logs sawing phases [3], conventional forest harvesting activities results in higher amount of timber losses. Major places of timber losses during timber extraction occurs throughout the harvesting process including tree felling in forest, sawing logs to final useable products conversion and manufacture of final aimed solid wood products [4]. Not much studies has been carried out till date about quantity of harvesting losses occurred during forest logging and in mature forest stands [5]. Restricting to minimal timber losses during forest trees harvesting and its processing could lead towards both higher local and national income [6]. As a thumb rule, the ratio of 1:1 (i.e. 1 $m^3$ of timber residue occurs in 1 $m^3$ of extracted useable timber) occurs as harvesting losses rate in different studies depending on its local conditions [7]. Wide range of timber losses occurs during selective logging i.e. starting from 20 percent, one to five times the extracted timber indicating a timber recovery rate [8].

In last decade, high impact conventional logging has highly expanded which results in greater forest degradation and its fragmentation [5]. Conventional logging (CL) includes impromptu, harvest of aimed stem diameter size, fellers fell on their own way and manual or semi manual transportation by tractors or skiding by skidders to collection depot [9]. Nearby tree and regeneration damage, hydrological cycles disorder, soil erosion promotion in slopy areas are some of the results of Conventional logging [10]. On the other hand, to control the results of conventional logging losses including more nearby tree and regeneration losses, workers safety issues and unplanned logging impacts, reduced impact logging (RIL) is getting more attention in recent days [11]. Although it is not a novel concept, its good harvest and operational planning features leads towards harvesting losses minimization and timber recovery increment with more safety and well-planned harvesting activities [9]. In tropical region, reduced impact logging is getting more attention and also proven far better that conventional logging [10, 12]. Despite of all these, many developing countries conventional logging is being practiced more considering less economic expenditure as a main-criteria [13].

Normally, harvesting operations are operated by respective forest user groups or by hired contractors in defined direction of respective forest user groups and government officials [14]. Semi-mechanized harvesting is widely being practiced in many developing countries like India and Nepal. In many developing countries, mechanized harvesting has not been practiced widely because of its higher installation and operational cost. Tree felling, debarking, limping and bucking are being done using hand saw, power chain saw and traditional axes by unskilled or semiskilled labors. Similar to it, in most of saw mills, semi-skilled labors operates horizontal band saw with a simple manual carriage and a vertical band saw for re-sawing. In hilly areas, two-man saws and crosscut saws for tree felling and bucking are being adopted. Similarly, skidding logs inside forest and transport them to defined depot are being done by farm tractors [15].


**Fig 1:** Overview of harvesting flow from standing tree to final outturn based on [16],[17]

To explore and explain forest tree harvesting losses, a framework suggested by [16] is most applicable. Volume obtained from forest inventories are termed as gross volume. During forest tree harvesting, certain part of the gross volume is obtained called a drain. After forest tree harvesting, the remaining volume in forests is termed as logging losses. Subtracting logging losses from the gross volume gives the net volume or net useable volume (Figure 1). As the demand of timber and other forest products is rising, the worth of raw wood and other wood products is also increasing rapidly [18]. Harvester operates their harvest to achieve higher timber and other forest products recovery. While processing forest products, achieving higher timber recovery with minimal loss is a crucial task for enhancement of local and national economy [16].

Quality of tree, felling and sawing equipments being used, final aimed products size and types of labors being used are the main reasons to obtain different rates of timber recovery or losses in different harvests [19]. In order to operate harvesting activities wisely, forest harvesting studies are vital which helps in better planning of harvesting processes and inspection of it and limits illegal logging and overexploitation too [16].

Being a serious issue in many countries, very little studies have been conducted on forest tree harvesting losses and its reduction strategies. This is a big gap in context of forest management and specially forest harvesting and utilization part which hampers highly in local and national economy. In this chapter, we aimed to explain different places of forest tree harvesting losses and its reduction strategies for its control in future. Harvesting study aims to achieve quantity of harvesting losses or objective volume reduction factors for targeted trees, species or tree species groups [16]. This chapter provides guideline as a baseline study that fills the knowledge gap on places and quantity of timber losses along the timber production chain and explore on corrective timber losses reduction strategies or actions to adopt in future.

## 2. Forest tree harvesting according to systems

Forest tree harvesting refers to a process of taking a tree from a forest to wood processing mills. Forest tree harvesting includes felling a tree, bucking into logs and transporting them to mills for making final use materials. It includes many stages like: felling, delimbing, debarking, bucking into logs, chipping, piling loading, transportation and unloading. The processing of tree may vary in accordance with desired size of final products. Forest tree harvesting leads to higher ecological and economical impacts [20]. Forest tree harvesting may differ according to forest harvesting system. There are a number of forest harvesting systems in practice and the four most common are the clearcut, seed-tree, shelterwood, and selection harvest.

**Clearcut system:** Clear cutting is the harvesting of every tree regardless of species or size. In this system, timber losses of tree itself and adjoining trees are comparably less than other forest harvesting systems. Even though clear-cut system may make more disturbances in biodiversity but continuously felling of trees in one direction and easy transportation can reduce timber losses during forest harvesting process.

**Seed-tree system:** This system is similar with clear cut system where some scattered trees are left for future seeds production. Timber losses during forest tree harvesting in this system results comparably lower rate of timber losses during felling, bucking and transportation stages. Similar to clear cut system it may make disturbances in biodiversity but continuously felling of trees in one direction and easy transportation can reduce timber losses during forest harvesting process.

**Shelterwood system:** In this system more trees are left as a shelter for remaining trees and regeneration. Under the partial canopy of remaining trees, new forest will be established. Comparing with clear cut and seed tree system, this system makes lower disturbances in biodiversity but results in higher timber losses rate due to felled tree itself damage and adjoining trees disturbances during harvesting process.

**Selection system:** In this system, individual or small groups of trees are harvested. With a designed proportion, trees of all sizes are harvested in every certain number of years to improve wood quality of remaining trees. Because of higher disturbances in forest, this system results in highest timber losses rate and more disturbances to adjoining trees and undergrowth.

## 3. Timber losses in tree felling and bucking stage

Tree felling involves cutting a standing tree and dropping it in ground. Limping is the removal of the branches from either standing or felled trees. Bucking is the process of cutting a felled tree into desired sized of pieces. During tree felling, limping and bucking, losses occurs in many places and in many ways such as chips, dust and so on. Comparison of some of the studies made in different countries and forests during forest trees felling are presented (Table 1).

**Table 1:** Timber losses rate from standing tree volume to log volume based on [17]

| Study area | Forest product recovery rate | Timber losses rate | Authors |
|---|---|---|---|
| Asia | 50% | 50% (1:1 ratio) | [8] |
| Tropical region (average) | 50% | 50% | [23] |
| Asia-Pacific | 46% | 54% | [23] |
| Sarawak Malaysia | 54% | 46% | [24] |
| Nepal | 80.2% (extracted volume) | 19.8% (left over) | [13] |
| Nepal | 73% | 27% (Average) | [27] |
| Terai forest, Nepal | 78.41% (with rot)<br>76.71% (without rot) | 21.59% (with rot)<br>23.29% (without rot) | [17] |

Different studies have different places of timber losses with different causes but to make it concrete; major timber losses were due to stem rot or tree damage itself, higher stump height and other logging losses remaining in felling site.

Most of the results in table 1 showed that around half of the timber volume is lost during timber harvesting which is noticeably higher. In some studies, more than half of losses occur because of taking whole tree as timber instead of main stem. Similarly, some studies showed less than one fourth of timber losses during tree harvesting which is due to considering even firewood as useful material.

Obtaining higher rate of timber losses could be due to

1) Taking total tree volume with branches volume.
2) Including skidding and transportation losses.
3) Multiple species studies which also includes more branching species.

Generally, in case of clean bole having species like dipterocarp have lower timber losses rate and higher branching species like Dalbergia species have higher timber losses rate based on outturn volume obtained.

## 4. Timber losses in sawing stage

Sawing of wood is the process of cutting a log into desirable sizes of lumber. It includes cutting sides of log and slicing a log into many desired sizes of wood pieces. During sawing stage, mainly timber losses occur in dust and chips form. Comparison of some of the studies made in different countries/regions during trees logs sawing are presented (Table 2).

**Table 2:** Timber losses rate from logs volume to usable timber volume based on [17]

| Study area | Saw mill recovery rate | Losses rate | Authors |
|---|---|---|---|
| Malaysia | 52% | 48% | [28, 29] |
| South East Asia | 50% | 50% | [28, 29] |
| Indonesia | 54% | 46% | [28, 29] |
| Asia-Pacific | 50% | 50% | [28, 29] |
| China | 60% | 40% | [28, 29] |
| Malaysia | 42-50% | 50-58% | [7] |
| Many developing countries | 50.8% (average) | 49.2% (average) | [28] |
| Nepal | 61% | 39% | [13] |
| Terai Sal forest, Nepal | 69.19% (with rot) | 30.81% (with rot) | [27] |
| | 70.27% (without rot) | 29.73% (without rot) | |

Different studies have different places of timber losses in sawing stage but to make it concrete; major timber losses were due to stem rot, knots, saw dust and *Bakal* (unfit and chips). Major causes for those losses could be due to variation in sawing equipments being used, different logs quality and final product size targeted [19].

Most of the results in table 2 showed that around half of the timber volume is lost during logs sawing which is noticeably higher. In some studies, more than half of losses occur because of logs not being cylindrical, thicker sawing blade being used, and less skilled manpower being used [28]. Similarly, some studies showed less than one third of timber losses during logs sawing which is due to smaller outturn size needed, developed furniture with advanced equipments being used and highly skilled manpower being used [3]. Generally, in case of cylindrical bole having species like dipterocarp have lower timber losses rate and non-uniform bole having species like Dalbergia species have higher timber losses rate based on outturn volume obtained.

## 5. Timber losses reduction strategies

### 5.1 Timber losses causes

Major causes of timber losses during forest tree harvesting are due to improper equipment being used, use of less skilled manpower and ignoring ergonomic facilities [17]. Using inappropriate tools and equipments leads towards higher timber losses but in other hand use of an appropriate equipments in forest tree harvesting can lead towards higher timber production with minimal losses [29]. In addition, traditional harvesting practice [30] and conventional saw mills are causing enormous amount of timber losses in transportation and in sawing stage [31]. Use of flexible and portable sawmills in the tree felling sites could minimize such timber losses in felling, transportation and sawing stages [31]. In tropics, majority of fellers, buckers and sawyers are unskilled and semi-skilled laborers which lead in higher timber losses. Compulsory provision of trainings and use of certified skilled manpower for timber production activities could be a best solution to it [32].

### 5.2 Timber losses reduction strategies during felling stage

For the reduction of timber losses, use of appropriate equipments during forest tree felling and whole harvesting process is a major strategy [17]. Good choice of tools and technology can reduce timber losses and has remarkable impact on tree itself, residual stand and regeneration [29]. Tree felling and bucking of logs can be done manually, motor-manually or by mechanized harvesters [33]. While comparing different methods of harvesting, mechanized harvesting creates minimal timber losses than manual or semi-manual harvesting i.e. using a chainsaw for felling and bucking trees [34]. Major losses occurs due to manual harvesting practices [30]. In addition to it, betterment with ergonomic condition reduces the risk of employers in work place and increase the ratio of timber recovery. Well experienced and adequately trained employees can reduce timber losses which minimizes tree itself damage and residuals damage [35]. Best option for obtaining higher timber recovery could be preparation of highly trained workers team and mobilization of then from operation to operation [36].

### 5.3 Timber losses reduction strategies during sawing stage

In sawing stage, a promotion of appropriate equipment is the best strategy to reduce the sawing losses rate [17]. Use of portable and flexible sawmills in tree felling site results higher timber and lower disturbance to remaining stand [31]. Small and portable sawmills are environment-friendly, highly profitable and local forest users could also operate it easily. Such sawmills are also a key option for sustainable harvesting and local employment generation opportunity [37]. It gives a clear idea for local managers to decide how much and where to fell trees so that it will not be over logging. It has lower establishment and operation cost as well as demands limited human resources. Using flexible and portable sawmills in felling site can also reduce left over materials in the forest [38]. So that modified sawing practices and leftover wood processing machines use can be a best option for reducing timber losses [39]. In addition to unskilled manpower and conventional equipments being used, conventional practice of sawing and lack of secondary wastage processing are also causes for such higher timber losses [39]. Live sawing can also increase timber recovery in great ration but it is only applicable in green logs [3]. If we need to saw green logs then live sawing techniques is a best practice as already proved in well-furnished Jepara area of Indonesia [3].

Generally, in many developing countries, taking consideration of ergonomic context is very limited. It is due to lack of economic investment in project and focusing more in benefit from the project where, ergonomic expenses are considered as liabilities. Even though, ergonomics in forest tree harvesting and sawing shows higher investment in an initial phase but it will payback by increasing downtime of equipment, controls overexploitation of trees and adjoining stand, reduces operational cost and long-lasting benefits [40]. As being one of the world’s most risky work as forest tree harvesting, up to 10 persons died per million $m^3$ harvested in Malaysia from 1976 to 1989 when there is no application ergonomic contact [41]. Not only workers but also forest managers need ergonomic facilities for more motivation and better harvesting plans [41].

## 6. Reduced Impact Logging (RIL)

In addition to quick timber losses reduction strategies, reduced impact logging (RIL) is the best solution for long-term enhancement of forest and timber losses control techniques. Even though it is not a new concept but its application is very limited in many developing countries. RIL helps to reduce different kinds of impact on forest stands and soil. It includes carefully designed and highly controlled implementation of timber harvesting operations. Within the forest management plan (mostly 20 years), RIL plans are of two types namely: Strategic plans and Tactical plans [42].

### 1. Strategic plans

Strategic plans are those special plans of harvesting forest trees which are also a component of forest management planning mechanism. These plans are prepared with an involvement of group of experts such as foresters, environmentalist, engineer, economist and social science experts. Generally, these plans are prepared for a period of 5 years or more. Such plans include bordering of forest areas and annual coupes, volume production estimation, main road design and managing harvesting equipment.

**2. Tactical plans**

Tactical plans are those specific plans of harvesting forest trees which are also a component of forest management planning mechanism. These plans are prepared with an involvement of small group with foresters and loggers. Generally, these plans are prepared for a period of 1 years or 2 years. Such plans include planning of felling, planning of skidding trails, pre-harvesting inventory and supervision of logging activities.

RIL generally involves different activities in three different stages i.e. pre-harvesting, harvesting and post harvesting phases. Major RIL operations in each phase based on [42] are as follows:

1) Pre-harvesting RIL activities

i) Forest stock survey.
ii) Climber cutting and cleaning forest.
iii) Topography assessment and identify accessibility.
iv) Protected areas detection.
v) Road, landing and skid trail design.
vi) Final planning of felling.
vii) Pre-logging RIL survey.
viii) Finalization of felling plan.

2) Harvesting RIL activities

i) Directional felling of tree
ii) Bucking into desirable sizes
iii) Skid trail mapping and skidding
iv) Landing in depot

3) Post harvesting activities

i) Rehabilitation of Skidding trails.
ii) Minor roads closure.
iii) Control access permanently in forest.
iv) Cleaning landing and temporary camps.

Reduced impact logging (RIL) could be a best strategy to reduce timber losses in all stages of forest tree harvesting and future effects of harvesting in remaining stand. Damage to the stand can be reduced by 30-50 percentages by using RIL method than using conventional harvesting method [10, 12, 43]. RIL includes forest inventory and harvesting planning that helps to minimize the damage to remaining stand and increase forest resources utilization [44]. A study from eastern kalimantan, project named "STREAK" confirmed that RIL method increased recovery by 50% than in conventional logging method [44]. Due to higher demand of economic expenses and large resources, RIL is also being criticized as "Reduced Income Logging". In other hand, stump height in tree felling in RIL method conventional one [45] and also it needs higher operating cost for planning and inspection of logging, training for loggers and other operators [44].

## 7. Conclusions and Recommendations

Conventional forest tree harvesting and sawing practices are being practiced which results in higher amount of losses in timber and remaining stand. Control of logging and sawing losses by using different timber losses reduction strategies could amplify timber recovery rate and alternative use of timber losses in long-term. Additionally, timber losses reduction could also control forest degradation and helps to reduce climate change effects. Comparison of timber losses rate in logging and sawing stage could help forest users to identify approximate quantity of usable timber from available resources. It also helps central and provincial government to formulate forest harvesting plans and operational plans of forest incorporating timber losses possibilities and its reduction strategies for sustainable management of forest. Also, Reduced Impact Logging (RIL) can minimize such timber losses in different stages and results less disturbance in forest with long-term benefits from it. Introduction of an appropriate tree harvesting equipment and its cost benefit analysis should be carried out for sustainable management of forest.

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# Chapter - 5
# Breeding Techniques of Forest Trees

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# Chapter - 5

## Breeding Techniques of Forest Trees

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### Abstract

In our earth, number of forests and trees are disappearing day by day at an alarming rate. There are many reasons behind deforestation like urbanization, wildfire, grazing, shifting cultivation and different biotic and abiotic stresses. Therefore, aim for tree breeding is to good adaptability to the environment, different biotic and abiotic stress resistance, increasing forest productivity and quality of forest products. Both conventional and modern tree breeding techniques are associated with forest tree improvement. In the conventional methods the basic techniques are selection of trees, provenance trail and hybridization and production of forest trees. Different methods of hybridization and vegetative propagation are used in tree improvement programme. In the modern methods of tree breeding, clonal seed orchard is very important to minimize selfing and maximize outcrossing for better adoptability of plants. Other methods like micro-propagation and genetic engineering for tree improvement are discussed in details. Some important forest tree improvement programme is briefly reviewed in this chapter.


**Keywords:** Deforestation, tree breeding, conventional and modern breeding method, clonal seed orchard

### Introduction

Genes are the basis for all genetic variation and biodiversity in the world. Genetics deals with study of different heritable variation among related organisms. Forest genetics is a branch of genetics deals with study of hereditary variation in forest trees. Forest genetics generally includes Mendelian genetics, population genetics and quantitative genetics. Mendelian genetics are usually traditional method of genetics include segregation, independent assortment, progeny-parent relationship, linkage of characters and different gene actions. Population genetics deals with genetic behaviour, distribution, and changes in large groups or populations of individuals over a period of time and responses to natural and artificial selection. It includes some concepts such as survival, the Hardy-Weinberg equilibrium for allele frequencies, fitness, and polymorphism. Tree improvement is the application of forest genetics and allied discipline, such as tree biology, silviculture and economics, to the development of genetically improved varieties of forest trees aims to develop varieties which increase the quality and quantity of product.

In our world, almost 4.06 billion hectares of forest are there which occupy nearly 31% of total land. More than 50% of the total world forest are found in only 5 countries (USA, China, Russian Federation, Brazil and Canada). The Global Tree database reported that 60082 species of trees exist in the world, out of 45% of those trees are the members of 10 families only (FAO, 2020). In India, total forests and total trees cover 7,12,249 sq. km which is estimated around 24.56% of total geographical area of this country (ISFR, 2019).

Genetic principles have been manifested widely in forest management within the last 100years and breeding operations were practiced earlier. The intent of this chapter is to describe different techniques of tree improvement such as conventional breeding technique (introduction of new plant species, selection, provenance trial, hybridization), modern tree breeding technique (seed orchard, micropropagation and genetic engineering) and important genetic constituents and breeding achievement for some important forest trees in Indian subcontinent (Table 1).

**Table 1:** Chronology of some important of Forest genetics and tree improvement

| Year | Discovery/Development | Reference |
|---|---|---|
| BC | Early crop and animal domestication. | Allard (1960), Briggs and Knowles (1967) |
| 1700s | Importance of seed origin. | Morgenstern (1996) |
| 1800s | Development of Hybridization, vegetative propagation. | Zobel and Talbert (1984) |
| 1856 | Progeny testing in plants. | Vilmorin |
| 1859 | Natural selection, evolution of species. | Darwin (1859) |
| 1866 | Classical laws of inheritance. | Mendel (1866) |
| 1908 | Gene frequency equilibrium in populations. | Hardy (1908), Weinberg (1908) |
| 1916 | Inheritance of quantitative traits. | Yule *et al*. |
| 1925 | Modern statistics: ANOVA, Randomization. | Fisher (1925) |
| 1930s | Mathematical theory of selection. | Fisher (1930), Haldane |
| 1930s | Genetics of populations, inbreeding. | Wright (1931) |
| 1942 | Reconciliation of Darwin's and Mendel's laws. | Huxley, Ridley (1993) |

| | | |
|---|---|---|
| 1944 | Discovery of DNA as hereditary material. | Avery *et al*. (1944) |
| 1950s | Large-scale tree improvement programs. | Zobel and Talbert (1984) |
| 1953 | Double helix structure of DNA. | Watson and Crick (1953) |
| 1960s | Isozymes for population genetic studies. | Soltis and Soltis (1989) |
| 1961 | Deciphering of genetic code. | Nirenberg and Matthai (1961) |
| 1970s | Mixed model analysis in quantitative genetics. | Henderson (1975, 1976) |
| 1971 | Isozymes applied to forest trees. | Conkle (1971) |
| 1977 | Chemical determination of DNA sequence. | Sanger *et al.* (1977) |
| 1980 | Discovery of RFLP mapping techniques. | Botstein *et al.* (1980) |
| 1980 | CAMCORE gene conservation cooperative. | Zobel and Dvorak, Dvorak and Donahue (1992) |
| 1981 | Transformation by Agrobacterium. | Mazke and Chilton (1981) |
| 1985 | Polymerase chain reaction. | Sakai *et al.* (1985) |
| 1986 | Paternal inheritance of chloroplast DNA in conifers. | Neale *et al.* (1986) |
| 1987 | First transgenic forest tree (Poplar) development. | Fillatti *et al.* (1987) |

**Sources of variation in forests**

It is well known that the source of variation is very important factor related to Tree Breeding. Variation is defined as any difference between cells, individual and/or organisms or groups of organisms of any species which caused either by genetic differences (genotypic variation) or by the effect of environmental factors (environmental variation) on the expression of the genetic potentials or appearance (phenotypic variation). Variation may be shown in physical appearance, metabolism, fertility, mode of reproduction, behaviour and other obvious or measurable characters. Genotypic variation is the difference in genotypes between individuals of the same species or between different species. Phenotypic variation usually occurs due to Environmental Variation (Fig. 1). The environmental effects on phenotype include all non-genetic factors such as climate, soil, diseases, insect pests and competition within and among species. Thus,

Phenotypic Variation ($V_p$) = Genotypic Variation ($V_g$) + Environmental Variation ($V_e$)

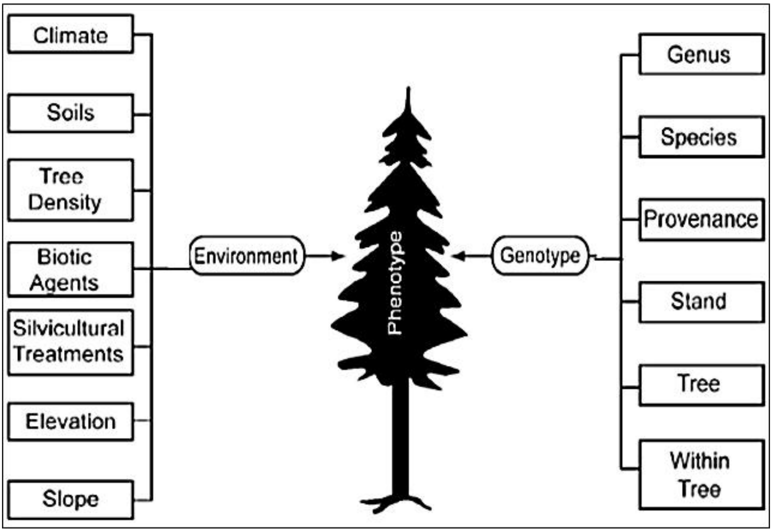



**Fig 1:** Schematic diagram showing environment and genotypic factors and their contribution towards phenotype development of tree.

**Source:** Forest Genetics book, White *et al*. (2007)

## Genetic variation

It is the difference of plants at genotypic level. Genetic Variation provides opportunity for plant breeders to develop new and improved cultivars with desirable characteristics. It is essential for natural selection because natural selection can only modify frequency of alleles that already exist in the population.

## Methods of forest tree breeding

Improvement in plants may be achieved in Conventional and Modern Technique-

## Conventional tree breeding technique

### 1. Introduction of new plant species

Introduction of new species of plants from different regions or different countries has been an important part of breeding programs for many species. In India, agencies like NBPGR are responsible for introduction of germplasms of many trees or forest plants. Based on Adaption, introduction in two types, i.e., Primary introduction and Secondary Introduction and based on utilization, it is also two types, viz. Direct and Indirect.

The Main objective of introduction is to introduce new plant species, creation of genetic variation and get new sources of resistance against biotic and abiotic stresses. But sometimes unwanted insects, weeds and diseases also introduce with it and became threat to the ecological balance. Example- In Sweden the floristic diversity is found to be greater under European larch (Larix decidua Mill.), which is an introduced tree species to Sweden in comparison to the native Norway spruce (Felton *et al.* 2013).

## 2. Selection

The important step in the tree- improvement cycle is the selection of parent trees in natural stands. Selection is made on physical characteristics, such as superior growth, reduced disease or insect damage based upon eye judgement. This enables to attain significant amount of genetic gain as quickly and inexpensively at the time of maintaining a broad genetic base. The breeder ensures that enough trees are selected to provide a level of genetic diversity that will buffer the future forest from extremes in the environment and attacks of insects and diseases. The selection is depending on availability of pedigree information, availability of genetic variation and condition of forest.

**Plus tree selection:** It is the process of selection in the conventional breeding methods. It is either by comparing phenotypic values of a candidate tree with those of base population (comparison methods) or evaluating a candidate tree on the basis of its score values (individual tree methods).

This method includes-

- Comparison Tree Selection.
- Base Value method or Baseline Selection or Individual Tree Selection.
- Regression Method.

**Comparison tree selection:** The comparison or check-tree method is most in vogue and preferred for species growing in relatively uniform, even-aged stands of a single dominant species or at most, only a few species. It is suitable for plantation and even aged natural stands. In practice, after a superior tree candidate is located, it is scored for traits of interest in relation to a number of surrounding trees, the "comparison trees" (Cech 1959, Pitcher and Dorn 1967). If the candidate exceeds the comparison trees by a certain arbitrary amount, it is selected for incorporation into the weeding program, often by grafting scion into a seed orchard. The objective is to adjust or correct the phenotypic value of the candidate tree for environmental effects common total particular stand. For selecting the candidate tree, it is necessary that candidate tree should be 5% superior in height and 20% in diameter at breast height (dbh) and free from disease and pest infestation (Fig.2).

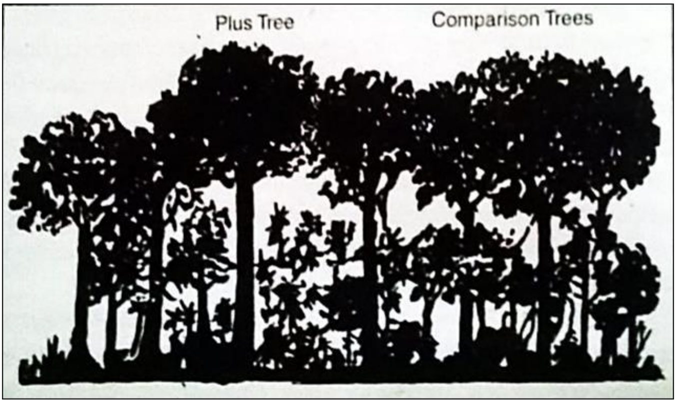



**Fig 2:** A candidate tree is compared with nearest neighbour in a stand

**Source:** Google Image

**Individual tree selection or baseline selection:** Individual-tree selection can be done when stands are uneven-aged and when high species diversity makes it impossible to find comparison trees adjacent to the select-tree candidate (Beineke and Lowe 1969). This selection is made simultaneously for all characters but rejecting all individual, which fail to meet the minimum selection standard for any one trait. Mixed hardwood forests are the best example. In its most simply-applied form, individuals are located and their value for traits of interest is compared to the average for the region in which the selections are made. If the candidate exceeds the base-line by an arbitrary amount, it is selected and incorporated into the breeding population. The base-line may take the form of a regression equation relating height or diameter to age but it could even be a multiple regression equation that takes into account physical factors of the site such as soil texture and drainage. The candidate tree is not compared to surrounding trees of the same species.

**Regression method of selection system:** It is very useful method of tree grading for uneven-aged of mixed species type stands. It is built by sampling of a number of trees for desired characteristics. Regression line is developed for a stand or site, relating the expression of characters to tree age by sampling a number of trees. This regression Method of selection system is suitable for all aged mixed species. The regression line should be based on at least 50 trees if the age spread is considerable. This method cannot be used for those species whose age cannot be determined.

## 3. Provenance trial

The important step in any tree improvement programme is the right choice of tree species followed by selection of suitable provenance within a species. It is very necessary to conduct species and provenance test before making right choice of species and provenance for specific site. Seeds are collected from a number of widely scattered stand and the seedling are grown under similar condition to select a seed source for better growth and adaptability. Species and provenance trial should be conducted according to written plans, which will usually form part of research programme of national forest authority.

The sequence of Provenance Testing is-

- Range-wide provenance sampling phase.
- Restricted provenance sampling phase.
- Provenance proving stage.

**Range-wide provenance sampling phase:** The objective of this phase is to determine the content and pattern of variation between provenances of promising species. The number of provenances included in this phase depends upon the geographical distribution and variation in the species. About 10-30 provenances are suggested in this phase. This phase is run concurrently with species elimination phase. The trail of this phase is laid on small plot size.

**Restricted provenance sampling phase:** Restricted provenance sampling phase is helps to find sub regions and ultimately provenances most suited to site under test and also detects minor trends and gives location of exact stands or small areas having the best germplasm. Around 3-5 promising provenances are selected and may be tested. This test provides information about comparative amount of geographic and individual tree variability to function as seed orchard.

**Provenance proving stage:** The importance of this phase is to confirm the result obtain from restricted provenance phase. Here only 1 or 2 provenances will usually be tested in pilot plantations.

### Features of provenance trial

- Selection of parent stands of a species in natural forest.
- Selection of site, planning and designs of experiments.
- Techniques and assessment in forest plants like the duration of the trials (short, medium and long), designing and conduct of experiments and assessment.

- Assessment of different design of experiment and planning of experiment.
- Design of nursery experiments, nursery assessment and conduction of this trials.

**Importance of provenance trial in tree breeding**

- Provenance test is essential to obtain yield per unit area.
- This test assure breeder about quality genotype.
- Provenance trials will usually result in the elimination of undesirable species.
- It also screens available genetic variation and choose the best one among all available genotype for further breeding work.

**4. Hybridization & Production**

**Hybridization:** Hybridization is an important component of the evolution of trees. Hybridization is recognized as an important mechanism involved in generating novel genetic variation and evolve of new recombinant types. These new recombinant types play an important component of evolutionary change, providing natural systems that are involved in the creation or maintenance of species differences. The term hybridization has been used to denote crossing between plants of different species. Hybridization is generally of two types, Interspecific and Intraspecific, with those another one is interracial hybridization. Duffield and Snyder (1958) suggest that interspecific hybridization refers to crosses between species while intraspecific hybridization to crosses between individuals within a species, another interracial hybridization to crosses between members of populations within species.

**Objectives**

- Breeding for tree plants are done for its timber characteristics, but lacking in resistance to an effective disease or insect pest, it may be combined with a closely related resistant species to produce a hybrid including all the desirable characteristics. Example- The hybrid between European *Populus tremula* x North American *Populus tremuloides* shows resistance to rust and aspen scab disease.
- A species desirable for a certain region from a forestry standpoint but lacking in environment hardiness may be crossing with a hardy species to produce a hybrid adaptable to the region. Example, Piatnitsky (1954) reported a drought-resistant hybrid, by crossing

Caucasian oak x English oak results in the hybrid has 30 to 40 percent less water loss in transpiration than English oak.

**Hybrid zone:** A hybrid zone refers to an area in which genetically dissimilar parental individuals form hybrids of mixed ancestry, which resulting in genetic clines from one parental genotype to the other across a variety. Zones of mixed ancestry are important sources of novel recombinant genotypes. Hybrids are considered the raw material of evolution and a source of functional novelty. Therefore, hybrid zones are important sources of genetic variation. Natural hybrid zones are maintained through a combination of selection and gene flow.

**Inbreeding:** In this process, where the mating of trees are done closely related by their ancestry or identical genetic constituents. It may cause great variability in self-fertility of forest trees. The degree of self-fertility may also be quite variable among individuals of a single tree species, as seen in case in Douglas-fir (Orr-Ewing, 1954). The demerit in this hybridization method is inbreeding depression. In certain cases, it may lose vigour and fitness of the trees evolve through it. An excellent example of this effect may be seen in western white pine seedlings (Bingham and Squillace, 1955).

**Polyploidy:** Polyploids can be used in hybridization and the heritable condition of having more than two complete sets of chromosomes is called Polyploidy. Polyploids are common among forest plants.

Examples of polyploids are-

- Natural triploid of European White birch (Johnsson, 1944).
- Natural tetraploids of Norway Spruce in Sweden (Kiellander, 1950).
- Tetraploid European Larch, and tetraploid Caucasian Alder (Larsen, 1956).
- Natural triploid hybrid of *Betula pubescents* and *Betula pendula*, discovered by Helms and Jorgensen (Larsen, 1956).

**Advantages of hybridization in tree improvement**

- To obtain large number of genetic combinations because variation among species present is often greater than among trees or races within species.
- It may be possible to obtain progeny with characters that do not occur in either parent.
- Hybrid vigour may occur in species crosses.

- This permits a very wide range of selection of material.
- Hybrids of many tree species are shown fertile.
- Hybridization is most efficiently used in connection with selection for not only race selection, but careful selection of superior individual specimens from each of the parent species.

**Disadvantages of hybridization in tree improvement**

- Crossing is limited to compatible species, and in some cases, this may limit the number of combinations possible.
- Seed set in some hybrids may be very low.
- Compatible species and species adapted to a specific geographic area may not vary widely in a large number of economically important traits, causes limited improvement like wood quality characteristics among southern pine sp.

**Production of forest trees (vegetative propagation):** Vegetative propagation is an asexual propagation of plant reproduction that can occur through fragmentation of specific plant parts. This method can transfer all genetic potential through use of vegetative propagation to the new tree and helps to mass production of plants. Thus, it is one of the most useful tools that are used in tree breeding frequently for managing the breeding population and mass multiplication.

The main methods of vegetative propagations are-

i) Cutting

ii) Grafting

iii) Layering

Cuttings are the earliest methods of vegetative propagation. It is very cost-effective method. Cutting in forest trees usually done by Stem Cutting (Eucalyptus) and Root Cutting (*Dalbergia sissoo*).

Grafting is mainly done by placing a part of tree (usually called scion) into a root or stem or any branch (namely stock) gives rise to genetically “composite” plants made up of the selected genotype of scion and of the unselected genotype of the rootstock. it is expensive and generally not used for mass propagation. Example- Teak grafting.

Layering is the method of propagation of new trees by which development of new roots from the stem, while the stem is attached with parent plant. The main drawback of this method is to take long time to generate of roots, also expensive.

## 5. Accelerated breeding approaches

It involves understanding about the factors/process influence to promote flowering, basic physiological process of trees and the reproduction of trees. It reduces the time needed to mate parent tree and collect the seed from those parent tree when they are selected.

**Modern tree breeding technique**

## 1. Seed orchard

A seed orchard is an intensively-managed plantation of genetically superior trees, isolated to reduce pollination from genetically inferior outside sources for the mass production of genetically improved seeds for the establishment of new forests. It is established by setting out clones or seedling progeny of trees selected for desired characteristics. A seed orchard is sometime composed of grafts of selected genotypes, but seedling seed orchards also occur mainly to combine orchard with progeny testing. Also, it is the common methods of mass-multiplication for transferring genetically improved material from breeding populations. The general requirement in seed orchard design is to minimize selfing and maximizing outcrossing and mating of all genotypes. The two methods are frequently used design are Randomized Complete Block Design and Incomplete Block Design.

Seed Orchards are two types-

i) Clonal seed orchard.

ii) Seedling seed orchard.

**i) Clonal seed orchard:** In clonal seed orchard, where vegetative material such as grafts, cuttings or plantlets of selected phenotypes or plus trees are planted in areas with good isolation, under optimum conditions favouring flowering and fertilization and accomplished for production of maximum number of seed. The main characteristic of the clonal orchard is maximum seed production by use of wide spacing. The seed orchard serves as production area only for seed or other vegetative propagules.

It is of two types-

a) Clonal seed orchard without progeny test.

b) Clonal seed orchard with progeny test.

**a) Clonal seed orchard without progeny test:** This seed orchard is mainly selection in wild plated stand, grafting for establishment of seed orchard. In this method no progeny testing is done.

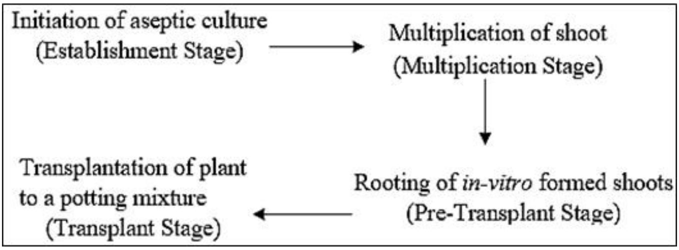
b) **Clonal seed orchard with progeny test:** This kind of orchard contains large number of clones are selected on the basis of their physical appearance and planted. Genetic worth for selection of desirable genotypes can be known on the basis of performance of their progeny. The main objective is to evaluate family lines or the purpose of rouging out seed orchards.

ii) **Seedling seed orchard:** In the seedling seed orchard the progenies from open pollination or controlled pollination of selected phenotypes are planted at normal plantation spacing. The seedlings are maintained and allow thinning before abundant seed production. The individual is selected according to their phenotypic performance. The main disadvantage is that it usually takes more time to start flowering.

**2. Micro-propagation**

It refers to *in-vitro* clonal propagation which can produce true type plants in large number at very short duration. It may be Meristem culture, callus culture, protoplast culture, cell suspension culture and organ culture.

It involves 4 steps-




**Embryo culture:** It is the culture of isolate embryos. Hybrid embryos of many interspecific crosses fail to grow meet the maturity mainly due to the deterioration of the endosperm or an abortion of the embryos. Embryo culture helps to overcome seed dormancy which with many trees take several years for germination under natural condition.

**Anther culture:** It means plants are to be generate from the haploid cells for haploid production. It can be used to produce homozygous lines which are vital for any breeding programmes and also for various genetic manipulation. It has been demonstrated on a large number of herbaceous species.

**Somatic embryogenesis:** It is an artificial non sextual development process in which a plant is produced from a somatic cell. It may be direct Somatic Embryogenesis which refers to development of embryos directly from explant and indirect somatic embryogenesis, in which embryos are formed through pre-embryogenic determined cell.

**Organogenesis:** It is the process of differentiation by which plant organs are formed. It can often be achieved through tissues from seedlings and sometimes from mature trees. It has been effective in propagating some species, for example, *Eucalyptus*, *Populus genera*, and *Pinus radiata.* Precocious flowering is main problem of plants arises and multiplied through organogenesis.

## 3. Genetic engineering

Forest trees are the most important component of earth biomass provide raw materials and help to maintain biodiversity. For achieving these goals may require the introduction or modified expression of genes for achieving desirable traits in a sustainable manner. It can be done using two methods. One is Agrobacterium mediated gene transfer and biolistic method of gene transfer.

**Agrobacterium mediated gene transfer:** Agrobacterium is a soil born gram negative bacteria. It is rod shaped and motile which belongs to family Rhizobiaceae. It was first discovered by Smith and Townsend at 1907. It is a phytopathogen hence most effective natural genetic engineer. It may be three species responsible for different traits. *A. tumefaciens* responsible for crown gall disease, *A rhizogenes* for hairy root disease and *A radiobacter* is a virulent strain.

Agrobacterium-mediated transformation of *Populus Species* Procedure as given below (Fig. 3).

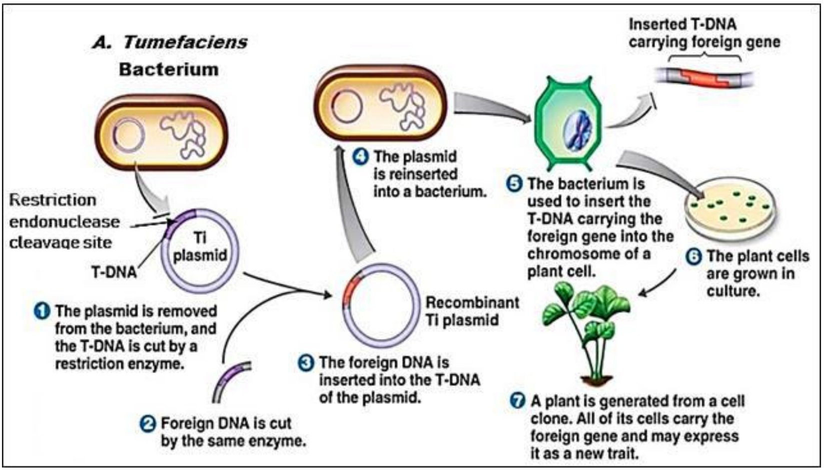



**Fig 3:** Agrobacterium-mediated transformation of Populus Species.

**Source:** https://www.slideshare.net

**Biolistic method of gene transfer:** It is also called Partial gun or gene gun method. In this method, gold or tungsten particles coated with plasmid DNA are used. The particle is forced into high speed into the target plant material where DNA is released and integrated into genome. It cannot be used very frequently as it may cause physical damage to the cell because of high force.

**Table 2:** Example of different methods of DNA transfer in Trees

| **Species** | **Technique** | **Transgene** | **Plant Regeneration** | **Reference** |
|---|---|---|---|---|
| Populus | Cocultivation with Agrobacterium tumefaciens | Bar gene | Yes | Busov *et al*. 2010 |
| *Picea abies* [L.] Karst | Biolistic transformation | ccr gen fused in antisense orientation | Yes, through embryogenesis | Wadenbäck *et al*., 2008 |
| *Pinus radiata* | Biolistic transformation | nptII and uidA genes | Yes, through embryogenesis | Walter *et al*. 1998 |
| *Quercus suber* L. | Cocultivation with Agrobacterium tumefaciens | nptII and uidA genes | Yes, through embryogenesis | Álvarez & Ordás, 2007 |
| *Prunus serotina* | Cocultivation with Agrobacterium tumefaciens | nptII and PsAG genes | Yes, through Organogenesis | Liu & Pijut 2010 |

**Genetic constituents and tree improvement of some forest trees-**

**Pines (*Pinus* sp.)**

**Origin, distribution and description:** Pine species are evergreen trees or shrubs belongs to the family Pinaceae. Pines are adopted from tropical to temperate and subalpine to boreal. The primary centre for diversity is Central America, having 43 species are found in Mexico and the secondary region is in China. Four species of pines were known in India, *Pinus roxburghii* Sarg., *P. wallichiana Jack.*, P. *Kesiya Royle ex Gordon* and *P. gerardiana Wall.*

**Genetic composition:** All Pinus species were 24 chromosomes and it is diploid species. (2n= 2x = 24). Pine species show the largest DNA contents per diploid cell ranging from ca. 44 pg (*P. banksiana*) to 75pg (*P. gerardiana*) whereas, 1 pg = 960 Mb (Arumuganathan and Earle 1991). Many attempts have been made to construct chromosome-specific karyotypes for various pine species using traditional cytogenetics techniques, like., C-banding, Giemsa, and fluorescent banding (Borzan and Papes 1978; MacPherson and Filion 1981; Drewry 1982; Saylor 1983). Recently, fluorescent *in situ* hybridization (FISH) has been utilized in several pine species for karyotype development (Doudrick *et al.* 1995; Lubaretz *et al*. 1996; Hizume *et al*. 2002).

**Tree improvement programme:** Setting of goals for breeding programme was originally done subjectively, based on observations of the main traits influencing profitability, of the variability and heritability of the traits concerned, and of the genetic correlations among traits (Burdon 2004). The setting of breeding goals is very important for any tree-improvement programme, but pine tree breeding programs do not have formally defined breeding objectives. Although breeding objective is to improve growth, form, climatic adaptation, and resistance to certain diseases of pine trees (Cahalan 1981; Danjon 1995; Paul *et al.* 1997). *Pinus roxburghii* is the low-level pine confined to the monsoon belt of the outer Himalaya from Bhutan to North Eastern part of West Pakistan which is valuable pine for its oleoresin content and also timber. The breeding programme for improving oleoresin content was done by Kedarnath (1971). Troup (1921) suggested that nine provenances on the basis of growth characteristics. Considerable variation in oleoresin yield was found among the trees in the different provenances growing at New Forest, Dehradun in a provenance trial. Gupta (1979) observed successful rooting of stem cuttings using hormones and mist tent has been reported from Himachal Pradesh Forest Department. Many molecular markers are deployed in pines for understanding polymorphism information content (PIC), level of polymorphism exhibited for the mapping progeny, mode of inheritance, genome size and also it can influence the choice of marker system for a particular trait. A number of nuclear SSR markers have been industrialized for *P. radiata*, almost all of which are based on the more frequently polymorphic dinucleotide repeat motifs (Smith and Devey 1994; Fisher *et al.* 1996). Snehalata Chawla (1977) reported valuable genetic information in the *Pinus roxburghii* by using an open-pollinated progeny trial and assessed the natural variation in morphological characters, growth habits and timber characters. Additionally, she has also found heritability estimates for the various traits and correlations both phenotypic and genetic amongst various timber characters.

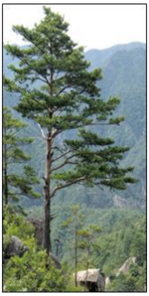


**Fig 4;** *Pinus roxburghii*

**Source:** Google Image

## Eucalyptus (*Eucalyptus* sp.)

**Origin, distribution and description:** Eucalyptus are generally long-lived, evergreen species belonging to the Myrtaceae family. The primary centre of origin is believed to be Australia and islands to its north (Potts and Pederick 2000) whereas they occur naturally from sea level to the alpine tree line, from the tropics to high latitudes and from high rainfall to semiarid zones. Three species of eucalypts are used for raising large scale plantations, *Eucalyptus tereticornis*, *Eucalyptus grandis* and *Eucalyptus globulus*, among them *E. globulus* is mostly used in the Nilgiris hills in South India. Eucalypts are well-known species with fast growth, straight form, valuable wood properties, wide adaptability to soils and climates. It is an important source of fuel and building material in countries like India, China, Ethiopia, and Vietnam.

**Genetic composition:** Oudjehih *et al*. (2006) reviewed the results the chromosomal count of 59 species of genus Eucalyptus. They found all these species having chromosome number 2n = 22 including the four species for which the numbers 2n= 20, 24 and 28 have been reported. They observed in pre-metaphase stages that number 2n = 24 previously reported in 9 species appears to result from a break of the chromosome first pair.

**Fig 5:** *Eucalyptus* sp.

**Source:** Google Image

### Breeding objective

- Improving profit from industrial pulpwood plantations by improving wood quality traits.
- Tolerance to diseases and pests.

- Increase rooting ability both in nursery and field.
- Increase biomass productivity.

**Tree improvement programme:** Jayashree *et al.* (1984) reported that differences in rate of growth and susceptibility to Cylindrocladium blight has been reported from a study of 39 provenances representing 15 species. Grattapaglia *et al.* (1996), Byrne *et al.* (1997) have reported the mapping of major QTLs for growth of Eucalyptus that if the QTL detection showed functional variability of some genes for growth variation, the identity of these genes remains undetermined. Major growth QTLs detected in interspecific pedigrees are often related to hybrid abnormality or viability effects, which are usually not useful for breeding purposes. Kedarnath (1980) reported a number of naturally occurring interspecific hybrids have been identified and studied in India. Those are *E. camaldulensis x E. tereticornis, E. grandis x E. tereticornis* and *E. citriodora x E. torelliana*. These hybrids evident good hybrid vigour for growth and reproduction. White *et al.* (2007) have recommended the incomplete block designs for eucalypt breeding field trials since large numbers of progenies or clones are usually tested.

**Populus tree (*Populus* sp.)**

**Origin, distribution and description:** Populus tree, commonly known as Cottonwood belongs to the family Salicaceae (willow family) and widely distributed over the northern hemisphere (Fig.6). Populus trees are dioecious in nature and single stemmed. it is wind-pollinated tree that contain approximately 60 staminate flowers or 35 pistillate flowers (Boes and Strauss, 1994) and produce large amounts of pollen and small, cotton-tufted seed that is spread by wind and water. It is believed that the primary centre of origin for Populus tree is widespread across North America. The Fossil records show evidence on primary centre of origin. Populus trees is cultivated mainly for pulp and paper, excelsior (packing material), wood products like oriented strand board and energy.

**Fig 6:** *Populus trichocarpa*

**Source:** Wikipedia

**Genetic composition:** Populus species are generally diploid in nature having chromosome number 2n = 38 (Smith 1943), sometimes cases of triploid or tetraploid genets are also seen. (Einspahr *et al.* 1963). The chromosomes present in the Populus are small and having absence of distinctive morphological features. The haploid genome size of Populus is 550 million base pairs (bp) (Bradshaw and Stettler 1993).

**Breeding objective**

- Improvement of the quality of wood, mostly focused on improvements in specific gravity.
- Improvement of agronomic characters like yield, adventitious rooting, adaptation to the climate.
- Tolerance to diseases and pests.

**Tree improvement programme:** It is already known to us Poplars trees are dioecious, so self-pollinations cannot be done. Interspecific hybridization is the most popular breeding method to produce large number of progenies. Stanton (2005) and Zsuffa *et al*. (1999) made inter-sectional crosses between *Aikairos* and *Tacamahaca* that are compatible for the most part while reciprocal crossing effects can be challenging at times. For example, the crosses combination between *P. deltoides* × *P. trichocarpa* and the *P. deltoides* × *P. maximowiczii* are far more productive than crosses in which they used Tacamahaca parent as the female parent. The first tree species of Populus in which complete genome sequencing is done, that is *P. trichocarpa* (Tuskan *et al*. 1998, 2002; US Department of Energy (DOE) 2002) and has an estimated 40,000 to 50,000 coding genes and also estimated a genome which is four times bigger than Arabidopsis. Heilman and Stettler (1985) and Dickmann *et al*. (1992) reported that the hybrids between *P. Trichocarpa* and *P. deltoides* in United States had a volume growth two or three times that of the best growing parent species of Populus. In India, the work on exotic clones of *P. deltoides* is continuing (Fig. 7) and also been planned to work on the genetic upgrading of *P. ciliata* and *P. gamble*, two of our native Popular sp. Khosla *et al*. (1979) have also evaluated the sex ratio in natural population of this species and also estimated the correlation between the sex of the tree and its growth. Farmer and Wilcox (1968) evaluated specific gravity for wood quality trait included in Populus breeding programs. It is usually as a component of biomass yield. Dr. Khurana in Solan of India worked with many species of Populus Species. He did breeding of superior clones of *P. deltoides* and associate exotic Popular species that were already present and proven in northern India, and also introduce a larger gene pool of *P. deltoides* which is most productive Populus sp. of northern India. Dr. Khurana did widespread testing, provenance testing of new clones of Populus species and introduce them to the East-central and northern Asia.

**Fig 7:** *Populus deltoides*

**Source:** https://plants.ces.ncsu.edu/pla nts/populus-deltoides/

**Teak (*Tectona grandis*)**

**Origin, distribution and description:** Teak is one of the most durable and valuable timber yielding tree species in the world, used in ship constructions, railway carriages, sleepers, furniture, veneer and other constructional needs (Fig 8). It belongs to the family Verbenaceae. The primary centre of origin is the Indo-Malayan region and introduced to the rest of the country except hills region. It also plated in Indonesia (hold 33% share of production), some parts of Sri Lanka, Vietnam, Malaysia, East and West

Africa, The Caribbean, Brazil and Central America (Costa Rica). It has a very wide range of adaptation, can grows from very dry to very moist conditions and grows well in alluvial soils, fairly moist, warm, tropical climate with soil pH ranges from 6.5 to 7.5. In India more than one lakh hectares are being planted annually.

**Fig 8:** *Tectona grandis*

**Source:** https://www.alamy.com/

**Genetic composition:** The Teak tree has somatic chromosome number of 36, 2n=36 (Kedharnath and Raizada 1961). Yasodha *et al.* (2018) finds that a draft genome of 317 Mb was assembled in Teak Tree with 172 protein-coding genes. Approximately about 11.18% of the genome was repetitive. Usually, Teak is diploid.

**Breeding objective**

- Breeding for superior stem.
- Superior rate of growth in height and diameter.
- Superior quality of timber.
- Resistance to biotic (resistance to leaf skeletoniser-*Eutectona machaeralis* syn. *Pyrausta machaeralis* and leaf defoliator) and abiotic stress.

**Tree improvement programme:** The improvement programme is usually done by using high yielding clones, better hybrids, selecting good site for Plantation and using genetically superior seeds (Fig 9). Simple budding and/or sometimes cleft grafting technique standardised for this species which has been used for clonal seed orchards and germplasm banks that have been established in a number of states (Rawat and Kedharnath, 1968). Clonal forestry increases the productivity significantly compared to seedling plantation. The clones are multiplied by stump planting, rooting of branch cuttings, budding and grafting method. Tissue culture also played an important role. Two leaf infecting fungi *Olivea tectonae* and *Caldariomyces tectonae* were relative resistance or susceptible of the different clones established in the clonal seed orchard at New Forest, Dehradun under natural conditions of infection showed consistent reaction, whether some were absolutely resistant and some were very susceptible while some were moderately resistant to this fungal infection. Kumaravelu (1979) conclude some of the teak plus trees of Tamil Nadu have been used as experimental material for gel electrophoresis studies to identify esterase bands. India has a rich repository of Teak genetic resources. It has major growth characters have reasonably high heritability and subsequently high genetic gains. There are many problems for Teak tree improvement in India like low seed yield in clonal seed orchard, less availability of quality planting stock for raising seed orchards, narrow genetic base and poor germination of seeds in this region.

**Fig 9:** Clonal Seed Orchard of Teak, Walayar (Kerala)

## Indian sandalwood (*Santalum album*)

Sandalwood is a precious gift of the plant kingdom associated with culture and heritage of India. It is the second most valuable trees in the world. The primary centre of origin is southern India and Southeast Asia. It has been distributed from Indonesia in the east to Chile in the west and from Hawaiian island in the north to New Zealand in the south. Sandalwood belongs to the family Santalaceae having chromosome number is 2n=20. It appears to be mixoploid i.e., both diploid (2x) and tetraploid (4x) (Xin-Hua *et al.,* 2010). Sandalwood is good drag treated against many diseases. Sandalwood oil has a warm, woody odour and is commonly used as a fragrance in cosmetics, perfumes, and soaps. So, the breeding objective is to increase the medicinal value and the quality of wood.

**Fig 10:** *Santalum album*

**Source:** Wikipedia

In tree improvement programme, Tamla *et al.* (2011) reported that the development of viable hybrid progeny has been reported for crosses between S. album with each of S. *austrocaledonicum* (Tamla *et al.* 2011) and S. yasi (Bulai and Nataniela 2005; Doran *et al.* 2005) despite total geographic isolation between them. Sindhu Veerendra and Anantha Padmanabha (1996) have reported that *S. album* is a predominantly outbreeding species. *S. album* is exhibits seed set by selfing. Some extent of self-incompatibility and heterostyly in some genotypes has been observed by them. Many Researchers have studied genetic diversity of *S. album* using isozyme, RAPD and RFLP analysis and they found important diversity among natural sandalwood populations. Rao *et al*. (2008) reported that genetic diversity was higher among populations in Karnataka than in other states of South India.

Many other forest trees are found in India having good timber value and also medicinal quality like Neem (*Azadirachta indica*), Shisham (*Dalbergia sissoo*), Babul (*Acacia nilotica*) etc.

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# Chapter - 6
# Indian Orchids in CITES Appendices

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# Chapter - 6

## Indian Orchids in CITES Appendices

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**Abstract**

CITES (The Convention on International Trade in Endangered species of wild fauna and flora) is an international treaty formulated to regulate and inspect the the international trade in selected species of plants and animals for ensuring the survival of populations in the wild. Three appendices are framed by the Convention which include the list of animals and plants subject to strict compliance of regulations of trade according to different degree of threats due to over exploitation from wild from forests. Species are listed by the CITES Parties (countries) at one of three levels of protection (appendices) with different requirements. These Parties regulate trade in specimens (live and dead) of Appendix-I, II and III species and their hybrids, parts, products and derivatives through a system of permits and certificates (CITES documents). About 10 species of Paphiopedilum and one species of Renanthera are included in the Appendix I. It includes all species threatened with extinction which are affected by trade. In India, 1295 species belonging to 179 genera are included in the Appendix II. It includes all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival.

**Keywords:** CITES, appendix-I, appendix-II, orchid species

### Introduction

CITES (The Convention on International Trade in Endangered species of wild fauna and flora) is an international treaty formulated to regulate and inspect the the international trade in selected species of plants and animals for ensuring the survival of populations in the wild. International trade in wild animals and plants accounts billions of dollars. The trade varies from live animals and plants to various products derived from them. Levels of exploitation of some plant species are very high and the trade in them, together with habitat loss, depleted them close to extinction.

As the trade in wild animals and plants used to found across the borders, the effort to regulate it requires international cooperation. CITES was incepted in the spirit of such cooperation. Thereby the representatives of 80 countries agreed to the Convention in Washington DC, U.S.A. on 3rd March 1973 and on 1st July 1975 CITES entered in force. At present, there are 175 countries that are parties to CITES. CITES gives varying degrees of protection to *ca* 5,000 species of animals and 29,000 species of plants which are traded as live specimens or as dried or preserved material.

Three appendices are framed by the Convention which include the list of animals and plants subject to strict compliance of regulations of trade according to different degree of threats due to over exploitation from wild from forests. Species are listed by the CITES Parties (countries) at one of three levels of protection (appendices) with different requirements. These Parties regulate trade in specimens (live and dead) of Appendix- I, II and III species and their hybrids, parts, products and derivatives through a system of permits and certificates (CITES documents).

The Parties would not allow unregulated trade in specimens of species included in Appendices I, II and III except in accordance with the provisions of the Convention. The CITES Appendices are periodically revised at the Conference of the Parties and the species are also shifted from one Appendix to another or deleted as required, depending on the situations.

An effort has been made here to list Indian Plants included in CITES and Negative List of Exports following IUCN Red List Categories and Criteria Version 3.1 (2001). Therefore, a brief account of 2001 IUCN Red List Categories and Criteria are given here.

**Orchid species in appendix I**

It includes all species threatened with extinction which are affected by trade. These species are subject to particularly strict regulation in order not to endanger further their survival and must only be authorized in exceptional circumstances; 10 species of Paphiopedilum and one species of Renanthera are included in this Appendix.

**Paphiopedilum (Ladies Slipper orchids)**

Paphiopedilums are most popular orchids because of their unique shape, colour and easy to cultivate. They are commonly called as ‘Slipper Orchids’ and can be grown windowsills, in basements, Wardian cases, small green houses, in large commercial green houses, lathhouses and shade houses and can be grown in different climates. These are terrestrial or lithophytic orchids distributed in Himalayas, China, South East Asia, Indonesia and New Guinea. These orchids are stemless, pseudobulbless sympodial orchids with well-developed leathery, elliptic-lanceolate leaves clasping at the base. The flowers are borne singly or in few flowered racemes on a short to elongate inflorescence. The inflorescence is 60 cm tall and often purplish brown. The dorsal sepals are distinct with markings. The two lateral sepals are fused to form a vertical sepal. The lateral sepals are narrow and long with wavy margins. The petals are right angle to the sepals and sometimes curve forward towards the lip. Ten species of Paphiopedilum included in appendix I are *Paphiopedilum charlesworthii* (Rolfe) Pfitzer, *Paph druryi* (Bedd.) Stein, *Paph fairrieanum* (Lindl.) Stein, *Paph hirsutissimum* (Lindl. ex Hook.) Stein, *Paph. insign*e (Wall. ex Lindl.) Pfitzer, *Paph spicerianum* (Rchb. f.) Pfitzer, *Paph spicerianum* (Rchb. f.) Pfitzer f. burkhardii O. Gruss & Roeth, *Paph. venustum* (Wall. ex Sims) Pfitzer, *Paph villosum* (Lindl.) Stein and *Paph wardii* Summerh.

### *Renanthera imschootiana* Rolfe (Red Vanda)

An endangered species, restricted to Manipur and other neighbouring states of North East India. Commonly called as ‘Red Vanda’. The stems are solitary, 90cm long arranged with a set of leaves closely packed on the stem. Inflorescence is horizontal, branched bearing more than 20 bright crimson flowers with red spots on a pale orange back ground of its dorsal sepal and petals. The flowers are long lasting, 6cm across and are produced during April-May.

### Orchid species in appendix II

It includes all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival; In India, 1295 species belonging to 179 genera are included in this Appendix.

### Acampe

This is a monopodial vandaceous orchid distributed in India, China, Malayasia, Philippines, Afric and Madagascar. *Acampe* give out slow-growing, medium-sized vines that form very large vegetative masses in nature. They are charcaterized by their thick, leathery, distichous leaves. They bear fragrant small to medium-sized yellow flowers, barred with orange or red stripes, in a few to many-flowered racemose inflorescence. The ear-shaped, fringed, white labellum is sac-shaped or has a spur, and has red markings at its base. Five species included in Appendix-II are *Acampe* *congesta* (Lindl.) Lindl., *Acampe ochracea* (Lindl.) Hochr., *Acampe papillosa* (Lindl.) Lindl., *Acampe praemorsa* (Roxb.) Blatt. & McCann and *Acampe rigida* (Buch. -Ham. ex Sm.) P.F. Hunt.

**Acanthephippium**

These are terrestrial sympodial orchids distributed in India, Taiwan, China, Japan, Southeast Asia and New Guinea. The plants are up to 80 cm tall having short rhizomes. The oblong and fleshy pseudobulbs are up to 25cm tall, arranged with 2 to 3 large plicate, lanceolate, parallel-veined leaves at apex, which can be up to 65cm long. The erect inflorescence emerges laterally from the pseudobulbs, with 3 to 6 flowers, subtended by large, glabrous bracts. The 4cm long flowers are prominent, large, striated cup-or urn-shaped, fleshy and waxy. The flowers are dull yellow to red to shades of orange and pink, marked with stripes or spots. The blossoms are fragrant. Three species included in Appendix-II are *Acanthephippium bicolor* Lindl., *Acanthephippium striatum* Lindl. and *Acanthephippium sylhetense* Lindl.

**Acariopsis**

*Acriopsis*, commonly known as ‘Chandelier Orchids’ are epiphytic herbs with spherical or cylindrical pseudobulbs, creeping, branched rhizomes, thin white roots, two or three leaves and many small flowers. The flowers are non-resupinate with the lateral sepals joined along their edges and have spreading petals and a three-lobed lip. This species is distributed in India, Yunnan, Southeast Asia, New Guinea, Melanesia, Micronesia and Queensland. Two species included in appendix-II are *Acriopsis indica* Wight and *Acriopsis liliifolia* (J. Koenig) Seiden f.

***Acrochaene punctata* Lindl.**

This is temperate epiphyte distributed in Assam, Sikkim, Bhutan, Thailand and Myanmar. Pseudo-bulbs are crowded, ovoid, arranged very close to each other, attached to a stout rhizome with many thick long roots; Inflorescence is pendent laxy flowered. Flowers are yellowish green with red spotting.

***Aenhenrya rotundifolia* (Blatt.) C.S. Kumar & F. Rasm.**

This is terrestrial orchids spreading by means of underground rhizomes. *Aenhenrya rotundifolia*, is a very rare plant endemic to southern India (Kerala and Tamil Nadu)

**Aerides**

These are monopodial epiphytic orchids grown on trunks or branches of trees. The stems are round, leafy and branched with aerial roots. The strap leaves are thick, leathery and bilobed. The inflorescence is auxillary and drooping and upto 60cm long in some species. The flowers are many and 2cm in diameter closely set on the inflorescence and generally fragrant. Eight species included in appendix-II are *Aerides crispa* Lindl., *Aerides emericii* Rchb. f., *Aerides falcata* Lindl., *Aerides maculosa* Lindl., *Aerides multiflora* Roxb., *Aerides odorata* Lour., *Aerides ringens* (Lindl.) C.E.C. Fisch. And *Aerides rosea* Lodd. ex Lindl. & Paxton.

**Agrostophyllum**

These are epiphytic orchids found in tropical lowland forests, growing on trunks or branches of trees. They are distributed in India, Sri Lanka, Malaysia, Indonesia to the Pacific Islands. These orchids have elongate, frequently pendulous stems with dense grassy leaves that overlap at their base. They have peculiar, ball-like inflorescences of many bracts, bearing small flowers. Five species included in Appendix-II are *Agrostophyllum brevipes* King & *Pantl.*, *Agrostophyllum* callosum Rchb.f., *Agrostophyllum flavidum* Phukan, *Agrostophyllum myrianthum* King & Pantl. and *Agrostophyllum planicaule* (Wall. ex Lindl.) Rchb.f.

**Androcorys**

These are terrestrial orchids distributed in Indian continent. Six species included in Appendix-II are *Androcorys angustilabris* (King & Pantl.) Agrawala & H.J. Chowdhery, *Androcorys gracilis* (King & Pantl.) Schltr., *Androcorys josephi* (Rchb. f.) Agrawala & H.J. Chowdhery, *Androcorys kalimpongensi*s (Pradhan) Agrawala & H.J. Chowdhery, *Androcorys monophylla* (D. Don) Agrawala & H.J. Chowdhery and *Androcorys pugioniformis* (Lindl. ex Hook. f.) Lang.

**Ania**

These are tropical to subtropical terrestrial orchids distributed in Eastern Himalayan, China and Indo-China regions at an elevation from 600-1600m. Two species included in appendix-II are *Ania penangiana* (Hook.f.) Summerh and *Ania viridifusca* (Hook.) T. Tang & F.T. Wang.

**Anoectochilus**

These are commonly known as 'Jewel Orchids'. These are pseudobulbless terrestrial orchids with creeping rhizomes and petioled green, brown, copper colour veined and striated, rose, yellow or white leaves.

Flowers appear in glandular pubescent spikes. Six species included in appendix-II are *Anoectochilus brevilabris* Lindl., *Anoectochilus elatus* Lindl., *Anoectochilus nicobaricus* N.P. Balakr. & Chakrab., *Anoectochilus regalis* Blume, *Anoectochilus roxburghii* (Wall.) Lindl. and *Anoectochilus narasimhanii* Sumathi, Jayanthi, Karthig. & Sreek.

***Anthogonium gracile* Wall. ex Lindl.**

This is a deciduous, miniature to medium sized terrestrial orchid found in Eastern Himalayas. The plants have ovoid pseudobulbs bearing stalked lance shaped narrow leaves. Inflorescence is a simple raceme with 10-12 flowers of pink-purple colours.

**Aorchis**

These are terrestrial orchids distributed in China, Japan, Korea, Russia. Plants are 8-15 cm tall, sympodial with slender creeping rhizomes and cylindric erect stems. Leaves are elliptic, spatulate and oblanceolate. The inflorescence is a simple raceme with 1-5 pink-purple flowers. Two species included in Appendix-II are *Aorchis roborovskii* (Maxim.) Seidenf. and *Aorchis spathulata* (Lindl.) Verm.

**Aphyllorchis**

*Aphyllorchis,* commonly known as Pauper orchids are terrestrial leafless orchids. They have fleshy, upright stems and small to medium sized resupinate flowers with narrow sepals and petals. They are distributed in India east, China, Japan, Indonesia, New Guinea and Queensland. Three species in Appendix-II are *Aphyllorchis alpina* King & Pantl., *Aphyllorchis gollanii* Duthie and *Aphyllorchis montana* Rchb. f.

**Apostasia**

*Apostasia*, commonly known as Grass orchids, are terrestrial, evergreen, grass-like plants, barely recognisable as orchids and are distributed in humid areas of the Himalayan region, China, India, Sri Lanka, Southeast Asia, New Guinea, and Queensland. They have many narrow leaves and small yellow or white, non-resupinate, star-like flowers usually arranged on a branched flowering stem. Three species included in Appendix-II *are Apostasia nuda* R. Br. ex Wall., *Apostasia odorata* Blume and *Apostasia wallichii* R. Br.

**Appendicula**

*Appendicula*, commonly known as Stream orchids are epiphytic or lithophytic terrestrial plants herbs with many flat, often twisted leaves and small resupinate, white or greenish flowers. Two species included in

Appendix-II are *Appendicula cornuta* Blume and *Appendicula reflexa* Blume.

**Arachnis**

These commonly known as 'Scorpion Orchid.' These are monopodial epiphytic plants, 30cm to 4.5 m tall with many leathery leaves. Leaves are strap shaped, clasping the stem at their base. Flowers are showy, large borne on simple racemes or branched panicles and the inflorescence is 50 to 65cm long arise from the stem just above the clasping leaves. Flowers are green, yellow, brown and purple in colour. Two species included in appendix-II are *Arachnis flosaeris* (L.) Rchb. f. and *Arachnis labrosa* (Lindl. & Paxton) Rchb. f.

***Archineottia microglottis* (Duthie) Chen**

This is a small to just medium sized, cold growing terrestrial orchid with a firm, stout, pale yellow to white stem carrying 2 to 4, loose, obtuse, pale sheaths that blooms on a terminal, erect, 10 to 20 cm long, glandular-pubescent, densely several to many flowered inflorescence.

***Armodorum senapatianum* Phukan & A.A. Mao**

This is a monopodial epiphytic orchid with thick cylindrical roots arising near the base. Leaves are linear oblong. Inflorescence is axillary, 24-30cm long bearing 12 flowers. Flowers are creamy white and fragrant.

***Arundina graminifolia* (D. Don) Hochr.**

These are terrestrial tropical and subtropical orchids attain a height upto 3 m, grown under full sun and grown as garden plant. The pseudubulb bears many grass like leaves with overlapping sheath. The inflorescence is held well above the plant. Flowers white purple produced on the top of the stem. Easily propagated by keikis.

**Ascocentrum**

These are dwarf monopodial epiphytes and characterized by large spur hangs from the tip. The plants are small, compact with small strap shaped leaves and short stalked erect and cylindrical covered with many closely spaced flowers. Flowers are long lasting and 1-2 cm in diameter. Four species included in appendix-II are *Ascocentrum ampullaceum* (Roxb.) Schltr., *Ascocentrum curvifolium* (Lindl.) Schltr., *Ascocentrum himalaicum* (Deb, Sengupta & Malick) Christenson and *Ascocentrum semiteretifolium* Seidenf.

**Bhutanthera**

These are terrestrial orchids, native to the Himalayan mountains. Two species included in Appendix-II are *Bhutanthera albomarginata* (King & Pantl.) Renz and *Bhutanthera alpina* (Hand. -Mazz.) Renz.

**Biermannia**

These are tropical epiphytes distributed in Eastern India, China and South East Asia. Stems are short with linear leaves. Inflorescence is racemose and several flowered. Four species included in Appendix-II are *Biermannia arunachalensis* A.N. Rao, *Biermannia bimaculata* (King & Pantl.) King & Pantl., *Biermannia jainiana* Hegde & A.N. Rao and *Biermannia quenquecallosa* King & Pantl.

**Bletilla**

*Bletilla*, common name ‘Urn orchid’, is a temperate, terrestrial orchid distributed through China, Japan, Taiwan, south to Vietnam, Thailand and Myanmar.

The pseudobulbs resemble spreading corms generally bears several pleated leaves around 40cm long. The racemes of flowers emerge from the center of the years new growth before it is mature. The flowers vary in color from white to purple. Two species included in appendix-II are *Bletilla foliosa* (King & Pantl.) Tang & Wang and *Bletilla sinensis* (Rolfe) Schltr.

**Brachycorythis**

These are terrestrial orchids with very leafy herbs, with undivided fusiform or ovoid tubers; and sessile leaves. Racemes are dense and many flowered. Distrubuted in India, Africa, China and Thailand. Seven species included in Appendix-II are *Brachycorythis acuta* (Rchb. f.) Summerh., *Brachycorythis galeandra* (Rchb. f.) Summerh., *Brachycorythis helferi* (Rchb. f.) Summerh, *Brachycorythis Iantha* (Wight) Summerh, *Brachycorythis obcordata* (Buch. -Ham. ex D. Don) Summerh, *Brachycorythis splendida* Summerh and *Brachycorythis wightii* Summerh.

**Bulbophyllum**

These are orchids from tropical and subtropical Asia. The name indicates that the leaves are attached to the top of pseudobulbs. These orchids are sympodial epiphytes having rhizomatous stems with angled pseudobulbs. The pseudobulbs form a chain like growth on the rhizomes. Inflorescence is erect or pendent and arises from the base of the pseudobulb. The flowers are solitary or in an umbel or united on spurs. Flower size ranges from few millimeters (*Bulbophyllum minutissimum, B. minututum*) to 40 cm in *Bulbophyllum echinolobium*. 117 species are included in Appendix-II are *Bulbophyllum acutiflorum* A. Rich., *Bulbophyllum acutum* J.J. Sm., *Bulbophyllum affine* Lindl., *Bulbophyllum albidum* (Wight) Hook. f., *Bulbophyllum ambrosia* ssp. *Nepalensis* J.J. Wood, *Bulbophyllum apodum* Hook. f., *Bulbophyllum aureum* (Hook. f.) J.J. Sm., *Bulbophyllum bakhuizenii* Steenis, *Bulbophyllum bisetum* Lindl., *Bulbophyllum blepharistes* Rchb. f., *Bulbophyllum capillipes* Parish & Rchb. f., *Bulbophyllum careyanum* (Hook.) Spreng., *Bulbophyllum cariniflorum* Rchb. f., *Bulbophyllum cauliflorum* Hook. f., *Bulbophyllum clandestinum* Lindl., *Bulbophyllum cornu-cervi* King & Pantl., *Bulbophyllum crassipes* Hook. f., *Bulbophyllum cupreum* Lindl., *Bulbophyllum cylindraceum* Lindl., *Bulbophyllum delictescens* Hance, *Bulbophyllum depressum* King & Pantl., *Bulbophyllum elassonotum* Summerh., *Bulbophyllum elatum* (Hook. f.) J.J. Sm., *Bulbophyllum elegans* Gard. ex Thwaites, *Bulbophyllum elegantulum* (Rolfe) J.J. Sm., *Bulbophyllum emarginatum* (Finet) J.J. Sm., *Bulbophyllum eublepharum Rchb. f., Bulbophyllum fimbriatum* (Lindl.) Rchb. f., *Bulbophyllum fuscopurpureum Wight, Bulbophyllum gracilipes* King & Pantl., *Bulbophyllum griffithii* (Lindl.) Rchb. f., *Bulbophyllum guttulatum* (Wall. ex Hook. f.) N.P. Balakr., *Bulbophyllum hirtum* (J.E. Sm.) Lindl., *Bulbophyllum hymenanthum Hook. f., Bulbophyllum keralense M. Kumar & Sequiera, Bulbophyllum khasianum Griff., Bulbophyllum leopardinum* (Wall.) Lindl., *Bulbophyllum leptanthum* Hook. f., *Bulbophyllum lilacinum* Ridl., *Bulbophyllum lobbii* Lindl., *Bulbophyllum longebracteatum* Seidenf., *Bulbophyllum macraei* (Lindl.) Rchb.f., *Bulbophyllum macranthum* Lindl., *Bulbophyllum macrocoelum* Seidenf., *Bulbophyllum manipurense* C.S. Kumar & Suresh, *Bulbophyllum maskeliyense* Livera, *Bulbophyllum monanthum* (Kuntze) J.J. Sm., *Bulbophyllum moniliforme* Parish & Rchb. f., *Bulbophyllum mysorense* (Rolfe) J.J. Sm, Bulbophyllum odoratissimum (Sm.) Lindl. ex Wall., *Bulbophyllum odoratissimum* var. *racemosum* N.P. Balakr., *Bulbophyllum orectopetalum* Garay, Hamer & Siegerist, *Bulbophyllum orezii* C.S. Kumar, *Bulbophyllum pantlingii* Lucksom, *Bulbophyllum parryae* Summerh., *Bulbophyllum parviflorum* Parish & Rchb. f., *Bulbophyllum pectinatum* Finet, *Bulbophyllum penicillium* Parish & Rchb. f., *Bulbophyllum piluliferum* King & Pantl., *Bulbophyllum polyrhizum* Lindl., *Bulbophyllum propinquum* Kraenzl., *Bulbophyllum protractum* Hook. f., *Bulbophyllum proudlockii* (King & Pantl.) J.J. Sm., *Bulbophyllum psychoon* Rchb. f., *Bulbophyllum reichenbachianum* Kraenzl., *Bulbophyllum repens* Griff., *Bulbophyllum reptans* (Lindl.) Lindl., *Bulbophyllum restrepia* (Ridl.) Ridl., *Bulbophyllum rigidum* King & Pantl., *Bulbophyllum rolfei*

(Kuntze) Seidenf., *Bulbophyllum rosemarianum* C.S. Kumar, P.C.S. Kumar & Saleem, *Bulbophyllum rothschildianum* (O'Brien) J.J. Sm., *Bulbophyllum rufinum* Rchb. f., *Bulbophyllum sarcophylloides* Garay, Hamer & Siegerist, *Bulbophyllum sarcophyllum* (King & Pantl.) J.J. Sm., *Bulbophyllum scabratum* Rchb. f, *Bulbophyllum secundum* Hook. f., *Bulbophyllum serratotruncatum* Seidenf., *Bulbophyllum siamense* Rchb. f., *Bulbophyllum silentvalliensis* M.P. Sharma & S.K. Srivast., *Bulbophyllum stenobulbon* Parish & Rchb. f., *Bulbophyllum sterile* (Lam.) Suresh, *Bulbophyllum striatum* (Griff.) Rchb. f., *Bulbophyllum thomsonii* Hook. f., *Bulbophyllum tortuosum* (Blume) Lindl., *Bulbophyllum tremulum* Wight, *Bulbophyllum trichocephalum* (Schltr.) Tang & Wang, *Bulbophyllum trichocephalum* var. wallongense Agrawala, Sabap. & H.J. Chowdhery, *Bulbophyllum tricorne* Seidenf. & Smit., *Bulbophyllum triste* Rchb. f., *Bulbophyllum umbellatum* Lindl., *Bulbophyllum viridiflorum* (Hook. f.) Schltr., *Bulbophyllum wallichii* Rchb. f., *Bulbophyllum xylophyllum* Parish & Rchb. f., *Bulbophyllum yoksunense* J.J. Sm., *Bulbophyllum amplifolium* (Rolfe) N.P. Balakr. & Sud. Chowdhury, *Bulbophyllum andersonii* (Hook. f.) J.J. Sm., *Bulbophyllum brienianum* (Rolfe) Merr., *Bulbophyllum retusiusculum* Rchb. f., *Bulbophyllum flabelloveneris* (J. König) Seidenf. & Ormerod ex Aver., *Bulbophyllum fischeri* Seidenf., *Bulbophyllum loherianum* (Kraenzl.) Ames, *Bulbophyllum neilgherensis* Wight, *Bulbophyllum panigrahianum* S. Misra, *Bulbophyllum picturatum* (Lodd.) Rchb. f., *Bulbophyllum pulchrum* (N.E.Br.) J.J. Sm., *Bulbophyllum roxburghii* (Lindl.) Rchb. f., *Bulbophyllum muscicola* Rchb. f., *Bulbophyllum Gymnopus* Hook. f., *Bulbophyllum appendiculatum (*Rolfe) J.J. Sm., *Bulbophyllum ornatissimum* (Rchb. f.) J.J. Sm., *Bulbophyllum putidum* (Teijsm. & Binn.) *J.J. Sm., Bulbophyllum forrestii Seidenf., Bulbophyllum helenae (Kuntze) J.J. Sm., Bulbophyllum* nodosum (Rolfe) J.J. Sm., *Bulbophyllum rheedii* Manilal & C.S. Kumar, *Bulbophyllum spathulatum* (Rolfe ex E.W. Cooper) Seidenf.

***Bulleyia yunnanensis* Schltr.**

These are subtropical epiphytes distributed in West Bengal and Arunachal Pradesh. Plants are arranged with creeping rhizomes. Pseudobulbs are ovoid-ellipsoid, Inflorescence is racemose, 10-20 flowered, pendent Flowers are translucent, charming and white.

**Calanthe**

*Calanthe* is a terrestrial species and are widespread throughout all tropical areas but are highly concentrated in Asia. The first man-made orchid hybrid created was a *Calanthe* Dominii, back in 1853, and *Calanthe* were very popular hot-house plants during the Victorian Era. There are two types of *Calanthe,* the deciduous ones which generally have large, silvery pseudobulbs, drop their leaves in winter, and require less water during winter, and the evergreen *Calanthe* which have either no pseudobulbs or very inconspicuous ones, usually keep their leaves for several seasons, and require even moisture year-round. The scape is axillary, terminal or lateral from a leafy pseudobulb. The racemes are long, bearing few to 20 flowers, which are subtended by leafy bracts. The flowers are basically white, red or mauve, medium sized and attractive. Twnety seven species included in appendix-II are *Calanthe alismaefolia* Lindl., *Calanthe alpina* Hook. f. ex Lindl., *Calanthe anthropophora* Ridl., *Calanthe biloba* Lindl., *Calanthe brevicornu* Lindl., *Calanthe ceciliae* Rchb. f., *Calanthe chloroleuca* Lindl., *Calanthe clavata* Lindl., *Calanthe densiflora* Lindl., *Calanthe fulgens* Lindl., *Calanthe griffithii* Lindl., *Calanthe herbacea* Lindl., *Calanthe mannii* Hook. f., *Calanthe keshabii* Lucksom, *Calanthe odora* Griff., *Calanthe pachystalix* Rchb. f. ex Hook. f., *Calanthe plantaginea* Lindl., *Calanthe puberula* Lindl., *Calanthe purpurea* Lindl., *Calanthe sylvatica* (Thou.) Lindl., *Calanthe tricarinata* Lindl., *Calanthe triplicata* (Willemet) Ames, Calanthe *trulliformis* King & Pantl., *Calanthe uncata* Lindl., *Calanthe vaginata* Lindl., *Calanthe whiteana* King & Pantl. and *Calanthe yuksomnensis* Lucksom.

**Cephalanthera**

*Cephalanthera*, are terrestrial orchids. Members of this genus have rhizomes rather than tubers. Most of them native to Europe and Asia. Two species included in Appendix-II are *Cephalanthera damasonium* (Mill.) Druce and *Cephalanthera longifolia* (L.) Fritsch.

***Cephalantheropsis longipes* (Hook.f.) Ormerod**

This species is native to Sikkim, China and Philippines. Plants are terrestrial with stout cylindric stem and elliptic leaves. Inflorescence is 5 to 15 flowered. Flowers are fragrant and white in colour.

**Ceratostylis**

*Ceratostylis* is distributed in China, India, Southeast Asia, New Guinea, the Philippines, and Melanesia. These are epiphytic or lithopytic orchids with creeping or pendulus rhizome. Leaves are linear or narrow lanceolate. Inflorescence is terminal with several clustered of flowers. Flowers are small and attractive. Two species included in Appendix-II are *Ceratostylis himalaica* Hook. f. and *Ceratostylis subulata* Blume.

**Chamaegastrodia**

These are small holomycotrophic herbs with fleshy coralloid rhizome, leafless erect stems. Inflorescence is racemose and many flowered. Distributed in India, China, Japan and Thailand. Two species included in Appendix-II are *Chamaegastrodia shikokiana* Makino & Maekawa and *Chamaegastrodia vaginata* (Hook.f.) Seidenf.

**Cheirostylis**

*Cheirostylis*, commonly known as Fleshy Jewel orchids are terrestrial herbs with a caterpillar-like rhizome and a loose rosette of leaves. Small, white, hairy flowers develop after withering of the leaves. They are distributed in tropical Africa, southern Asia, Southeast Asia, Malesia, New Guinea and Australia. Twelve species included in Appendix-II are *Cheirostylis flabellata* Wight, *Cheirostylis griffithii* Lindl., *Cheirostylis gunnarii* A.N. Rao, *Cheirostylis moniliformi*s (Griff.) Seidenf., *Cheirostylis munnacampensis* A.N. Rao, *Cheirostylis parvifolia* Lindl., *Cheirostylis pusilla* Lindl., *Cheirostylis sessanica* A.N. Rao, *Cheirostylis seidenfadeniana* C.S. Kumar & F. Rasm., *Cheirostylis tippica* A.N. Rao, *Cheirostylis yunnanensis* Rolfe, *Cheirostylis malleifera* Parish & Rchb. f.

**Chiloschista**

These are epiphytic or lithophytic, usually leafless monopodial herbs with flat, green, photosynthetic roots radiating from a short, central rhizome. The flowers are borne on long, thin flowering stems, open sporadically in groups and only last for a few hours to one or two days. Four species included in Appendix-II are *Chiloschista fasciata* (F. Muell.) Seidenf. & Ormerod, *Chiloschista glandulosa* Blatt. & McCann, *Chiloschista parishii* Seidenfand *Chiloschista usneoides* (D. Don) Lindl.

**Chrysoglossum**

These are terrestrial herbs with creeping rhizomes. Leaf is one per pseudobulb. Infloresence is erect raceme. Distributed in India, China, Japan and South East Asia. Two species included in Appendix-II are *Chrysoglossum hallbergii* Blatt. and *Chrysoglossum ornatum* Blume.

**Chusua**

These are terrestrial orchids distributed in India, Bhutan and Burma. Five species included in Appendix-II are *Chusua chrysea* (W.W. Sm.) P.F. Hunt, *Chusua nana* (King & Pantl.) Pradhan, *Chusua pauciflora* (Lindl.) P.F. Hunt, *Chusua puberula* (King & Pantl.) N. Pearce & P.J. Cribb and *Chusua renzii* (Deva & H.B. Naithani) S. Misra.

***Cleisocentron pallens* (Cathcart ex Lindl.) N. Pearce & P. J. Cribb**

This is an epiphytic herb with erect slender stem; coverd with leaf sheaths, rooting throughout the stem. Leaves are fleshy, slightly curved, 7-10cm long. Distributed in India, South East Asia, Indonesia, New Guinea and Australia.

**Cleisostoma**

These are epiphytic or rarely lithophytic, monopodial, small to medium-sized herbs. Stems are erect or pendulous, many noded. Leaves are few to many, dorsiventrally flattened or terete. Inflorescence is racemose or paniculate, lateral, axillary, erect, horizontal, or pendulous, few to many flowered; Flowers are small, fleshy. Distributed in India, China, South East Asia and New Guinea. Twenty species included in Appendix-II are *Cleisostoma appendiculatum* (Lindl.) Benth. & Hook. f. ex Jackson, *Cleisostoma arietinum* (Rchb. f.) Garay, *Cleisostoma aspersum* (Rchb. f.) Garay, *Cleisostoma discolor* Lindl. *Cleisostoma duplicilobum* (J.J. Sm.) Garay, *Cleisostoma elegans* Seidenf., *Cleisostoma filiforme* (Lindl.) Garay, *Cleisostoma linearilobatum* (Seidenf. & Smitinand) Garay, *Cleisostoma paniculatum* (Ker Gawl.) Garay, *Cleisostoma parishii* (Hook.f.) Garay, *Cleisostoma racemiferum* (Lindl.) Garay, *Cleisostoma rolfeanum* (King & Pantl.) Garay, *Cleisostoma simondii* (Gagnep.) Seidenf., *Cleisostoma striatum* (Rchb. f.) N.E.Br., *Cleisostoma striolatum* (Rchb. f.) Garay, *Cleisostoma subulatum* Blume, *Cleisostoma tenuifolium* (L.) Garay, *Cleisostoma tricallosum* S.N. Hegde & A.N. Rao, *Cleisostoma uraiensis* (Hayata) Garay & Sweet and *Cleisostoma williamsonii* (Rchb. f.) Garay.

***Coeloglossum viride (*L.) Hartm.**

This is known as "Frog orchid" distributed in the Himalayas, Russia, China and Japan. Plants arise from fleshy forked roots. Leaves are obovate to elliptical and subsequently lanceolate. Inflorescence is a dense raceme (spike-like cluster) containing 7 to 70 small flowers. Flowers are greenish in color, and often tinged with purple, reddish, or red-brown color.

**Coelogyne**

These are sympodial and pseudobulbous orchids. The pseudobulbs are topped by 2 to 4 leaves, slender in size and arranged along with creeping rhizomes. The leaves are coriaceous, thick and leathery with pronounced stalks. Inflorescences are erect or pendulous. The flowers are in white or in shades of brown, yellow and green and subtended by a papery bracts. Forty-four species included in appendix-II are *Coelogyne albolutea* Rolfe, *Coelogyne arunachalensis* H.J. Chowdhery & G.D. Pal, *Coelogyne assamica* Linden & Rchb. f., *Coelogyne barbata* Griff., *Coelogyne breviscapa* Lindl., *Coelogyne corymbosa* Lindl., *Coelogyne cristata* Lindl., *Coelogyne fimbriata* Lindl., *Coelogyne flaccida* Lindl., *Coelogyne fuliginosa* Hook., *Coelogyne fuscescens* Lindl., *Coelogyne fuscescens* var. *brunnea* (Lindl.) Lindl., *Coelogyne ghatakii* T.K. Paul, S.K. Basu & M.C. Biswas, *Coelogyne glandulosa* Lindl., *Coelogyne glandulosa* var. *bournei* S. Das & S.K. Jain, *Coelogyne glandulosa var. sathyanarayanae* S. Das & S.K. Jain, *Coelogyne griffithii* Hook. f., *Coelogyne hajarae* Phukan, *Coelogyne hitendrae* S. Das & S.K. Jain, *Coelogyne holochila* Hunt & Summerh., *Coelogyne longipes* Lindl., *Coelogyne micrantha* Lindl., *Coelogyne mosseae* Rolfe, *Coelogyne nervosa* A. Rich., *Coelogyne nitida* (Wall. ex D. Don) Lindl., *Coelogyne occultata* Hook. f., *Coelogyne occultata* var. *uniflora* N.P. Balakr., *Coelogyne odoratissima* Lindl., *Coelogyne ovalis* Lindl., *Coelogyne pantlingii* Lucksom, *Coelogyne pempahisheyana* H.J. Chowdhery, *Coelogyne pendula* Summerh. ex D.A. Clayton & J.J. Wood, *Coelogyne prolifera* Lindl., *Coelogyne pulverula* Teijsm. & Binn., *Coelogyne punctulate* Lindl., *Coelogyne quadratiloba* Gagnep., *Coelogyne radicosa* Ridl., *Coelogyne raizadae* S.K. Jain & S. Das, *Coelogyne rigida* Parish & Rchb. f., *Coelogyne schultesii* S.K. Jain & S. Das, *Coelogyne stricta* (D. Don) Schltr., *Coelogyne suaveolens* (Lindl.) Hook. f., *Coelogyne trinervis* Lindl. and *Coelogyne viscosa* Rchb. f.

**Collabium**

These are terrestrial orchids grown under shade in forests. Distributed in South East Asia, India, Burma, China and the Philippines. Two species included in Appendix-II are *Collabium assamicum* (Hook. f.) Seidenf and *Collabium chinense* (Rolfe) Tang & Wang.

***Corallorhiza trifida* Chatel.**

Commonly known as Yellow Coralroot, is distributed in the United States, Canada, Russia, China, Japan, Korea, India, Nepal, Kashmir, Pakistan and almost every country in Europe. Stems are unbranched, single to multiple clusters. Racemes are erect, 4 to 9 flowers.

***Corybas himalaicus* (King & Pantl.) Schltr.**

This is a terrestrial herb grown to a height of 4 to 5 cm. Stem is glabrous, with a single sheath near its base. Leaves solitary, 1 to 1.5 cm long, sessile, just under the flower, green with many white nerves. Flower solitary with no petals.

***Corymborkis veratrifolia* (Reinw.) Blume**

This is commonly known as the White Cinnamon Orchid is distributed from tropical and subtropical Asia to Australia and the Pacific Islands. It is an evergreen, terrestrial orchid with a thin, upright stem, papery, narrow elliptic leaves and a short flowering stems with up to sixty crowded, short-lived green and white scented flowers.

***Cottonia peduncularis* (Lindl.) Rchb. f.**

This is an epiphyte or occasional lithophyte with elongate stems carrying many, linear, obtuse, leaves that blooms on an erect, to upto 150 cm long, usually sparsely branched, densely racemose towards the apex inflorescence with successive, foul smelling, long-lived flowers. Distributed in India and Sri Lanka.

***Cremastra appendiculata* (D. Don) Makino**

This is a terrestrial herb with elliptic to lanceolate leaves. Inflorescence is racemose, 25-70 cm long densely 5-22-flowered; Flowers fragrant and pinkish in colour. Distributed in India, China, Nepal, Thailand, Japan.

**Cryptochilus**

These are lithophytic orchids with egg shaped pseudobulbs and oblong to elliptic leaves. Inflorescence is terminal, erect and lateral bearing many flowers. Two species included in Appendix-II are *Cryptochilus lutea* Lindl and *Cryptochilus sanguinea* Wall.

***Cryptostylis arachnites* (Blume) Hassk.**

This is a terrestrial orchid with several thick, very hairy roots with 1 to 4, reticulate, ovate, leaves with a slender stalk that blooms in the winter on an erect, basal, 60 cm long, many successively flowered inflorescence with resupinate flowers. Distributed in India, China, Sri Lanka, Thailand, Java and Sumatra.

**Cymbidium**

Cymbidiums are among the most popular winter and spring blooming semi-terrestrial orchids originated from tropical and subtropical Asia covering North Eastern India, China, Japan, Malayasia, the Philippines, Borneo islands and North Australia, usually growing in cooler climates at high elevations. The important Cymbidium growing countries in the world are Australia, New Zealand, Japan, the Netherlands, the USA and England. The plants are characterized by short and stout pseudobulbs ensheathed by encircling leaf bases. Leaves are long, ribbon shaped, leathery or soft and lanceolate. The flower spikes develop from the base of the pseudobulbs. The spikes are erect, arching or pendulous and arranged with 2 to 15 flowers. The individual florets are 1cm to 12.5cm across and are of various colours of shades of colour. Twenty-eight species included in appendix-II are *Cymbidium aloifolium* (L.) Swartz, *Cymbidium bicolor* Lindl., *Cymbidium bicolor* ssp. *obtusum* Du Puy & P. J. Cribb, *Cymbidium bicolor* ssp. *pubescen*s (Lindl.) Du Puy & P.J. Cribb, *Cymbidium cochleare* Lindl., *Cymbidium cyperifolium* Lindl., *Cymbidium dayanum* Rchb. f., *Cymbidium devonianum* Paxton, *Cymbidium eburneum* Lindl., *Cymbidium ensifolium* (L.) Sw., *Cymbidium ensifolium* ssp. *haematodes* (Lindl.) Du Puy & P.J. Cribb, *Cymbidium erythraeum* Lindl., *Cymbidium faberi* Rolfe, *Cymbidium faberi* var. *szechuanicum* (Wu & Chen) Wu & Chen, *Cymbidium gammieanum* King & Pantl., *Cymbidium goeringii* (Rchb. f.) Rchb. f., *Cymbidium hookerianum* Rchb. f, *Cymbidium insigne* Rolfe, *Cymbidium iridioides* D. Don, *Cymbidium longifolium* D. Don, *Cymbidium lowianum* (Rchb. f.) Rchb. f., *Cymbidium mastersii* Griff. ex Lindl., *Cymbidium munronianum* King & Pantl., *Cymbidium parishii* Rchb. f., *Cymbidium sinense* (Jacks.) Willd., *Cymbidium tigrinum* Parish ex Hook. f., *Cymbidium tracyanum* (L.) Castle and *Cymbidium whiteae* King & Pantl.

**Cymbidiopsis**

It has the flowers with four pollinia with two unequal pairs and lip with two callus ridges converging to form a short tube at the base of mid lobe. Two species included in Appendix-II are *Cymbidiopsis lancifolia* (Hook.) H.J. Chowdhery and *Cymbidiopsis macrorhiza* (Lindl.) H.J. Chowdhery

**Cypripedium**

They are most commonly known as Slipper Orchids or Lady's Slipper Orchids. Most of *Cypripedium* grow in temperate and subtropical climates. The *Cypripedium* are terrestrial herb with short and robust rhizome growing in the uppermost soil layer. The rhizome grows annually with a growth bud at one end and dies off at the other end. The stem usually grows from the bud at the tip of the rhizome. Most slipper orchids have an elongate erect stem, with leaves growing along its length. The often-hairy leaves are ovate to elliptic or lanceolate, folded (plicate) along their length. The stems lack pseudobulbs. The inflorescence is racemose. It can carry one to twelve flowers. The flower has three acute petals with the third a striking slipper-shaped lip, which is lowermost. The flowers have a column with a unique shield-like staminode. Five spescies included in Appendix-II are *Cypripedium cordigerum* D. Don, *Cypripedium elegans* Rchb. f., *Cypripedium guttatum* Sw., *Cypripedium himalaicum* Rolfe ex Hemsl., *Cypripedium tibeticum* King ex Rolfe.

***Cyrtosia javanica* Blume**

This is a miniature to small sized, warm to cold growing leafless mycoheterotrophic herb with a stout, erect rhizome, cylindrical fleshy roots and erect, branched, often curved stems with numerous scale leaves and blooms on a terminal, elongating inflorescence with successive, non-resupinate flowers. Distributed in India, Chian, Japan, Korea and South east Asia.

**Dactylorhiza**

These are commonly known as 'Marsh Orchids' or 'Spotted Orchids'. They are hardy tuberous geophytes and they can store a large amount of water to survive arid conditions. The tuber is flattened and finger-like. The long leaves are lanceolate and speckled. Leaves higher on the stem are shorter than leaves lower on the stem. The inflorescence is short consisting of a compact raceme with 25-50 flowers. The dominant colors are white and all shades of pink to red, sprinkled with darker speckles. Two species included in Appendix-II are *Dactylorhiza hatagirea* (D. Don) Soo and *Dactylorhiza kafiriana* Renz.

**Dendrobium**

These are sympodial epiphytic orchids. The genera are characterized by long pseudobulbs or canes with soft leaves on entire length or in some species, pseudobulbs are short or swollen terminating in two coriaceous leaves. The pseudobulbs are of four types,

a) Cane woody.

b) Cane cylindric.

c) Cane clavate fleshy.

d) Bulbous round.

The leaf size ranges from 2.5cm to 40cm, thick, are deciduous or evergreen. In some groups, the flowers joined in pairs or three on small peduncle on the entire length of the pseudobulbs, with caduceus leaves. In some species, with persistent leaves, the flowers are grouped in pairs or threes or alternately closely set forming erect or pendent thyrses. In another group, flowers are generally solitary and small, arising from the axils of leaves. The inflorescences are terminal or subterminal and arranged with one to several dozens of flowers with extremely diverse dimensions, size and ranges of flower colour. 117 species included in appendix-II are *Dendrobium acinaciforme* Roxb., *Dendrobium aduncum* Wall. ex Lindl., *Dendrobium amoenum* Wall. ex Lindl., *Dendrobium anamalayanum* Chandrab., V. Chandras. & N.C. Nair, *Dendrobium anceps* Sw., *Dendrobium angulatum* Lindl., *Dendrobium aphyllum* (Roxb.) C.E.C. Fisch., *Dendrobium aphyllum* var. *katakianum* I. Barua, *Dendrobium aqueum* Rchb. f., *Dendrobium arunachalense* C. Deori, S.K. Sarma, Phukan & A.A. Mao, *Dendrobium barbatulum* Lindl., *Dendrobium bellatulum* Rolfe, *Dendrobium bensonae* Rchb. f., *Dendrobium bicameratum* Lindl., *Dendrobium brymerianum* Rchb. f, *Dendrobium candidum* Wall. ex Lindl., *Dendrobium capillipes* Rchb. f., *Dendrobium cariniferum* Rchb. f., *Dendrobium cathcartii* Hook. f., *Dendrobium chrysanthum* Lindl., *Dendrobium chryseum* Rolfe [= *D. aurantiacum* Rchb. f.], *Dendrobium chrysotoxum* Lindl., *Dendrobium crepidatum* Lindl. & Paxton, *Dendrobium cretaceum* Lindl., *Dendrobium crumenatum* Swartz, *Dendrobium crystallinum* Rchb. f., *Dendrobium cumulatum* Lindl., *Dendrobium dantaniense* Guill., *Dendrobium darjeelingense* Pradhan, *Dendrobium densiflorum* Lindl., *Dendrobium denudans* D. Don, *Dendrobium devonianum* Paxton, *Dendrobium dickasonii* L.O. Williams, *Dendrobium diodon* Rchb. f. ssp. *kodayarensis* Gopalan & A.N. Henry, *Dendrobium draconis* Rchb. f., *Dendrobium eriiflorum* Griff., *Dendrobium falconeri* Hook., *Dendrobium falconeri* Hook. var. *senapatianum* C. Deori, R. Gogoi & A.A. Mao, *Dendrobium farmeri* Paxton, *Dendrobium fimbriatum* var. *fimbriatum* Hook., *Dendrobium fimbriatum* var. *oculatum* Hook., *Dendrobium formosum* Roxb. Ex Lindl., *Dendrobium gibsonii* Lindl., *Dendrobium grande* Hook. f., *Dendrobium gratiotissimum* Rchb. f., *Dendrobium griffithianum* Lindl., *Dendrobium gunnarii* P.S.N. Rao, *Dendrobium haemoglossum* Thwaites, *Dendrobium herbaceum* Lindl., *Dendrobium heterocarpum* Lindl., *Dendrobium heyneanum* Lindl., *Dendrobium hookerianum* Lindl., *Dendrobium incurvum* Lindl., *Dendrobium indragiriense* Schltr., *Dendrobium jaintianum* Sabap. [= *Dendrobium meghalayense* C. Deori, S.K. Sarma, Hynn. & Phukan non-Y. Kumar & S. Chaudhury], *Dendrobium jenkinsii* Wall. ex Lindl., *Dendrobium jerdonianum* Wight, *Dendrobium keithii* Ridl., *Dendrobium khasianum* Deori, *Dendrobium lindleyi* Steud., *Dendrobium linguella* Rchb. f., *Dendrobium lituiflorum* Lindl., *Dendrobium longicornu* Lindl., *Dendrobium macrostachyum* Lindl., *Dendrobium mannii* Ridl., *Dendrobium meghalayense* Y. Kumar & S. Chaudhury, *Dendrobium microbulbon* A. Rich., *Dendrobium miserum* Rchb. f., *Dendrobium monticola* P.F. Hunt & Summerh., *Dendrobium moschatum* (Buch. -Ham.) Sw., *Dendrobium moschatum var. unguipetalum* I. Barua, *Dendrobium nanum* Hook. f., *Dendrobium nareshbahadurii* H.B. Naithani, *Dendrobium nathanielis* Rchb. f., *Dendrobium nobile* Lindl., *Dendrobium numaldeorii* C. Deori, Hynn. & Phukan, *Dendrobium nutantiflorum* Hawkes & Heller, *Dendrobium ochreatum* Lindl., *Dendrobium ovatum* (L.) Kranzl., *Dendrobium pachyphyllum* (Kuntze) Bakh. f., *Dendrobium palpebrae* Lindl., *Dendrobium panduratum* var. *Panduratum* Lindl., *Dendrobium panduratum* var. *villosum* Gopalan & A.N. Henry, *Dendrobium parciflorum* Rchb. f. ex Lindl., *Dendrobium parcum* Rchb. f., *Dendrobium parishii* Rchb. f., *Dendrobium peguanum* Lindl., *Dendrobium pendulum* Rchb. f., *Dendrobium pensile* Ridl., *Dendrobium perula* Rchb. f., *Dendrobium plicatile* Lindl., *Dendrobium porphyrochilum* Lindl., *Dendrobium praecinctum* Rchb. f., *Dendrobium primulinum* Lindl., *Dendrobium pulchellum* Roxb. ex Lindl., *Dendrobium pycnostachyum* Lindl., *Dendrobium regium* Prain, *Dendrobium rhodocentrum* Rchb. f., *Dendrobium ruckeri* Lindl., *Dendrobium secundum* (Blume) Lindl., *Dendrobium salaccense* (Blume) Lindl., *Dendrobium seidenfadenii* Senghas & Bockemühl, *Dendrobium sessanicum* O. Apang, *Dendrobium shompenii* B.K. Sinha & P.S.N. Rao, *Dendrobium spatella* Rchb. f., *Dendrobium stuposum* Lindl., *Dendrobium sulcatum* Lindl., *Dendrobium tenuicaule* Hook. f., *Dendrobium terminale* Parish & Rchb. f., *Dendrobium thyrsiflorum* Rchb. f., *Dendrobium tortile* Lindl., *Dendrobium transparens* Wall. ex Lindl., *Dendrobium vexabile* Rchb. f., *Dendrobium wardianum* Warner, *Dendrobium wattii* (Hook. f.) Rchb. f., *Dendrobium wightii* Hawkes & Heller and *Dendrobium williamsonii* Day & Rchb. f.

***Dickasonia vernicosa*** **L.O. Williams**

This is miniature epiphyte with small, smooth and round pseudobulbs and a single, apical lanceolate to lanceolate-elliptic, acute, membraneous, plicate leaf that blooms in the spring on a pendant, 4.5 to 10 cm long, few to several flowered, racemose inflorescence arises from the base of the mature pseudobulb and the flowers have a slightly musky smell. Distributed in India, Bhutan and Myanmar.

***Didiciea cunninghamii*** **King & Pantl.**

This is a terrestrial herb with a small pseuedobulb giving rise from it's side a single, broadly ovate, leaf that blooms in the summer on an erect, 12.5 to 24.6 cm long, laxly several flowered inflorescence and flowers that are confined to the upper 1/3 of the inflorescence. Distributed in the Eastern Himalayas, the Western Himalayas and Taiwan.

**Didymoplexis**

These are commonly known as Crystal orchids**,** terrestrial leafless herbs have swollen, fleshy rhizomes and thin, pale, upright fleshy flowering stems with resupinate, bell-shaped white or pale yellowish-brown flowers. They are distributed in Africa, Madagascar, Southeast Asia, Australia and various islands of the Pacific. Three species included in Appendix-II are *Didymoplexis himalaica* Schltr., *Didymoplexis pallens* Griff. and *Didymoplexis seidenfadenii* C.S. Kumar & Ormerod.

***Diglyphosa latifolia*** **Blume**

This a terrestrial herb with a creeping rhizome carrying a tall cylindrical pseudobulb with a single, oval, leaf which gradually narrows into a 20 cm long, purple stalked, petiole that blooms in the spring on a basal, 20 cm long, densely many flowered inflorescence holding the Bulbophyllum-like, foul smelling orange red flowers towards the apic. Distributed in NE India, Indonesia and Malayasia.

**Diphylax**

These are small terrestrial herbs with ovoid to cylindric, fleshy tubers. Stem is erect, terete, short, glabrous, 1-3 subradical leaves. Leaves are lanceolate to elliptic, adaxially often with yellow or white reticulate veins, basally contracted into a petiole-like amplexicaul sheath. Inflorescence with 1 to several foliaceous sterile bracts, and with several to more than 20 secund flowers in a terminal raceme. Distributed in China to the Himalayas. Distributed in *Diphylax griffithii* (Hook. f.) Kraenzl and *Diphylax urceolata* (C.B. Clarke) Hook. f.

**Diplocentrum**

These are short stemmed warm growing epiphytes bearing linear leaves and pink fllowers in racemes. Distributed in South India.Two species included in Appendix-II are *Diplocentrum congestum* Wight and *Diplocentrum recurvum* Lindl.

**Diplomeris**

These are terrestrial or lithophytic herb. Tubers are subglobose, fleshy, unlobed, neck with several slender roots. Stem is short, with 1 or 2 leaves. Leaves are basal, ensiform to oblong, pubescent or glabrous. Inflorescence is suberect, terminal, 1- or 2-flowered; floral bracts lanceolate, green. Flowers resupinate, large; ovary twisted, cylindric-fusiform. Three species included in Appendix-II are *Diplomeris hirsuta* (Lindl.) Lindl, *Diplomeris josephii* A.N. Rao & Swamin and *Diplomeris pulchella* D. Don.

**Diploprora**

These are epiphytic herbs. Stems are pendent, terete or slightly flattened, sometimes branched, with many nodes. Leaves are distichous, narrowly ovate to falcate-lanceolate. Inflorescence is lateral, racemose, few-flowered. Flowers used to appear a few at a time, widely opening. Distributed in India, Himalaya and Taiwan. Two species included in Appendix-II are *Diploprora championii* (Lindl.) Hook. f. and *Diploprora truncata* Rolfe ex Downie.

**Disperis**

The genus name *Disperis* derives from the ancient greek δίς (*dís*), meaning "twice", and πήρα (*pḗra*), meaning "bag", "pouch", because of to the pouches formed by the lateral sepals. Native to tropical to subtropical Asia and Africa. These are small terrestrial herbs arising from small tubers. Flowers are small, white, yellow, green, pink or magenta, solitary or in several- many-flowered racemes. Three species included in Appendix-II are *Disperis monophylla* Blatt. ex C.E.C. Fisch., *Disperis neilgherrense* Wight and *Disperis zeylanica* Trimen.

***Doritis pulcherrima* Lindl.**

*Doritis* is a monotypic epiphytic orchid from Burma to Sumatra. *Doritis pulcherrima* is a small, stemless and clump forming monopodials with oblong elliptic leathery leaves. The inflorescence is erect and arranged with 25 flowers. The flowers are 1.5 to 4.0 cm in diameter with pear shaped lip. The flowers are dark lavender, rose purple or magenta rose in colour and produced during autumn and winter season.

**Epigeneium**

These are epiphytic sympodial herbs found in diverse habitats throughout much of south, east and southeast Asia, including China, Japan, India, the Philippines, Indonesia, Australia, New Guinea, Vietnam and many of the islands of the Pacific. They have roots that creep over the surface of trees or rocks, rarely having their roots in soil. They develop up to six leaves in a tuft at the tip of a shoot and from one to a large number of flowers are arranged along an unbranched flowering stem. Eight species are included in Appendix-II are *Epigeneium amplum* (Lindl.) Summerh, *Epigeneium arunachalense* A.N. Rao, *Epigeneium chapaense* Gagnep, *Epigeneium fargesii* (Finet) Gagnep, *Epigeneium fuscescens* (Griff.) Summerh, *Epigeneium naviculare* (N.P. Balakr. & Sud. Chowdhury) Hynn. & Wadhwa [= *Epigeneium navicularis* (M.S. Balakr. & Sud. Chowdhury) A.N. Rao; *Katherinea navicularis* N.P. Balakr. & Sud. Chowdhury], *Epigeneium rotundatum* (Lindl.) Summerh and *Epigeneium treutleri* (Hook. f.) Ormerod.

**Epipactis**

These are terrestrial orchids with creeping fleshy rhizomes and lanceolate leaves. Flowers are borne on terminal racemes and greenish white to violet-purple in colour. Six species included in Appendix-II are *Epipactis gigantea* Douglas ex Hook, *Epipactis helleborine* (L.) Crantz, *Epipactis mairei* Schltr, *Epipactis persica* (Soo) Hausskn. ex Nannf, *Epipactis royleana* Lindl and *Epipactis veratrifolia* Boiss. & Hohen.

**Epipogium**

These are terrestrial leafless herbs, commonly known as Ghost Orchids have a fleshy, underground rhizome and a fleshy, hollow flowering stem with small, pale coloured, drooping, short-lived flowers with narrow sepals and petals. They are distributed from tropical Africa to Europe, temperate and tropical Asia, Australia and some Pacific Islands. Six species included in Appendix-II are *Epipogium africanus* Schltr., *Epipogium aphyllum* Sw., *Epipogium indicum* H.J. Chowdhery, G.D. Pal & G.S. Giri, *Epipogium roseum* (D. Don) Lindl., *Epipogium sessanum* S.N. Hegde & A.N. Rao and *Epipogium tuberosum* Duthie.

**Eria**

These are epiphytic, rarely lithophytic perennial herbs. They have pseudobulbs which elongated to form stem. Leaves are terete. Inflorescence is terminal or axillary, usually spike, rarely 1 or 2 flowered. Flowering rachis is hirsute or wooly. Distributed in India, China, and South East Asia. Sixty species are included in Appendix-II are *Eria acervata* Lindl., *Eria alba* Lindl., *Eria albiflora* Rolfe, *Eria amica* Rchb. f., *Eria andamanica* Hook. f., *Eria arunachalensis* A.N. Rao, *Eria bambusifolia* Lindl., *Eria biflora* Griff., *Eria bipunctata* Lindl., *Eria braccata* (Lindl.) Lindl., *Eria bractescens* var. *bractescens* Lindl., *Eria bractescens* var. *affinis* (Lindl.) Hook. f., *Eria bractescens* var. kurzii Hook. f., *Eria carinata* Lindl., *Eria clausa* King & Pantl., *Eria clavicaulis* Wall. ex Lindl., *Eria connata* J. Joseph, S.N. Hegde & Abbar., *Eria corneri* Rchb. f., *Eria coronaria* (Lindl.) Rchb. f., *Eria crassicaulis* Hook. f., *Eria cristata* Rolfe, *Eria filliformis* (Wight) Rchb. f., *Eria discolor* Lindl., *Eria excavata* Lindl., *Eria exilis* Hook. f., *Eria extinctoria* (Lindl.) Oliv., *Eria ferruginea* Lindl., *Eria glandulifera* Deori & Phukan, *Eria globulifera* Seidenf., *Eria graminifolia* Lindl., *Eria javanica* (Swartz) Blume, *Eria hegdei* Agrawala & H.J. Chowdhery, *Eria kamlangensis* A.N. Rao, *Eria lacei* Summerh., *Eria lasiopetala* (Willd.) Ormerod, *Eria lohitensis* A.N. Rao, Harid. & S.N. Hegde, *Eria meghasaniensis* (S. Misra) S. Misra, *Eria microchilos* (Dalzell) Lindl., *Eria* *muscicola* (Lindl.) Lindl., *Eria mysorensis* Lindl., *Eria nana* var. nana A. Rich., *Eria nana* var. brevilinguis (J. Joseph & Chandrasek.) Agrawala & H.J. Chowdhery, *Eria obesa* Lindl., *Eria occidentalis* Seidenf., *Eria paniculata* Lindl., *Eria pannea* Lindl., *Eria pauciflora* Wight, *Eria polystachya* A. Rich., *Eria pseudoclavicaulis* Blatt., *Eria pudica* Ridl., *Eria pulchella* Lindl., *Eria Pumila* Lindl., *Eria pusilla* (Griff.) Lindl., *Eria reticosa* Wight, *Eria sharmae* H.J. Chowdhery, G.S. Giri & G.D. Pal, *Eria spicata* (D. Don) Hand. -Mazz., *Eria stricta* Lindl., *Eria sutepensis* Rolfe ex Downie, *Eria tomentosa* (Koen.) Hook. f. and *Eria vittata* Lindl.

***Eriodes barbata* (Lindl.) Rolfe**

These are epiphyte or lithophyte with sulcate, globose pseudobulbs and carrying 1 to 3, lanceolate, gradually narrowing below into the petiolate base leaves that blooms on a basal, erect, laxly 9 flowered, narrowing from broad base, pubescent, slender, weakly fractiflex, to 80 cm long, racemose inflorescence carrying fragrant flowers**.** Distributed in India, Bhutan, Thailand and Myanmar.

**Erythrodes**

These are terrestrial herbs with creepin, cylindric, fleshy rhizomes with several roots at nodes. Stems are erect or decumbent, terete, with several to many subrosulate leaves. Leaves are green to reddish purple, ovate to elliptic, slightly fleshy, with amplexicaul petiole-like bases. Inflorescences are erect, pubescent, terminating in a short, many-flowered raceme. Distributed in India, tropical Asia, China and New Guinea. Two species included in Appendix-II are *Erythrodes blumei* (Lindl.) Schltr. and *Erythrodes hirsuta* (Griff.) Ormerod.

***Erythrorchis ochobiensis* (Hayata) Garay**

This is a large sized, warm growing mycoheterotrophic terrestrial orchid that blooms in the spring. This is a climbing herb that cling to surfaces with small, unbranched roots from the main stems. Densely crowded, resupinate flowers are borne on a highly branched flowering stem. The sepals and petals are fleshy, often fused to each other and spread widely, the petals narrower than the sepals. Distributed in India, Japan, Taiwan, Malayasia, Thailand and Myanmar.

**Esmeralda**

This is a monopodial epiphytic herb with terete stout stem and oblong twisted leaves. Inflorescence is lateral, racemose, erect, few flowered. Flowers are showy and thickly textured. Distributed in the Himalayas, China, Thailand and Myanmar. Two species included in Appendix-II are *Esmeralda cathcartii* (Lindl.) Rchb. f. and *Esmeralda clarkei* Rchb. f.

**Eulophia**

These are sympodial terrestrial orchids from Africa, Madagascar, Malayasia, Sri Lanka, China, America and India. The pseudobulbs are subterranean topped by 3 to 5 linear-lanceolate leaves. The leaves are leathery or soft, 1.8m tall and 10-12.5cm breadth. The inflorescence is simple or branched and bears few to many attractive flowers which are long lasting. The flower spikes are 2cm tall and arranged with diverse type of flowers, yellowish or greenish in colour with some brown and purplish markings. Twenty-four species included in appendix-II are *Eulophia andamanensis* Rchb. f., *Eulophia bicallosa* (D. Don) Hunt & Summerh., *Eulophia bracteosa* Lindl., *Eulophia cullenii* (Wight) Blume, *Eulophia dabia* (D. Don) Hochr., *Eulophia densiflora* Lindl., *Eulophia epidendraea* (J. König ex Retz.) C.E.C. Fisch., *Eulophia explanata* Lindl., *Eulophia flava* (Lindl.) Hook. f., *Eulophia graminea* Lindl., *Eulophia herbacea* Lindl., *Eulophia kamarupa* Sud. Chowdhury, *Eulophia mackinnonii* Duthie, *Eulophia macrobulbon* Parish & Rchb. f., *Eulophia mannii* Hook. f., *Eulophia nicobarica* N.P. Balakr. & N.G. Nair, *Eulophia obtusa* (Lindl.) Hook. f., *Eulophia ochreata* Lindl., *Eulophia pratensis* Lindl., *Eulophia promensis* Lindl., *Eulophia pulchra* (Thouars) Lindl., *Eulophia santapaui* Panigrahi & Kataki, *Eulophia spectabilis* (Dennst.) Suresh and *Eulophia zollingeri* (Rchb. f.) J.J. Sm.

**Flickingeria**

These are epiphytic or lithophytic herb with vestigial rhizomes. Stems are aerial, clustered, rootless, multi-noded, branched, each branch with a terminal pseudobulb. Pseudobulbs are single noded. Leaves are solitary on each pseudobulb, sessile, thin textured. Inflorescence is short, perennial. Flowers arise individually but mature in groups, lasting for 8-10 hours. Distributed in Asia, Malayasia, Philippines, Indonesia and Australia. Nine species included in Appendix-II are *Flickingeria abhaycharanii* Phukan & A.A. Mao, *Flickingeria albopurpurea* Seidenf., *Flickingeria bancana* (J.J. Sm.) Hawkes, *Flickingeria fimbriata* (Blume) Hawkes, *Flickingeria fugax* (Rchb. f.) Hawkes, *Flickingeria hesperus* Seidenf., *Flickingeria macraei* (Lindl.) Seidenf., *Flickingeria nodosa (*Dalzell) Seidenf. and *Flickingeria ritaeana* (King & Pantl.) Hawkes.

**Galeola**

These are mycotrophic, erect, or scrambling vines, often with rather stout, tuberous rhizomes. Stem is yellowish brown or reddish brown, often stout, slightly fleshy, with scales at nodes. Raceme or panicle is terminal and lateral, with many slightly fleshy flowers. Flowers are usually yellow or tinged with reddish brown, medium-sized. Distributed in China, Tropical Asia, Japan, Madagascar and New Guinea. Five species included in Appendix-II are *Galeola altissima* Blume, *Galeola cathcartii* Hook. f., *Galeola falconeri* Hook. f., *Galeola lindleyana* (Hook. f. & Thomson) Rchb. f. and *Galeola nudifolia* Lour.

**Gastrochilus**

These are epiphytic orchids distributed in India, East Asia and Malayasia. These are short to long stemmed epiphytic orchids with lance shaped, thick, 6 to 11 leathery leaves. The inflorescences are solitary or spicate with one or more flower spikes arise from the axil of the leaves. The flowers are attractive, 1 to 4 cm in diameter and white in colour with reddish spots and blotched with yellow. Twenty-one species included in appendix-II are *Gastrochilus acaulis* (Lindl.) Kuntze, *Gastrochilus acutifolius* (Lindl.) Kuntze, *Gastrochilus affinis* (King & Pantl.) Kuntze, *Gastrochilus arunachalensis* A.N. Rao, *Gastrochilus bellinus* (Rchb. f) Kuntze, *Gastrochilus calceolaris* (Buch.-Ham. ex Sm.) D. Don, *Gastrochilus carnosus* Z.H. Tsi, *Gastrochilus corymbosus* A.P. Das & Chanda, *Gastrochilus crassilabris* (King & Pantl.) Garay, *Gastrochilus dasypogon* (J.E. Sm.) Kuntze, *Gastrochilus distichus* (Lindl.) Kuntze, *Gastrochilus flabelliformis* (Blatt. & McCann) C.J. Saldanha, *Gastrochilus garhwalensis* Z.H. Tsi, *Gastrochilus intermedius* (Griff. ex Lindl.) Kuntze, *Gastrochilus linearifolius* Z.H. Tsi & Garay, *Gastrochilus obliquus* (Lindl.) Kuntze, *Gastrochilus obliquus* var. *suavis* (Seiden f.) Z.H. Tsi, *Gastrochilus pseudodistichus* (King & Pantl.) Kuntze, *Gastrochilus rutilans* Seidenf., *Gastrochilus sessanicus* A.N. Rao and *Gastrochilus sonamii* Lucksom.

**Gastrodia**

These are commonly known as Potato orchids terrestrial leafless herbs have fleshy, upright stems and small to medium-sized resupinate flowers with narrow sepals and petals. They are native to Asia (China, the Russian Far East, Japan, Korea, Southeast Asia, the Indian Subcontinent), Australia, New Zealand, central Africa and various islands of the Indian and Pacific Oceans. Six species included in Appendix-II are *Gastrodia arunachalensis* S.N. Hegde & A.N. Rao, *Gastrodia dyeriana* King & Pantl., *Gastrodia elata*

Blume, *Gastrodia exilis* Hook. f., *Gastrodia falconeri* Jones & Clements and *Gastrodia mishmensis* A.N. Rao, Harid. & S.N. Hedge.

**Geodorum**

These are commonly known as Shepherds' Crooks are deciduous, terrestrial herbs with underground pseudobulbs, broad, pleated leaves and small to medium-sized, tube-shaped or bell-shaped flowers on a flowering stem with a drooping end. They are distributed in southern Japan, tropical Asia, Australia and islands of the southwest Pacific Ocean. Six species distributed in Appendix-II are *Geodorum appendiculatum* Griff., *Geodorum attenuatum* Griff., *Geodorum citrinum* Jacks., *Geodorum densiflorum* (Lam.) Schltr., *Geodorum laxiflorum* Griff. and *Geodorum recurvum* (Roxb.) Alston.

**Goodyera**

These are commonly known as 'Jade Orchids', terrestrial herbs with creeping fleshy rhizomes and a loose rosette of leaves at the base of flowering stem. Leaves are elliptic, asymmetrical and green with pale green or white markings. The entire plant apart from the flowers is covered with slightly sticky hairs. Distributed in India, Australia and Europe. Eighteen species are included in Appendix-II are *Goodyera alveolata* Pradhan, *Goodyera biflora* (Lindl.) Hook. f., *Goodyera clavate* Pearce & Cribb, *Goodyera dongchenii* Lucksom, *Goodyera foliosa* (Lindl.) Benth. ex C.B. Clarke, *Goodyera fumata* Thwaites, *Goodyera fusca* (Lindl.) Hook. f., *Goodyera hemsleyana* King & Pantl., *Goodyera hispida* Lindl., *Goodyera micrantha* Maxim., *Goodyera procera* (Ker. Gawl.) Hook., *Goodyera recurva* Lindl., *Goodyera repens* (L.) R.Br., *Goodyera robusta* Hook. f., *Goodyera schlechtendaliana* Rchb. f., *Goodyera thailandica* Seidenf., *Goodyera viridiflora* (Blume) Lindl. ex Dietrich and *Goodyera vittata* Benth. ex Hook. f.

**Grosourdya**

These are small monopodial epiphytic herbs. Stems very short. Leaves are narrowly oblong to lanceolate, jointed and shortly sheathing at base. Inflorescences are lateral, with 1 or 2 flowers open at a time; rachis usually thickened. Flowers are ephemeral, opening widely, to 1.5 cm in diameter. Distributed in A & N, Myanmar, Thailand, Indonesia and China. Two species included in Appendix-II are *Grosourdya appendiculata* (Blume) Rchb. f. and *Grosourdya muscosa* (Rolfe) Garay.

## Gymnadenia

These are hardy terrestrial deciduous orchids. They survive the winter through their corms. Leaves are long, lanceolate, green grow at the bottom of the stem. There are some small leaves at the stop of the stem. The inflorescence is a dense cylindrical spike between 5 and 30 cm long. It can consist of up to 150 small pleasant-smelling flowers which are pale purple to pink and white. Distributed in China, Japan, and The Himalayas. Three species included in Appendix-II are *Gymnadenia camtschatica* (Cham.) Miyabe & Kudo, *Gymnadenia orchidis* Lindl. *and Gymnadenia orchidis* var. *pantlingii R*enz.

## Habenaria

These species have small to large underground root tubers and erect stems. These are terrestrial orchids with lanceolate or ovate leaves and are borne either along the stem or only at the base. The inflorescence is terminal, long with many small to large flowers. Flowers are mostly green, white, yellow and green or white and green. Sixty-eight species included in Appendix-II are *Habenaria acuifera* Wall. *ex* Lindl., *Habenaria acuminata* (Thw.) *Trimen, Habenaria aitchisonii* Rchb. f., *Habenaria andamanica* Hook. f., *Habenaria arietina* Hook. f., *Habenaria barnesii* Summerh. ex C.E.C. Fisch., *Habenaria caranjensis* Dalzell, *Habenaria cephalotes* Lindl., *Habenaria commelinifolia* (Roxb.) Lindl., *Habenaria concinna* Hook. f., *Habenaria crassifolia* A. Rich., *Habenaria crinifera* Lindl., *Habenaria cubitalis* (L.) R. Br., *Habenaria decipeins* Wight, *Habenaria dentata* (Swartz) Schltr., *Habenaria dichopetala* Thwaites, *Habenaria digitata* Lindl., *Habenaria diphylla* Dalzell, *Habenaria diphylla* var. josephii N. Pearce & P.J. Cribb, *Habenaria elliptica* Wight, *Habenaria elwesii* Hook.f., *Habenaria ensifolia* Lindl., *Habenaria flabelliformis* Summerh. ex C.E.C. Fisch., *Habenaria furcifera* Lindl., *Habenaria gibsonii* Hook.f., *Habenaria gibsonii* var. foetida Blatt. & McCann, *Habenaria gibsonii* var. foliosa (A. Rich.) Santapau & Kapadia, *Habenaria grandifloriformis* Blatt. & McCann, *Habenaria heyneana* Lindl., *Habenaria indica* Sath. Kumar & Manilal, *Habenaria intermedia* D. Don, *Habenaria khasiana* Hook. f., *Habenaria longicorniculata* J. Graham, *Habenaria longicornu* Lindl., *Habenaria longifolia* Buch.-Ham. ex Lindl., *Habenaria macrostachya* Lindl., *Habenaria malintana* (Blanco) Merr., *Habenaria malleifera* Hook. f., *Habenaria mandersii* Collett & Hemsl., *Habenaria marginata* Coleb., *Habenaria multicaudata* Sedgw., *Habenaria ovalifolia* Wight, *Habenaria pallideviridis* Seidenf., *Habenaria panchganiensis* Santapau & Kapadia, *Habenaria panigrahiana* S. Misra, *Habenaria panigrahiana* var. parviloba

S. Misra, *Habenaria pantlingiana* Kraenzl., *Habenaria pectinata* D. Don, *Habenaria peloroides* Parish & Rchb. f., *Habenaria periyarensis* Sasidh., K.P. Rajesh & Augustine, *Habenaria perrotteniana* A. Rich., *Habenaria plantagenia* Lindl., *Habenaria polyodont* Hook. f., *Habenaria pubescens* Lindl., *Habenaria ramayyana* Ram. Chary & J.J. Wood, *Habenaria rariflora* A. Rich., *Habenaria reflexa* Blume, *Habenaria reniformis* (D. Don) Hook. f., *Habenaria rhynchocarpa* (Thwaites) Trimen, *Habenaria richardiana* Wight, *Habenaria roxburghii* R. Br., *Habenaria stenopetala* Lindl., *Habenaria suaveolens* Dalzell, *Habenaria travancorica* Hook. f., *Habenaria trichosantha* Wall. ex Lindl., *Habenaria trifurcata* Hook. f., *Habenaria virens* (Lindl.) Hunt & Summerh. and *Habenaria viridiflora* (Rottler ex Sw.) Lindl.

***Hemipilia cordifolia*** Lindl.

This is a terrestrial orchid, upto 30cm tall with ovoid to subspherical tuber. Stem is one tubular cataphyll at the base and one leaved. Leaf is heart shaped or round, purplish below and dark green with purple spots above. Inflorescence is 10-25 cm long bearing 3 to more than 10 flowers. Flowers are purplish red to pink. Distributed in the Himalayas.

**Herminium**

These are terrestrial orchids having globose to oblong to ovoid tubers and slender roots above the tubers. Leaf shape in Herminium varies from linear, oblong, lanceolate, ovate, Stems are erect. Leaves are linear oblong, lanceolate, ovate to orbicular. Inflorescence is unbranched raceme spirally arranged with resupinate flowers pale to yellow green. Distrubuted in Asia, Japan and New Guinea. Ten species included in Appendix-II are *Herminium haridasanii* A.N. Rao, *Herminium jaffreyanum* King & Pantl., *Herminium kamengense* A.N. Rao, *Herminium kumaunensis* Deva & H.B. Naithani, *Herminium lanceum* (Thunb. ex Sw.) Vujik, *Herminium longilobatum* S.N. Hegde & A.N. Rao, *Herminium mackinnonii* Duthie, *Herminium macrophyllum* (D. Don) Dandy, *Herminium monorchis* (L.) R. Br. and *Herminium quinquelobum* King & Pantl.

***Herpysma longicaulis* Lindl.**

This is terrestrial orchid with a long, creeping at base, erect higher up stem carrying to 9 ovate to ovate-lancolate, narrowing below into the grooved petiolate base leaves that blooms on a terminal, 25 cm long, subglobose, racemose, densely 8 to many flowered inflorescence. Flowers are white. Distributed in Eastern Himalayas, Nepal, Myanmar, Thailand and Sumatra.

**Hetaeria**

These are commonly known as 'Hairy Jewel Orchids', terrestrial herbs with a succulent rhizome and a loose rosette of leaves. Small, pale, hairy non-resupinate flowers are borne on a thin, hairy flowering stem. They are distributed in tropical Africa and Asia to New Guinea, Australia and some Pacific Islands. Five species included in Appendix-II are *Hetaeria affinis* (Griff.) Seidenf. & Ormerod, *Hetaeria anomala* Lindl., *Hetaeria obliqua* Blume, *Hetaeria oblongifolia* (Blume) Blume and *Hetaeria ovalifolia* (Wight) Benth. ex Hook. f.

***Holcoglossum amesianum* (Rchb. f.) Christ.**

This is commonly known as 'Pine Needle Orchid', a monopodial epiphyte with terete leaves. The stem is long and leafy. The plant produces bloom on a simple or branched axillary racemose inflorescence. Flowers are ovate with strap shaped lip and has several fragrant flowers which opens slowly. The flowers are attractive with pink, purple and white flowers.

***Hygrochilus parishii* (Vitch & Rchb. f.) Pfitzer**

It is commonly known as 'Parish's Vanda' a warm growing epiphytic orchid with a short stout stem carrying bilobed leaves. Inflorescnce is axillary, 45 cm long arranged with 5 to several flowers. Flowers are fragrant, yellow to yellow green and long lasting. Distributed in Burma, Thailand, Vietnam and NE India.

***India arunachalensis* A.N. Rao**

This is a pendent, mini-miniature sized, hot growing epiphyte with a pendent, short stem carrying obong-lanceolate, unequally obtusely bilobed apically, basally clasping leaves that blooms on 1 to 2, axillary, pendent, 4 cm long, racemose, several flowered inflorescence. Distributed in Arunachal Pradesh.

**Ione**

These are small epiphytic monopodial orchids with branching rhizomes and linear oblong leaves and several flowered inflorescence. It is very close to the Bulbophyllum Genus. Distributed in China, Thailand and South East Asia. Six species included Appendix-II are *Ione andersonii* King & Pantl., *Ione arunachalense* A.N. Rao, *Ione bicolor* (Lindl.) Lindl., *Ione candida* Lindl., *Ione cirrhata* Lindl. and *Ione jainii* (Hynn. & Malhotra) Seidenf.

***Ipsea malabarica* (Rchb. f.) Hook. f.**

This is a rare and beautiful terrestrial orchid with disc shaped tubers, coomonly known as 'Malabar Daffodil Orchid'. Leaves appear after flowering are 8-10cm long and plicate. Infloresence is 10-15 cm long, 2-6 flowered, Flowers are bright yellow and opening partially. Distributed in Southern India.

***Jejosephia pusilla*** **(J. Joseph & H. Deka) A.N. Rao & Mani**

This is a miniature epiphyte with very small flowers measuring 3 mm in diameter.

***Kingidium niveum*** **C.S. Kumar**

This is a a mini-miniature sized, warm to cool growing epiphyte with a very short stem carrying 1 to 3, oblong-elliptic, leaf that blooms on a terete, short, between the leaves, 1 to 8 cm long, purplish violet, few flowered inflorescence. Distributed in South India.

***Lecanorchis sikkimensis*** **N. Pearce & P.J. Cribb**

These are terrestrial, leafless myco-heterotrophs (formerly called saprophytes). They produce many, long, thick, horizontal roots under a short rhizome. Stems are erect, dark, branched or unbranched, thin and brittle. They bear few to many dull brown, purple, yellow or green flowers with a brighter lip. They are distributed in mountain forest of the Himalayas, China, Japan, Korea, Southeast Asia, and New Guinea at altitudes of 300-1,500 metres.

**Liparis**

These are commonly known as 'Widelip orchids' or 'Sphinx orchids'. Plants are terrestrial, lithophytic or epiphytic herbs with a wide range of forms. The flowers are usually resupinate and small to medium sized, yellow, yellow-green or purplish with spreading sepals and petals. Distributed in Tropical Asia, Australia and Africa. Forty-nine species are included in Appendix-II are *Liparis acuminata* Hook. f., *Liparis assamica* King & Pantl., *Liparis atrosanguinea* Ridl., *Liparis atropurpurea* Lindl., *Liparis beddomei* Ridl., *Liparis biloba* Wight, *Liparis bistriata* Parish & Rchb. f., *Liparis bootanensis* Griff., *Liparis campylostalix* Rchb. f., *Liparis cathcartii* Hook. f., *Liparis caespitosa* (Lam.) Lindl., *Liparis chungthangensis* Lucksom, *Liparis cordifolia* Hook. f., *Liparis deflexa* Hook. f., *Liparis delicatula* Hook. f., *Liparis distans* C.B. Clarke, *Liparis dongcheni* Lucksom, *Liparis downii* Ridl., *Liparis elegans* Lindl., *Liparis elliptica* Wight, *Liparis espeevijii* S. Misra, *Liparis gamblei* Hook.f., *Liparis glossula* Rchb. f., *Liparis lydiaii* Lucksom, *Liparis luteola* Lindl., *Liparis mannii* Rchb. f., *Liparis nervosa* (Thunb.) Lindl., *Liparis nervosa* var. *khasiana* (Hook. f.) P.K. Sarkar, *Liparis odorata* (Willd.) Lindl., *Liparis* *perpusilla* Hook. f., *Liparis petiolata* (D. Don) P.F. Hunt & Summerh., *Liparis plantagenia* Lindl., *Liparis platyphylla* Ridl., *Liparis platyrachis* Hook. f., *Liparis pygmaea* King & Pantl., *Liparis resupinata* Ridl., *Liparis rostrata* Rchb. f., *Liparis rupestris* Griff., *Liparis somai* Hayata, *Liparis stricklandiana* Rchb. f., *Liparis tigerhillensis* A.P. Das & Chanda, *Liparis torta* Hook. f., *Liparis udaii* S. Misra, *Liparis vestita* Rchb. f., *Liparis viridiflora* (Blume) Lindl., *Liparis walakkadensis* M. Kumar & Sequiera, *Liparis walkeriae* Graham, *Liparis wightiana* Thwaites and *Liparis wrayi* Hook. f.

**Listera**

These are terrestrial orchids having usually a single pair of broad shining leaves near the middle of the stem; having racemose greenish flowers without spurs. Distributed in temperate Asia and North America and Europe. Eleven species included in Appendix-II are *Listera alternifolia* King & Pantl., *Listera brevicaulis* King & Pantl., *Listera dentata* King & Pantl., *Listera divaricata* Panigrahi & Taylor, *Listera longicaulis* King & Pantl., *Listera micrantha* Lindl., *Listera mucronata* Panigrahi & J.J. Wood, *Listera nandadeviensis* Hajra, *Listera ovata* (L.) R. Br., *Listera pinetorum* Lindl. and *Listera tenuis* Lindl.

**Luisia**

These are commonly known as 'Velvet Orchids', epiphytic or lithophytic herbs. Plants have flattened roots, long leafy stems, narrow, thick, terete leaves and short-lived flowers that open sporadically. They are distributed from tropical and subtropical Asia to the Western Pacific. Nineteen species included in Appendix-II are *Luisia abrahamii* Vatsala, *Luisia antennifera* Blume, *Luisia balakrishnanii* S. Misra, *Luisia birchea* (A. Rich.) Blume, *Luisia brachystachys* (Lindl.) Blume, *Luisia evangelinae* Blatt. & McCann, *Luisia filliformis* Hook. f., *Luisia jonesii* J.J. Sm., *Luisia micrantha* Blatt. & McCann, *Luisia macrotis* Rchb. f., *Luisia platyglossa* Rchb. f., *Luisia psyche* Rchb. f., *Luisia recurva* Seidenf., *Luisia secunda* Seidenf., *Luisia teretifolia* Gaudich., *Luisia trichorhiza* (Hook.) Blume, *Luisia volucris* Lindl., *Luisia zeylanica* Lindl. and *Luisia zollingeri* Rchb. f.

***Luisiopsis inconspicuua* (Hook.f.) C.S. Kumar & P.C.S. Kumar**

This is a epiphytic orchid, 35 cm tall with dark green terete leaves. Inflorescence is supra-axillary stuffs with short and sheathed peduncle bearing 6-8 flowers. Flowers are greenish white. Distributed in A&N islands and NE India.

**Macropodanthus**

These are epiphytic pendent herbs with leafy stems and narrow strap shaped bilobed leaves. Inflorescences are clustered, racemose and 7-25 flowered. Flowers are showy, long-lasting, sometimes sweetly scented, white or yellow, marked with red, lilac-pink or orange-brown. Distributed in A& N islands, Thailand, Malayasia, Indonesia and Philippines. Two species included in Appendix-II are *Macropodanthus alatus* (Holtt.) Seidenf. & Garay and *Macropodanthus berkeleyi* (Rchb.f.) Seidenf. & Garay.

**Malaxis**

These are terrestrial orchids with solid tubers that produce simple stems bearing smooth textured leaves. Plants are upto 15 cm tall arranged with variable inflorescences densely covered with small flowers of green, cream and pink colours. Lips are bilobed, trilobed or trifid. Distributed in South East Asia. Fourteen species included in Appendix-II are *Malaxis acuminata* D. Don, *Malaxis aphylla* King & Pantl., *Malaxis andamanica* (King & Pantl.) N.P. Balakr., *Malaxis biaurita* Lindl., *Malaxis calophylla* Rchb.f., *Malaxis josephiana* Rchb. f., *Malaxis khasiana* (Hook. f.) Kuntze [= *M. khasiana* (Hook. f.) H. Hara; *M. khasiana* (Hook. f.) K.M. Matthew], *Malaxis mackinnonii* Duthie, *Malaxis maximowicziana* King & Pantl., *Malaxis purpurea* Lindl., *Malaxis saprophyta* King & Pantl., *Malaxis cylindrostachya* (Lindl.) Kuntze (Lindl.) Kuntze, *Malaxis ophrydis* (J. König) Ormerod and *Malaxis muscifera*.

***Malleola andamanica* N.P. Balakr. & N. Bhargava**

This is an epiphytic herb with 6-10 cm long stems. Leaves are few, jointed, narrowly broad; sheathing base, striate. Inflorescence is perforating the leaf-sheaths; scape 5-10 mm long, densely 10-30-flowered; flowers facing in all directions; peduncle hirsute with stiff hairs. Flowers are not resupinate, 8-9 mm across, white or creamy white with crimson stripes on sepals and petals. Distributed in Little Andaman Island and South Andaman.

**Micropera**

These are climbing, epiphytic herbs. Stem is simple or branching, up to 1m long bearing many support roots at intervals. Leaves are linear. Inflorescence is lateral, bending through a right angle so the rachis points either straight up or straight down, racemose, 15 cm long, few-to many-flowered. Flowers are usually non-resupinate, fleshy, usually yellow with purple markings or pink. Distributed India (Sikkim), Bhutan, China (Hainan) and Indochina, south to Malaysia and Indonesia, east to the Philippines, New

Guinea, Australia and the Solomon Island. Four species included in Appendix-II are *Micropera mannii* (Hook.f.) Tang & Wang, *Micropera obtusa* (Lindl.) Tang & Wang, *Micropera pallida* (Roxb.) Lindl. and *Micropera rostrata (*Roxb.) N.P. Balakr.

**Mischobulbum**

These are terrestrial orchids with a short, creeping rhizome carrying cylindrical pseudobulbs a single, apical ovate, obtuse to subacute leaf that blooms on an erect, basal, lateral, 25 cm long, laxly 4 to 8 flowered inflorescence that has lanceolate, acuminate bracts and showy flowers. Distributed in China, Hong Kong and Taiwan. Two species included in Appendix-II are *Mischobulbum megalanthum* Tang & Wang and *Mischobulbum wrayanum* (Hook.f.) Rolfe.

***Monomeria barbata*** **Lindl.**

This is a miniature sized, warm to cool growing lithophytes or epiphyte with 7 to 9 cm between each smooth, ovoid to pear shaped pseudobulb carrying a single, apical, erect, leathery, strap shaped, leaf and blooms on a basal, erect to arching, 30 cm to 45 cm long, flexuous, 10 to 15 flowered inflorescence. Distributed in NE India, Thailand, Nepal and Vietnam.

**Myrmechis**

These are terrestrial or rarely epiphytic herbs with small elongate, creeping or decumbent rhizome. Stem is ascending, terete, glabrous, with few to many scattered leaves. Leaves are green, ovate or orbicular, small, usually less than 2 cm, slightly fleshy, base shortly petiolate and dilating into tubular amplexicaul sheath. Inflorescence is abbreviated or occasionally elongate, glabrous to pubescent, with 1 to few flowers in a short terminal raceme. Flowers not opening fully, resupinate, small; ovary erect, twisted, glabrous to pubescent. Distributed in NE India and the E Himalayas to S Japan, the Philippines, SE Asia, and New Guinea. Two species included in Appendix-II are *Myrmechis bakhimensis* D. Maity, N. Pradhan & Maiti and *Myrmechis pumila* (Hook. f.) Tang & Wang.

***Neogyna gardneriana*** **(Lindl.) Rchb. f.**

This is a lithophyte or epiphyte herb, 30-45 cm tall with ovoid-cylindric to conical pseudobulb. Leaves are lanceolate, acute yellow green above, pale beneath. Inflorescence is proteranthous or hysteranthous, 6-12 flowered; peduncle sheathed; raceme is 7-15cm long Flowers are 4-4.5cm long, white keels yellow pedicel. Distributed in India and China.

**Neottia**

These are small terrestrial orchids. In the photosynthetic members of the genus there are two more-or-less opposite green leaves. They produce a racemose inflorescences with flowers in shades of green or dull pink through to maroon and purple. The lip of each flower is prominently forked or two-lobed. They are native to temperate, subarctic and arctic regions across most of Europe, northern Asia (Siberia, China, the Himalayas, Central Asia, etc), and North America. Nine species included in Appendix-II are *Neottia acuminata* Schltr., *Neottia chandrae* Raskoti, J.J. Wood & Ale, *Neottia confusa* Bhaumik, *Neottia dihangensis* Bhaumik, *Neottia inayatii* (Duthie) Schltr., *Neottia kashmiriana* (Duthie) Schltr., *Neottia listeroides* Lindl., *Neottia mackinnonii* Deva & H.B. Naithani and *Neottia pantlingii* (W.W. Smith) Tang & Wang.

**Neottianthe**

It is terrestrial herb, growing from tubers, to a height of up to 30 cm, with pinkish flowers arranged in a one-sided spike. Distributed in the Himalayas and Eurasia. Three species included in Appendix-II are *Neottianthe cucullata* (L.) Schltr., *Neottianthe cucullata* var. calcicola (W.W.Sm.) Soo and *Neottianthe secundiflora* (Hook.f.) Schltr.

**Nephelaphyllum**

These are terrestrial herbs with small pseudobulbs and variegated leaves. Inflorescence is erect raceme with 2-16 flowered. Distrubuted in India, Bhutan, Myanmar, Thailand and Indochina north to China and Japan, eastward through Malaysia and Indonesia to the Philippines. Three species included in Appendix-II are *Nephelaphyllum cordifolium* (Lindl.) Blume, *Nephelaphyllum nudum* Hook.f. *and Nephelaphyllum sikkimensis* (Hook.f.) Karthik.

**Nervilia**

These are terrestrial, perennial, deciduous, sympodial herbs with an oval to almost spherical tubers. One or two flowers are borne on an erect, fleshy, leafless flowering stem. During flowering the plants lack leaves, but a single erect or gound-hugging leaf develops after the flower has fully opened. The leaves are usually wrinkled or crumpled. The flowers are often short-lived, lasting for only a few days. Distributed in India, China, Australia and South Africa. Sixteen species included in Appendix-II are *Nervilia aragoana* Gaud., *Nervilia crociformis* (Zoll. & Mor.) Seidenf., *Nervilia falcata* (King & Pantl.) Schltr., *Nervilia gammieana* (Hook. f.) Schltr., *Nervilia gleadowii*

A.N. Rao, *Nervilia hispida* Blatt. & McCann, *Nervilia hookeriana* (King & Pantl.) Schltr., *Nervilia infundibulifolia* Blatt. & McCann, *Nervilia Juliana* (Roxb.) Schltr., *Nervilia khasiana* (King & Pantl.) Schltr, *Nervilia mackinnonii* (Duthie) Schltr., *Nervilia macroglossa* (Hook. f.) Schltr., *Nervilia pangteyana* Jalal, Kumar & G.S. Rawat, *Nervilia plicata* (Andr.) Schltr, *Nervilia prainiana* (King & Pantl.) Seidenf. and *Nervilia punctata* (Blume) Makino.

**Oberonia**

These are epiphytic or lithophytic herbs with the leaves arranged fan-like, overlapping at the base and spreading near the tips. Large numbers of tiny, short-lived, cup-shaped, non-resupinate flowers are arranged on an arching flowering stem that emerges from the base of the uppermost leaf. Distributed in India and South Africa. Fifty-eight species included in Appendix-II are *Oberonia acaulis* Griff., *Oberonia agastyamalayana* C.S. Kumar, *Oberonia anamalayana* J. Joseph, *Oberonia angustifolia* Lindl., *Oberonia anthropophora* Lindl., *Oberonia arnottiana* Wight, *Oberonia arunachalensis* A.N. Rao, *Oberonia balakrishnanii* R. Ansari, *Oberonia bellii* Blatt. & McCann, *Oberonia bicornis* Lindl., *Oberonia brachyphylla* Blatt. & McCann, *Oberonia brachystachys* Lindl., *Oberonia brunoniana* Wight, *Oberonia caulescens* Lindl., *Oberonia cavaleriei* Finet *Oberonia chandrasekharanii* V.J. Nair, V.S. Ramach. & R. Ansari, *Oberonia clarkei* Hook. f., *Oberonia emarginata* King & Pantl., *Oberonia ensiformis* (J.E. Sm.) Lindl., *Oberonia falcata* King & Pantl., *Oberonia falconeri* Hook.f., *Oberonia* ferruginea Parish ex Hook.f., *Oberonia forcipata* Lindl., *Oberonia helferi* Hook. f., *Oberonia jenkinsiana* Griff. ex Lindl., *Oberonia josephii* C.J. Saldanha, *Oberonia kamlangensis* A.N. Rao, *Oberonia katakiana* A.N. Rao, *Oberonia kingii* Lucksom, *Oberonia lobulata* King & Pantl., *Oberonia longibracteata* Lindl., *Oberonia mannii* Hook.f., *Oberonia maxima* Parish ex Hook. f., *Oberonia mucronata* (D. Don) Ormerod & Seidenf., *Oberonia nayarii* R. Ansari & N.P. Balakr., *Oberonia obcordata* Lindl., *Oberonia pachyphylla* King & Pantl., *Oberonia pachyrachis* Rchb. f. ex Hook. f., *Oberonia platycaulon* Wight, *Oberonia prainiana* King & Pantl., *Oberonia proudlockii* King & Pantl., *Oberonia pumilio* Rchb. f., *Oberonia pyrulifera* Lindl., *Oberonia raoi* L.R. Shakya & R.P. Chaudhary, *Oberonia recurve* Lindl., *Oberonia recurve* var. *lingmalensis* (Blatt. & McCann) Santapau & Kapadia, *Oberonia rufilabris* Lindl., *Oberonia santapaui* Kapadia, *Oberonia sebastiana* Shetty & Vivek., *Oberonia seidenfadeniana* J. Joseph & Vajr., *Oberonia sulcate* J. Joseph & Sud. Chowdhury, *Oberonia swaminathanii* Ratheesh, Manudev & Sujanapal, *Oberonia tenuis* Lindl., *Oberonia* *thwaitesii* Hook. f., *Oberonia verticillata* Wight, *Oberonia wightiana* Lindl., *Oberonia wynadensis* Sivad. & R.T. Bala and *Oberonia zeylanica* Hook. f.

***Odisha cleistantha* S. Misra**

This is a monotypic terrestrial orchid characterizded by the anther two-loculed, the locules longitudinally divided by a membranous septum, without basal canals. Pollinaria two, each with two oblong sectile pollinia, separated by the septum, and a minute acicular caudicle; viscidium absent. Stigma lobes basally joined; rostellum tongue-like, erect, somewhat petaloid, expanded and three-lobed at apex; the lobes triangular, free; lateral lobes not connected with anther lobes, not with sac-like structures; auricles reduced to slender hooks. Distributed in Orissa and Jharkhand.

**Odontochilus**

These are terrestrial, mycoparasitic orchids distributed in China, Japan, the Himalayas, Southeast Asia, New Guinea and Melanesia.Eight species are included in Appendix-II are *Odontochilus asraoa* (J. Joseph & Abbar.) Ormerod, *Odontochilus clarkei* Hook. f., *Odontochilus crispus* (Lindl.) Hook. f., *Odontochilus elwesii* C.B. Clarke ex Hook. f., *Odontochilus grandiflorus* (Lindl.) Benth. ex Hook. f., *Odontochilus lanceolatus* (Lindl.) Blume, *Odontochilus tortus* King & Pantl. and *Odontochilus tetrapterus* (Hook. f.) Av. Bhattacharjee & H.J. Chowdhery.

**Oreorchis**

The common Oreorchis is a terrestrial orchid with a sympodial habit of growth. Flowers are borne on an inflorescence bearing yellow blooms. It is known from East Asia, Japan, Korea, the Russian Far East, and China. Four species included in Appendix-II are *Oreorchis foliosa* Lindl., *Oreorchis foliosa* var. indica (Lindl.) N. Pearce & P.J. Cribb, *Oreorchis micrantha* Lindl. and *Oreorchis patens* Lindl.

**Ornithochilus**

These are epiphytic, monopodial, small herbs. Stems are short, unbranched, rigid with many flat aerial roots. Leaves are flat, fleshy, base jointed and shortly sheathed. Inflorescences are axillary, paniculate, many flowered. Flowers are small to medium-sized. Distributed in South East Asia and the Himalayas. Two species included in Appendix-II are *Ornithochilus cacharensis* Barbhuiya, B.K. Dutta & Schuit. and *Ornithochilus difformis* (Lindl.) Schltr.

**Otochilus**

These are epiphytic herbs, with erect or pendulous rhizome. Pseudobulbs superposed, subcylindric, 2-leaved. Leaves are petiolate, plicate, linear to elliptic, papery, acute. Inflorescence is proteranthous or synanthous, pendulous, racemose, many flowered. Flowers are resupinate, often white, with or without brown markings or flesh-colored, small. Distrubuted in South-East Asia, China and the Himalayas. Four species included in Appendix-II are *Otochilus albus* Lindl., *Otochilus fuscus* Lindl., *Otochilus lancilabius* Seidenf. and *Otochilus porrectus* Lindl.

**Pachystoma**

These are are deciduous, terrestrial herbs with a branching underground rhizome and one or two linear, papery, pleated or veiny leaves. A thin, wiry flowering stem bears smallish, pink drooping hairy flowers. Distributed in tropical and subtropical Asia. Two species included in Appendix-II are *Pachystoma hirsutum* (J. Joseph & Vajr.) C.S. Kumar & Manilal and *Pachystoma pubescens* Blume.

**Panisea**

These are epiphytic or lithophytic herbs with creeping rhizome. Pseudobulbs are cylindric to ovoid-globose, sometimes prostrate basally, 1- or 2-leaved. Leaves are conduplicate linear-lanceolate, thinly leathery. Inflorescence is synanthous, proteranthous, or heteranthous, 1-8-flowered, erect to decurved. Flowers are resupinate, variously colored. Distributed in India and China. Four species included in Appendix-II are *Panisea apiculata* Lindl., *Panisea demissa* (D. Don) Pfitzer, *Panisea tricallosa* Rolfe *and Panisea uniflora* (Lindl.) Lindl.

**Pantlingia**

Distributed in South East Asia, India, China, Taiwan and Thailand. Two species included in Appendix-II *are Pantlingia paradoxa* Prain and *Pantlingia serrata* Deori.

**Papilionanthe**

These monopodial epiphytic or terrestrial species, are characterized by their thin stems with alternate terete leaves. These leaves, either straight or recurved, are up to 20 cm long and their leaf bases clasp the stem. Aerial roots arise from the nodes and are usually at right angles from the leaves. The short inflorescence also emerges from a node but is opposite the leaf. It can be up to 30 cm long and bear from a few to twenty flowers, which may be small or up to 10 cm in diameter. The base flower colors are lavender and white. Four species included in Appendix-II are *Papilionanthe cylindrica* (Lindl.) Seiden f., *Papilionanthe teres* (Roxb.) Schltr., *Papilionanthe uniflora* (Lindl.) Garay and *Papilionanthe vandarum* (Rchb. f.) Garay.

**Pecteilis**

These are terrestrial, medium-sized to large herbs. Tubers are solitary or paired, oblong, ellipsoid, or subglobose, undivided, fleshy, neck with several slender roots. Stems are erect, often stout, leafy. Leaves are cauline and alternate or in a basal rosette, ovate-elliptic or ovate, slightly fleshy. Inflorescences are terminal, with 1 to several flowers. Flowers are resupinate, often large, showy, usually white. It is distributed across eastern and southern Asia including the Russian Far East, China, Japan, India, Pakistan, Indochina, and Indonesia. Five species included in Appendix-II are *Pecteilis gigantea* (J.E. Sm.) Raf., *Pecteilis henryi* Schltr., *Pecteilis rawatii* Kumar & Veldkamp, *Pecteilis susannae* (L.) Raf., and *Pecteilis triflora* (D. Don) Tang & Wang.

***Pelantheria insectifera* (Rchb. f.) Ridl.**

This is a epiphytic or lithophytic monopodial herb with cylindrical ramified stems and alternate fleshy ovate-elliptic leaves. Inflorescences are racemose bearing 2-5 close flowers of greenish-yellow colours. Distributed In A& N islands, India, Myanmar, Nepal and Thailand.

***Penkemia nagalandensis* Phukan & Odiyo**

This is an epiphyte with erect to ascending stems and fleshy leaves that blooms on 1 to 2, arching to pendulous, 3 to 4.5 cm long, 2 to 10 flowered inflorescence. Flowers are greenish yellow in colour. Distributed in NE India and China.

**Pennilabium**

The plants are small twig or branch epiphytes. Flowers are ephemeral and open in succession, and the lip is spurred with small or large and often fimbriate or marginally toothed side lobes, often with a fleshy mid-lobe. The column lacks a foot and contains two pollinia on a long strap-like stipe; the rostellum is normally beaked. Distributed In NE India, China and Philippines. Two species included in Appendix-II are *Pennilabium proboscideum* A.S. Rao & J. Joseph and *Pennilabium struthio* Carr.

**Peristylus**

These are are terrestrial, perennial, deciduous, sympodial herbs with paired fleshy tubers and thread-like, unbranched roots. The stems are upright and unbranched. The leaves are arranged in a rosette at the base of the plants or near the centre of the stem. The flowers are resupinate, usually small, often crowded, white, green or yellowish and usually only last a few days. Distributed in South East Asia and Indian Oceans. Thirty tree species included in Appendix-II are *Peristylus affinis* (D. Don) Seidenf., *Peristylus aristatus* Lindl., *Peristylus balakrishnanii* Karthig., Sumathi & Jayanthi, *Peristylus brachyphyllus* A. Rich., *Peristylus constrictus* (Lindl.) Lindl., *Peristylus densus* (Lindl.) Santapau & Kapadia, *Peristylus Duthie* var. inayatii Deva & H.B. Naithani, *Peristylus duthiei* (Hook. f.) Deva & H.B. Naithani, *Peristylus elisabethae* (Duthie) Gupta, *Peristylus exilis* Wight, *Peristylus fallax* Lindl., *Peristylus fallax* var. dwarikaii Deva & H.B. Naithani, *Peristylus goodyeroides* (D. Don) Lindl., *Peristylus gracilis* Blume, *Peristylus hamiltonianus* Lindl., *Peristylus kumaonensis* Renz, *Peristylus lacertiferus* (Lindl.) J.J. Sm., *Peristylus lancifolius* A. Rich., *Peristylus lawii* Wight, *Peristylus mannii* (Rchb. f.) Mukerjee, *Peristylus nematocaulon* (Hook. f.) J.J. Wood, *Peristylus orbicularis* (Hook. f.) Agrawala, H.J. Chowdhery & S. Choudhury, *Peristylus parishii* Rchb. f., *Peristylus plantagenius* (Lindl.) Lindl., *Peristylus prainii (*Hook.f.) Kraenzl., *Peristylus pseudophrys* (King & Pantl.) Kraenzl., *Peristylus richardianus* Wight, *Peristylus sahanii* Kumar, G.S. Rawat & Jalal, *Peristylus secundus* (Lindl.) Rathakr., *Peristylus spiralis* A. Rich., *Peristylus stocksii* (Hook. f.) Kraenzl., *Peristylus superanthus* J.J. Wood and *Peristylus tipuliferus* (Parish & Rchb. f.) Mukerjee.

**Phaius**

These are terrestrial orchids distributed in East Africa to Tropical Asia, Pacific Islands, Himalayas, New Caledonia, Indonesia and Fiji Islands. The pseudobulbs are stocky and thickened and arranged with 2 to 8 large, thin, deeply grooved, long and lance shaped leaves. The individual leaf is 1.2 m long and 20-25cm wide. The inflorescence is 90 to 120cm long, arises from the rhizome base between the point of attachment of two leaves. The flowers are large, showy, 10cm across, long lasting and of various colours. Seven species included in appendix-II are *Phaius epiphyticus* Seiden f., *Phaius flavus* (Blume) Lindl., *Phaius luridus* Thwaites, *Phaius mishmensis* (Lindl. & Paxton) Rchb. f., *Phaius nanus* Hook. f., *Phaius tankervilleae* (Banks ex L' Her.) Blume and *Phaius wallichii* Lindl.

**Phalaenopsis**

*Phalaenopsis* called as 'Moth Orchid' because when the *amabilis* species was first observed in its natural habitat, the long inflorescences of pendulous white flowers that festooned the jungle tree tops were thought to be clusters of moths. This orchid has originated from jungles of South and Southeast Asia, Indonesia, Malayasia and the Philippines. The plants are pseudobulbless with short stems covered by the clasping leaves. The leaves are leathery, thick. The inflorescence arises from the axil of leaves, drooping or erect bearing spikes of 100cm length. The flowers are spectacular, long lasting and white, pink, yellow or mottled. Twelve species included in appendix-II are *Phalaenopsis braceana* (Hook. f.) Christenson, *Phalaenopsis cornucervi* (Breda) Blume & Rchb. f., *Phalaenopsis deliciosa* Rchb. f., *Phalaenopsis deliciosa* ssp. *hookeriana* (Gruss & Rollke) Christenson, *Phalaenopsis fasciata* Rchb. f., *Phalaenopsis lobbii* (Rchb. f.) Sweet, *Phalaenopsis mannii* Rchb. f., *Phalaenopsis mysorensis* Saldanha, *Phalaenopsis parishii* Rchb. f., *Phalaenopsis speciosa* Rchb. f., *Phalaenopsis taenialis* Lindl. and *Phalaenopsis tetraspis* Rchb. f.

**Pholidota**

These are clump-forming epiphytes or lithophytes with pseudobulbs, arranged with a single large leaf and a large number of small, whitish flowers arranged in two ranks along a thin, wiry flowering stem that emerges from the top of the pseudobulb. Distributed in tropical and subtropical Asia. Twelve species included in Appendix-II are *Pholidota articulata* Lindl., *Pholidota chinensis* Lindl., *Pholidota convallariae* (Rchb. f.) Hook. f., Pholidota *convallariae v*ar. *breviscapa* Deori & J. Joseph, *Pholidota imbricata* Hook., *Pholidota katakiana* Phukan, *Pholidota pallida* Lindl., *Pholidota protracta* Hook. f., *Pholidota pygmaea* H.J. Chowdhery & G.D. Pal, *Pholidota recurva* Lindl., *Pholidota undulata* Wall. ex Lindl. and *Pholidota wattii* King & Pantl.

**Phreatia**

These are epiphytes, sometimes with pseudobulbs, arranged with usually one or two leaves. Others lack pseudobulbs but have up to twelve leaves. A large number of small white or greenish flowers are borne on a flowering stem emerging from a leaf axil or from the base of the pseudobulb when present but the flowers do not open widely. Distributed in tropical and subtropical Asia. Three species included in Appendix-II are *Phreatia elegans* Lindl., *Phreatia laxiflora* (Blume) Lindl. and *Phreatia plantaginifolia* (Koen.) Ormerod.

**Platanthera**

These are perennial terrestrial herbs, erect in habit and have tubercles which are lanceolate to fusiform and not ovoid. The leaves are generally fleshy and oblong or ovoid to lanceolate. Leaf shape often varies with the lower leaves more ovoid in shape, progressively becoming more lanceolate as they progress up the scape. The inflorescence is terminal and solitary, and the flowers form a cylindrical spike that ranges from sparse to dense. The flowers are typically resupinate, and attractive and colorful. Distributed in temperate regions. Fourteen species included in Appendix-II are *Platanthera arcuata* Lindl., *Platanthera bakeriana* (King & antl.) Kraenzl., *Platanthera biermanniana* (King & Pantl.) Kraenzl., *Platanthera bhutanica* Inoue, *Platanthera clavigera* Lindl., *Platanthera cumminsiana* (King & Pantl.) Renz, *Platanthera dyeriana* (King & Pantl.) Kraenzl., *Platanthera edgeworthii* (Hook. f. ex Collett) R.K. Gupta, *Platanthera exelliana* Soo, *Platanthera latilabris* Lindl., *Platanthera leptocaulon* (Hook. f.) Soo, *Platanthera pachycaulon* (Hook. f.) Soo, *Platanthera sikkimensis* (Hook. f.) Kraenzl. and *Platanthera stenantha* (Hook. f.) Soo.

**Pleione**

These are species of cool growing terrestrial or lithophytic orchids distributed in China, Formosa, the Himalayas and South East Asia. These deciduous orchids are known as 'Indian Crocus'. The psedubulbs are angular, one clustered, small and sometimes mottled with black. These pseudobulbs are topped by a solitary folded leaf. Pseudobulbss arise from the base of each pseudobulb, one or two flowered and attractive. The flowers are delicate and frilled. Seven species included in appendix-II are *Pleione grandiflora* (Rolfe) Rolfe, *Pleione hookeriana* (Lindl.) B.S. Williams, *Pleione humilis* (J.E. Sm.) D. Don, *Pleione maculata* (Lindl.) Lindl., *Pleione praecox* (J.E. Sm.) D. Don, *Pleione Saxicola* Tang & Chen and *Pleione scopulorum* W.W. Sm.

**Plocoglottis**

These are sympodial terrestrial plants with short to very short rhizomes. Pseudobulbs consist of one to several internodes, 1-or few-leaved, when absent stem elongated, few- to many-leaved. Leaves are glabrous, plicate, green, sometimes purple, or with silvery green longitudinal bands, or with pale yellow spots, thin-textured. Inflorescence is lateral from the base of the plant, a many-flowered raceme, with the flowers opening in succession. Flowers are medium-sized, resupinate. Distributed in South East Asia, Andaman Islands and Indo-China regions. Two species included in Appendix-II are *Plocoglottis javanica* Blume and *Plocoglottis lowii* Rchb. f.

**Podochilus**

These are small moss like sympodial epiphytes or lithophytes. Rhizomes very short. Stems either branching and forming dense mats, or not branched, many-leaved. Leaves are duplicate, distichous, thin-textured to carnose, glabrous. Inflorescence is terminal, sometimes lateral as well, usually less than 2cm long, a few-to several-flowered raceme or carrying a single flower. Flowers are very small, resupinate, often hardly opening, usually whitish with purple spots at the apex. Distributed in China, India and South-East Asia. Five species included in Appendix-II are *Podochilus cultratus* Lindl., *Podochilus falcatus* Lindl., *Podochilus khasianus* Hook. f., *Podochilus malabaricus* Wight and *Podochilus microphylus* Lindl.

***Polystachya concreta*** **(Jacq.) Garay & Sweet**

This is an epiphytic herb, commonly known as Yellow Helmet Orchid. It has 2-5 thin lanceolate-linear leaves from the tip of the pseudobulb and 10-60 non-resupinate waxy pale-yellow flowers arranged on a panicle. Distributed in Asia, Africa and America.

**Pomatocalpa**

These are monopodial epiphytes or lithophytes with thick, leathery leaves and a large number of small flowers with a three-lobed labellum borne on panicle or raceme. Distributed in tropical and subtropical Asia. Seven species included in Appendix-II are *Pomatocalpa andamanica* (Hook. f.) J.J. Sm., *Pomatocalpa armigera* (King & Pantl.) Tang & Wang, *Pomatocalpa bambusara* (King & Pantl.) Garay, *Pomatocalpa decipiens* (Lindl.) J.J. Sm., *Pomatocalpa mannii* (Rchb. f.) J.J. Sm., *Pomatocalpa spicata* Breda and *Pomatocalpa undulata* (Lindl.) Tang & Wang.

**Porpax**

These are epiphytic or lithophytic tiny, clump-forming herbs. Pseudobulbs are crowded together, flattened globose, 2-or 3-leaved, covered by a sheath. Leaves are elliptic, ovate, or oblong, sometimes minutely hairy on margin. Inflorescence 1-flowered borne either from base of pseudobulb, breaking through sheath, or from apex of a developed pseudobulb; peduncle and pedicel are very short, flower appearing sessile at edge or center of pseudobulb. Flowers are orange-red to deep dull red, sometimes flushed with greenish yellow. Distributed in India, China, Malayasia and Thailand. Six species included in Appendix-II are *Porpax elwesii* (Rchb.f.) Rolfe, *Porpax fibuliformis* (King & Pantl.) King & Pantl., *Porpax gigantea* Deori, *Porpax jerdoniana* (Wight) Rolfe, *Porpax reticulata* Lindl. and *Porpax seidenfadenii* A.N. Rao.

**Pteroceras**

These are epiphytic or rarely lithophytic herbs. Stems produce leaves from apex while gradually dying from its base, terete, glabrous, erect to pendent, usually unbranched. Leaves are sessile, 17 per flowering shoot, conduplicate, coriaceous, rarely semi-terete, linear to narrowly elliptic, unequally bilobed to acute. Inflorescences are racemose, up to 30 per shoot; peduncle sub-terete. Flowers are about 1.5cm across, variously coloured, usually sweetly scented. Distributed in India, China and South East Asia. Six species included in Appendix-II are *Pteroceras muriculatum* (Rchb.f.) P.F. Hunt, *Pteroceras indicum* Punekar, *Pteroceras leopardinum* (Parish & Rchb. f.) Seidenf. & Smitinand, *Pteroceras monsooniae* Sasidh. & Sujanapal, *Pteroceras teres* (Blume) Holtt. and *Pteroceras unguiculatum* (Lindl.) H.A. Pedersen.

***Rhinerrhiza freemanii* (Rchb. f.) Garay**

This is ommonly known as the 'Raspy Root Orchid'. It is an epiphytic or lithophytic orchid with usually only a single stem, many flat, raspy roots, between two and six leathery leaves and up to sixty pale orange flowers with red spots and blotches. The sepals and petals are narrow, thin and pointed.

**Rhomboda**

These are sympodial terrestrial orchids. Stems are elongated, slightly succulent, basal part creeping, forming a rhizome, apical part erect, few-leaved. Leaves are crowded at the stem apex, sheathing at the base, glabrous, dark green or brownish, with a white or reddish mid-vein, herbaceous. Inflorescence is a terminal, many-flowered raceme. Flowers are small, usually only partly resupinate (lip pointing sideways), brownish with white petals and lip. Distributed in India, China, Japan, Australia and South East Asia. Three species included in Appendix-II are *Rhomboda arunachalensis* A.N. Rao, *Rhomboda lanceolata* (Lindl.) Ormerod and *Rhomboda longifolia* Lindl.

***Rhynchostylis retusa* (L.) Blume**

This species is native to India, Sri Lanka and Philippines. The stems are robust, woody with small stout aerial white roots. The leaves are leathery, strap shaped, linear, deeply channeled, arching. The inflorescence is pendulous, 60cm long, many flowered, cylindrical. The flowers are waxy, short or long lived, sweet scented, 1cm across with white sepals and petals spotted with bluish purple and are produced during April-May.

***Risleya atropurpurea* King & Pantl.**

These are mini-minaiture to small sized, cold growing terrestrial with a narrowly conic to cylindric, fleshy rhizome giving rise to a dark purple stem with 3, basal, tubular, membraneous sheaths that blooms on an erect, 6 to 20 cm long, densely 15 to 40 flowered inflorescence with triangular-lanceolate to linear-lanceolate, membraneous floral bracts. Distributed in Assam, Sikkim, Bhutan, Myamar and Tibet.

**Robiquetia**

These are are epiphytic, monopodial herbs with pendulous, fibrous, sometimes branching stems and many smooth roots. The leaves are thick and leathery, oblong to elliptic, with a divided, asymmetrical, tip. Many small, densely crowded flowers are arranged on a pendulous flowering stem that emerges from a leaf axil. Distributed in tropical to subtropical Asia. Six species included in Appendix-II are *Robiquetia gracilis* (Lindl.) Garay, *Robiquetia josephiana* Manilal & C.S. Kumar, *Robiquetia rosea* (Lindl.) Garay, *Robiquetia spatulata* (Blume) J.J. Sm., *Robiquetia succisa* (Lindl.) Seidenf. & Garay and *Robiquetia virescens* Ormerod & Fernando.

***Saccolabiopsis pusilla* (Lindl.) Seidenf. & Garay**

This is an epiphytic small herb, up to 6cm high. Roots are many, greenish-white, slender, 1mm thick. Stem is short, pendulous, stout, terete, up to 8mm long and 3mm thick, slightly compressed, base woody covered with old leaf bases. Leaves are 2-5, alternate, distichous, subcoriaceous, sessile, falcate, linear-oblanceolate, notched or unequally bilobed at apex, undulate or subentire at margins, sheathing at base. Inflorescence is lateral, shorter than the leaves, erect, up to 2.5cm long, in racemes; peduncle short, slender, terete, up to 0.5mm thick, winged, racemes angled, winged, up to 1.8cm long, laxly few-flowered. Distributed in India, Bhutan, Thailandand Malayasia.

***Sarcoglyphis arunachalensis* A.N. Rao**

This is an epiphytic herb. Stem is few-leaved. Leaves are distichously arranged, ligulate, flat, unequally bilobed, with sheathing base, articulate, duplicate. Inflorescence arising from lower portion of stem, axillary, pendent, branched or unbranched, many-flowered. Flowers are resupinate. Sepals and petals free, similar. Petals usually smaller and narrower than sepals. Distributed in Arunachal Pradesh.

**Satyrium**

These are terrestrial herbs with globose, ovoid or ellipsoid tubers. Leaves are basal or ± basal on flowering stem, or if leaves on separate sterile shoots then flowering stem with sheathing leaves. Inflorescence is terminal, few- to many-flowered; bracts often large, frequently reflexed. Flowers are non-resupinate. Distributed in tropical & S. Africa, W. Indian Ocean, Indian Subcontinent to S. Central China. Two species included in Appendix-II are *Satyrium ciliatum* Lindl. and *Satyrium nepalense* D. Don.

**Schoenorchis**

These are commonly known as 'Flea Orchids' small epiphytic, monopodial herbs with thin roots, sometimes with branching stems and flat to almost cylindrical leaves with their bases sheathing the thin, fibrous stems. The flowers are small, fleshy, fragrant, often white or reddish purple and do not open widely. The sepals and petals overlap at the base so that the flowers often appear tube-shaped. Distributed in tropical to subtropical Asia. Six species included in Appendix-II are *Schoenorchis fragrans* (Parish & Rchb. f.) Seidenf. & Smitinand, *Schoenorchis gemmata* (Lindl.) J.J. Sm., *Schoenorchis jerdoniana* (Wight) Garay, *Schoenorchis manilaliana* M. Kumar & Sequiera, *Schoenorchis minutiflora* (Ridl.) J.J. Sm. and *Schoenorchis nivea* (Lindl.) Schltr.

**Seidenfadeniella**

These are pendulous epiphytes, to 30 cm long, stem woody, terete, green. Leaves are 10-11, terete, linear, acute. Flowers are orange-yellow arranged in 5-6 cm long, erect, dense axillary racemes. Distributed in South India and Sri Lanka. Two species included in Appendix-II are *Seidenfadeniella filliformis* (Rchb. f.) Christenson & Ormerod and *Seidenfadeniella rosea* (Wight) C.S. Kumar.

**Seidenfia**

These are terrestrial herbs. Stems swollen towards base, to 15 cm long. Leaves are broadly ovate or elliptic, with purple shades. Inflorescence is 15-20 cm long. Flowers are orange yellow and of various colours. Distributed in India, Thailand, China and Sri Lanka.Six species included in Appendix-II are *Seidenfia crenulata* (Ridl.) Szlach., *Seidenfia densiflora* (A. Rich.) Szlach., *Seidenfia intermedia* (A. Rich.) Szlach., *Seidenfia malabarica* Marg. & Szlach., *Seidenfia rheedii* (Swartz) Szlach and *Seidenfia versicolor* (Lindl.) Marg. & Szlach.

**Sirhookera**

These are epiphytes with very short stem or stemless and vermiform roots. Leaves are petiolate, elliptic oblong or oblong or oblanceolate. Flowers white, in 15-20 cm long compound racemes. Distributed in South India and Sri Lanka. Two species included in Appendix-II are *Sirhookera lanceolata* (Wight) Kuntze and *Sirhookera latifolia* (Wight) Kuntze.

**Smithsonia**

These are monopodial epiphytes with 2-3 leaves bearing few to many flowered racemes. Distributed in South India. Three species included in Appendix-II are *Smithsonia maculata* (Dalzell) C.J. Saldanha, *Smithsonia straminea* C.J. Saldanha and *Smithsonia viridiflora* (Dalzell) C.J. Saldanha.

**Smitinandia**

These are pendant epiphyte with an elongated, branching, turning pendulous stem carrying several linear, axillary, unequally and obtusely bilobed apically leaves that blooms on an lateral, simple, 8 to 20 cm long, densely many flowered inflorescence with triangular-ovate, acute to acuminate floral bracts and the fleshy, successively opening flowers arranged in a spiral manner. Distributed in India, Bangladesh, Nepal, Bhutan, Thailand and Myanmar. Two species included in Appendix-II are *Smitinandia helferi* (Hook.f.) Garay and *Smitinandia micrantha* (Lindl.) Holtt.

**Spathoglottis**

Commonly known as 'Purple orchids' are evergreen terrestrial herbs with crowded pseudobulbs, a small number of leaves and medium-sized resupinate flowers on an upright flowering stem. The sepals and petals are all similar to each other and are white, yellow, pink or purple in colour. Distributed in South-East Asia and Australia. Three species included in Appendix-II are *Spathoglottis ixioides* (D. Don) Lindl., *Spathoglottis plicata* Blume and *Spathoglottis pubescens* Lindl.

***Spiranthes sinensis* (Pers.) Ames**

It is a small plant with small tubers arranged with rosette of leaves. It has spiral inflorescence, 30-40 cm long. It is characterized by pretty pink to dark pink petals surrounding the white heart. Native to China and Japan.

***Staurochilus ramosus* (Lindl.) Seidenf.**

This is a tropical, monopodial, dwarf, epiphyte orchid with a short stem having loriform, diagonally placed two-lobed apical leaves that blooms in the spring. Inflorescence is racemose paniculate, 25-35 flowered; peduncle is 15-20 cm long. Flowers are small, broadly opened, petiole 7-8 mm. Sepal and petals are yellowish brown but light yellow at marginal surroundings; lip white. Distributed in NE India, Bangladesh and Thailand.

**Stereochilus**

These are epiphytic herbs. Stem is suberect. Leaves are several to many, distichous, coriaceous, articulate to a sheathing base, deciduous, duplicate.

Inflorescences are lateral, racemose, many-flowered, often pendent. Peduncle and rachis sometimes glandular-pubescent. Flowers are resupinate, often widely opening. Distributed in northeastern India, Bhutan, Burma, Thailand, Vietnam, and China.Two species included in Appendix-II are *Stereochilus hirtus* Lindl. and *Stereochilus ringens* (Rchb. f.) Garay.

***Stereosandra javanica* Blume**

This is a mycoheterotrophic terrestrial herb with an elongated tuber of several short, swollen internodes with erect, pale yellowish shoots carrying a few short sheaths to 40 cm tall and blooms on a terminal, 15 cm long, successively laxly several to many flowered rachis with to 6 flowers open at any one time**.** Distributed in Java, Sumatra, Borneo, Vietnam, Thailand, the Philippines, New Guinea, Solomon islands, Taiwan.

**Sunipia**

These are epiphytic herbs bearing creeping elongate rhizome. Pseudobulbs are usually well spaced on rhizome, with 1 leaf at apex. Scape develops laterally from base of pseudobulb; raceme usually several to many flowered, rarely reduced to a solitary flower. Flowers small. Distrubuted in India, China, Nepal and Thailand. Two species included in Appendix-II are *Sunipia intermedia* (King & Pantl.) P.F. Hunt and *Sunipia scariosa* Lindl.

**Taeniophyllum**

These are epiphytic or lithophytic herbs. Roots are flattened and ribbon-like or rarely subterete, appressed to substrate or pendent and spreading, green and photosynthetic in rainy season. Stem is inconspicuous. Leaves are absent or rudimentary and reduced to tiny brown scales, or basal, distichous, few, articulate to sheath, blade usually oblong-obovate, membranous, conduplicate in bud, deciduous. Inflorescence is lateral, racemose, glabrous or muricate, few- to many-flowered bearing flowers in succession, one or two at a time. Flowers are distichously arranged, ephemeral or lasting only a few days, usually resupinate, pale green to yellowish white. Distributed in tropical Africa, Sri Lanka, India, China and Japan. Eleven species included in Appendix-II are *Taeniophyllum alwisii* Lindl., *Taeniophyllum andamanicum* N.P. Balakr. & N. Bhargava, *Taeniophyllum arunachalense* A.N. Rao & J. Lal, *Taeniophyllum campanulatum* Carr, *Taeniophyllum crepidiforme* (King & Pantl.) King & Pantl, *Taeniophyllum filiforme* J.J. Sm., *Taeniophyllum glandulosum* Blume, *Taeniophyllum khasianum* J. Joseph & Yogan., Taeniophyllum *retrospiculatum* (King & Pantl.) King & Pantl., *Taeniophyllum scaberulum* Hook.f. and *Taeniophyllum stella* Carr.

## Tainia

Commonly Known as 'Ribbon Orchids', are evergreen, terrestrial herbaceous plants with upright, crowded, thin fleshy pseudobulbs. Each pseudobulb is arranged with a single, smooth or pleated leaf. The flower stalk develops from the pseudobulb on the top of a leafless shoot and bears resupinate yellowish, brownish, red or purple small to moderately large flowers. Distributed in India, China, Japan and South East Asia. Three species included in Appendix-II are *Tainia bicornis* (Lindl.) Rchb.f., *Tainia latifolia* (Lindl.) Rchb. f. and *Tainia minor* Hook. f.

## *Taprobanea spathulata* (L.) Christenson

This is a climbing, epiphytic herb. Stem is climbing, with elongated internodes. Leaves are many, distichous, rigid, slightly decurved or held horizontally to stem, elliptic, shortly sheathing at base. Inflorescence is axillary, unbranched, racemose, few-flowered, much longer than leaves. Flowers are showy, resupinate, widely opening, uniform bright sulphur yellow in colour. Distributed in South India and Sri Lanka.

## *Thecostele alata* Parish & Rchb. f.

This is an epiphyte with clustered, ovoid to ellipdsoidal, compressed, unifoliate, deeply sulcate pseudobulbs carrying a single, apical, thinly coriaceous, linear-lancelate, to elliptic-obovate, leaf with a grooved stalk that blooms on a pendant, laxly 20 to 40 flowered, 15 to 50 cm long, slender, flexuous, branching inflorescence arising from the base of the mature, often leafless pseudobulb. The inflorescence lengthen as the flowers open and new ones arise and the process can take 2 to 3 months. The cute, insect-like flowers are slightly scented and are incredibly intricate if viewed with a magnifying glass. Distributed in Bangladesh, Myanamar, Thailand, Malayasia, Laos, Vietnam, Borneo, Java, Sumatra and the Philippines.

## Thelasis

These are climbing epiphytes or lithophytes with thin roots and small pseudobulbs carrying 1-3 terminal leaves or flattened stems with several leaves. Spikes are erect, thin develop from leaf axils or the base of the pseudobulbs bearing tiny white, cream, greenish, yellowish or brownish tubular flowers. Distributed in India, South East Asia, Malayasia and Indonesia. Four species included in Appendix-II are *Thelasis bifolia* Hook.f., *Thelasis khasiana* Hook. f., *Thelasis longifolia* Hook. f. and *Thelasis pygmaea* (Griff.) Blume.

**Thrixspermum**

These are are epiphytes, lithophytes or terrestrial plants with flat, leathery leaves and short-lived flowers with the sepals and petals more or less similar to each other. Distributed in tropical and subtropical Asia. Thirteen species included in Appendix-II are *Thrixspermum album* (Ridl.) Schltr., *Thrixspermum amplexicaule* (Blume) Rchb. f., *Thrixspermum centipeda* Lour., *Thrixspermum freemanii* Rchb. f., *Thrixspermum hystrix* Rchb. f., *Thrixspermum merguense* (Hook. f.) Kuntze, *Thrixspermum muscaeflorum* A.S. Rao & J. Joseph, *Thrixspermum pauciflorum* (Hook. f.) Ridl., *Thrixspermum pulchellum* (Thwaites) Schltr., *Thrixspermum pygmaeum* (King & Pantl.) Holtt., *Thrixspermum saruwatarii* (Hayata) Schltr., *Thrixspermum trichoglottis* (Hook. f.) Kuntze and *Thrixspermum walkeri* Seidenf. & Ormerod.

**Thunia**

These are terrestrial or semi-epiphytic herbs. The plants are medium to large without pseudobulb. Flowers are large and attractive, white or blue-purple in colour. Distributed in India, China and South East Asia. Three species included in Appendix-II are *Thunia alba* (Lindl.) Rchb.f., *Thunia bensoniae* Hook. f. and *Thunia bracteata* (Roxb.) Schltr.

***Tipularia josephi* Rchb. f. ex Lindl.**

This is a temperate terrestrial herb, 20-50cm tall with sub-globose pseudobulb arranged in clumps. Leaves are petilate, ovate-elliptic and solitary. Inflorescence is raceme, 10-35 flowered, erect, emerges from the base of pseudobulb. Flowers are 1-1.5 cm in diameter, pale green with brownish purple spots. Distributed in NE India, Nepal, Bhutan, China and Myanmar.

***Trachoma coarctum* (King & Pantl.) Garay**

This is an epiphytic herb s with leafy stems, crowded, leathery leaves arranged in two ranks and a large number of relatively small, short-lived flowers that often open in successive clusters. Distributed in NE India and Myanmar.

**Trias**

These are epiphytic miniature orchids which are closely related to Bulbophyllum orchids. Flowers are small and short living. Distributed in India, Thailand, Myanmar and Bangladesh. Six species included in Appendix-II are *Trias bonaccordensis* C.S. Kumar, *Trias crassifolia* (Thw. ex Trimen) C.S. Kumar, *Trias disciflora* (Rolfe) Rolfe, *Trias nasuta* (Rchb.f.) Stapf, *Trias oblonga* Lindl. and *Trias stocksii* Benth. ex Hook.f.

**Trichoglottis**

These are epiphytic plants with thick roots, relatively thick, fibrous stems and many large, thick, leathery leaves. The flowers are usually small and yellowish with light brown or purple spots. The flowers have broad sepals, narrower petals and a labellum which has three lobes and is often hairy. Distributed in tropical and subtropical Asia. Four species included in Appendix-II are *Trichoglottis cirrhifera, Trichoglottis orchidea* (Koen.) Garay, *Trichoglottis quadricornuta* Kurz and *Trichoglottis tenera* (Lindl.) Rchb. f.

**Trichotosia**

These are sympodial epiphytes with very short rhizomes. Leaves are many, thin-leathery and deciduous. Inflorescences are lateral, opposite to the leaf and few to several flowered. Flowers are small to medium and resupinate. Distributed in South-East Asia, Nepal, Indonesia and Malayasia. Three species included in Appendix-II are *Trichotosia dasyphylla (*Parish & Rchb. f.) Kraenzl., *Trichotosia pulvinata* (Lindl.) Kraenzl. and *Trichotosia velutina* (Lodd. ex Lindl.) Kraenzl.

**Tropidia**

Commonly known as Crown orchids which are evergreen terrestrial herbs. They have thin, wiry stems with two or more tough, pleated lance or egg-shaped leaves with a flowering spike at the top of the stem, bearing crowded white, greenish or brown flowers. Distributed in tropical to subtropical Asia. Five species included in appendix-II are *Tropidia angulosa* (Lindl.) Blume, *Tropidia curculigoides* Lindl., *Tropidia hegderaoi* S. Misra, *Tropidia pedunculata* Blume and *Tropidia thwaitesii* Hook. f.

**Uncifera**

These are epiphytic herbs with pendent leafy stems. Leaves are overlapping, distichous, conduplicate, oblong to lanceolate, deciduous. Inflorescence is lateral, racemose, few- to many-flowered, usually pendent. Flowers are resupinate. Distributed in NE India, Nepal, Bhutan, Burma, and China to Thailand and Vietnam.Three species included in Appendix-II are *Uncifera acuminata* Lindl., *Uncifera lancifolia* (King & Pantl.) Schltr. and *Uncifera obtusifolia* Lindl.

**Vanda**

The Vanda orchids are totally tropical and are easy to grow. Genera like *Vandas, Aerides, Ascocentrum, Renanthera, Rhyncostylis, Aranda, Mokara, Kagawara* are included in the *Vanda Alliance*. Many of orchids under this group are called as ‘Scorpion Orchids’ or ‘Spider Orchids’. They are ideal for hanging baskets, pots or tree logs. They are monopodial epiphytic orchids distributed in India, China, The Himalayas, Sri Lanka, Philippines and throughout South East Asia. These commercial orchids are grown in Thailand, Singapore, Malayasia and Hawai. They are diversified in vegetative and reproductive growth. Based on leaf characters they grouped into four categories, e.g., strap shaped, terete, semi-terete and channeled. The lip of strap shaped leaves is very irregular while the terete leaves are of pencil thickness. The inflorescence arise from the axil of the leaves in strap leaved orchids whereas in case of terete leaved orchids inflorescence emerge from on the side of the stem of opposite leaf. The inflorescence is axillary, erect, and simple. The flowers are small to large, few to many, fleshy, heavy textured, long lasting and yellow, brown, purple, magenta, blue, lavender in colour. The flower size varies from 2.5 to 10 cm. Fifteen species included in appendix-II are *Vanda alpina* (Lindl.) Lindl., *Vanda bicolor* Griff., *Vanda coerulea* Griff. ex Lindl. [= Vanda coerulea f. luwangalba Kishor], *Vanda caerulescens* Griff., *Vanda cristata* Lindl., *Vanda griffithii* Lindl., *Vanda jainii* A.S. Chauhan [= Trudelia jainii (A.S. Chauhan) S. Misra], *Vanda liouvillei* Finet, *Vanda pumila* Hook. f., *Vanda stangeana* Rchb. f., *Vanda tessellata* (Roxb.) Hook. ex G. Don, *Vanda testacea* (Lindl.) Rchb. f., *Vanda thwaitesii* Hook.f., *Vanda tricolor* Lindl. and *Vanda wightii* Rchb. f.

***Vandopsis undulata* (Lindl.) J.J. Sm.**

This is a large sized epiphytic orchid with elongated stems and oblong leaves. Inflorescence is 15-25 cm long and 4-8 flowered. Flowers are waxy, fragrant, white with yellow lip. Distributed in NE India, Nepal, Bhutan and China.

**Vanilla**

These are vine-like plants have a monopodial climbing habitus. They can develop long thin stems with a length of more than 35m, with alternate leaves spread along their length. The short, oblong, dark green leaves are thick and leathery, even fleshy in some species. Long and strong aerial roots grow from each node. The racemose inflorescence is short-lived flowers arise successively on short peduncles from the leaf axils or scales. There may be up to 100 flowers on a single raceme, but usually no less than 20. The flowers are quite large, sweet scented and attractive with white, green, greenish yellow or cream colors. Fruit is technically an elongate, fleshy and later dehiscent capsule 10-20cm long. Distributed in tropical Asia, America and West Africa. Six species included in appendix-II are *Vanilla andamanica* Rolfe, *Vanilla aphylla* Blume, *Vanilla pilifera* Holtt., *Vanilla walkeriae* Wight, *Vanilla wightiana* Lindl. ex Hook. f. and *Vanilla sanjappae* Rasingam, R.P. Pandey, J.J. Wood & S.K. Srivast.

***Vrydagzynea albida* (Blume) Blume**

This is a terrestrial orchid with creeping rhizomes, 20 cm tall, carrying 6 to 8, ovate, acuminate, slightly asymetrical, shiny green, narrowing below into the petiolate base leaves that blooms on a terminal, densely many flowered, 5.5cm long, pubescent inflorescence with the few to many at a time, sequentially opening flowers all held in an apical corymb. Distributed in tropical and subtropical Asia.

**Xenikophyton**

These are epiphytic herbs, 30cm tall, with villose or papillose roots and stout pendulous stems. Leaves are 10-15cm long, linear-oblong in shape. Inflorescence emerges from axil of leaves, simple or branched raceme, 6-15 cm long. Flowers are small and greenish white in colour. Distributed in Kerala, Western Ghat and Tamil Nadu. Two species included in Appendix-II are *Xenikophyton seidenfadenianum* M. Kumar, Sequiera & J.J. Wood and *Xenikophyton smeeanum* (Rchb. f.) Garay.

**Yoania**

Plants are 10-30 cm tall. Rhizomes are branching. Stem is pinkish white, covered with scattered scalelike sheaths. Rachis is terminal, subdensely 3-5-flowered; floral bracts ovate to broadly ovate, 5-7 mm, clasping pedicel. Flowers are erect, spreading, pinkish purple. Distributed in China, NE India, Japan and Taiwan. Two species included in Appendix-II are *Yoania japonica* Maxim. and *Yoania prainii* King & Pantl.

**Zeuxine**

These are are terrestrial, perennial, deciduous, sympodial herbs with a fleshy, creeping, above-ground rhizome anchored by wiry roots. The leaves are thinly textured and stalked, arranged in a rosette at the base of the flowering stem or scattered along it. Flowers are small, resupinate dull-coloured crowded along the short flowering stem. The dorsal sepal and petals overlap, forming a hood over the column. The labellum has a pouched base and its tip has two lobes. Distributed in tropical Africa, Asia, Southeast Asia, New Guinea, Australia and some Pacific Islands. Twenty-three species included in Appendix-II are *Zeuxine affinis* (Lindl.) Benth. ex Hook.f., *Zeuxine andamanica* King & Pantl., *Zeuxine assamica* I. Barua & K. Barua, *Zeuxine bidupensis* Aver., *Zeuxine chowdherii* Av. Bhattacharjee & Sabap., *Zeuxine clandestine* Blume, *Zeuxine debrajiana* Sud. Chowdhury, *Zeuxine dhanikariana* Maina, Lalitha & Sreek., *Zeuxine flava* (Wall. ex Lindl.) Benth. Ex Hook. f., *Zeuxine glandulosa* King & Pantl., *Zeuxine goodyeroides* Lindl., *Zeuxine gracilis* (Breda) Blume, *Zeuxine grandis* Seiden f., *Zeuxine lindleyana* A.N. Rao, *Zeuxine longilabris* (Lindl.) Benth. & Hook. f., *Zeuxine membranacea* Lindl., *Zeuxine mooneyi* S. Misra, *Zeuxine nervosa* (Wall. ex Lindl.) Benth. ex C.B Clarke, *Zeuxine pulchera* King & Pantl., *Zeuxine reflexa* King & Pantl., *Zeuxine rolfeana* King & Pantl., *Zeuxine seidenfadenii* Deva & H.B. Naithani and *Zeuxine strateumatica* (L.) Schltr.

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# Chapter - 7
# Silvicultural Applications in the Regeneration of Some Non-Timber-Forest-Products Species

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# Chapter - 7

## Silvicultural Applications in the Regeneration of Some Non-Timber-Forest-Products Species

**Anjah-Mendi Grace Ndum and Mendi-Anjah Grace**


### Abstract

Cultivation and the propagation of non-forest-timber species ex-situ usually pose a problem to farmers in the tropics. This is partially due to an insufficient knowledge of their ecology, especially with respect to their seeds and soil status. Simple experiments are described in this chapter to assist propagators of some non-forest-timber-product species, notably *Aframomum citratum, Equinox giganteus* and *Hibiscus sabdariffa* on some conditions necessary for a successful germination and early seedling growth of these species. These are useful especially in the establishment of these species under different ecosystems and in nurseries. Pretreatment, sowing depths, planting numbers per drilled holes, are discussed.


**Keywords:** Cultivation propagation non-forest-timber-products seeds ecosystems Pretreatment sowing depths planting number *Aframomum citratum, Equinox giganteus Hibiscus sabdariffa*

### Introduction

Most often in the tropics, the management of non-timber forest products NTFP is always a problem. This stems from a poor knowledge of the biology, ecology, and regeneration potential of most of these species. Poor methods of exploitation, agriculture and over-exploitation are putting most timber and non-timber products of forests under pressure of extinction.

The importance of trees and NTFP is attracting increasing attention, to help meet growing demands and reduce pressure on natural forests and plantations. In Cameroon, the economy is based essentially on the exploitation of natural resources; among which are the NWFPs (MIDNEF, 1995) [1]. Non wood forest products are derived from both plants and animals. Hence Lamien and Bamba (2008) [2] define non wood forest products (NWFPs) as materials derived from forests, excluding timber, some of which are tree barks, roots, tubers, corms, leaves, flowers, seeds, fruits, sap, resins, honey, fungi and animal products. These NWFPs are of economic, socio-cultural and pharmaceutical importance to the population. For this reason, CIFOR (2011) [3] estimates that the market value of priority NWFPs and special products in Cameroon is 76.33 billion FCFA per year.

Niang-Diop *et al.*, (2010) [4] observed that the germination of seeds in natural ecosystems can be limited by a number of factors which include environmental conditions of the ecosystem, tegumentary seed dormancy, the field water retention capacity, the sowing depth, the spacing distance and the postharvest handling of the seeds.

This chapter addresses a number of germination and early growth Silvicultural management applications for some NTFP species which farmers can apply in natural regeneration and rehabilitation programmes of these species.

The NTFP species include:

1) *Aframomum citratum*
2) *Equinox giganteus*
3) *Hibiscus sabdariffa*

**Content**

1) ***Aframomum citratum*:** Seed planting depths on the germination and early growth of fresh and dry seeds of *Aframomum citratum.*
2) ***Equinox giganteus*:** Seed pretreatment and spacing distance on regeneration potential of *Equinox giganteus.*
3) ***Hibiscus sabdariffa*:** Assessment of regeneration potential under established ecosystems.

### 1. *Aframomum citratum*

**Background**

The genus *Aframomum* K. Schum belongs to the Zingiberaceae family. It is represented in Cameroon by over 20 species of rhizomatous herbs (Anjah *et al*., 2015a) [5]. It can be propagated by seed and vegetative parts (rhizomes), but by seed is the easier way, as virus diseases are not transmitted through seeds (Dawid *et al*., 2014) [6]. Among these NWFPs, we have *Aframomum* species including *A. citratum* found in Guinea, Nigeria, Gabon and Cameroon (Guedje *et al*., 1996) [7]. Those of Cameroon are found in the Western highlands in specific forest plant formations. The synonyms for *Framomumcitratum* (Pereira) K. Shum are *Amomuncitratum* and *Amomum macrolepis* K. Shum.

In Cameroon, the local names are ‘mbongo’, ‘mvonlo’ and ‘chor’.

**The fruits of *Amomum macrolepis***

*Aframomum citratum* is a perennial herb with underground rhizome; stem up to 4m high which are red at the young stage of growth. Its leaflets have petioles about 2cm long; oblong linear blades and an asymmetric rounded base. Their inflorescences originate at the base of the stem with reddish ovate bracts up to 6cm wide. Trimmer flowers; tubular calyx, oblique truncates, up to 7.5cm in length. They possess 3-lobed tubular corolla, spreading oval with sharp edges, measuring about 7cm x 5cm. They have ovoid fruits with capsule 3cm in diameter, extended by the long tube of the calyx. Their seeds are small (± 3mm in diameter), numerous, sub-globulous, contained in a white pulp.

**Ecology and geographic repartition**

As reported by Aronu *et al.* (2010) [8], there are several species of *Aframomum* including *A. melegueta, A. pruinosum and A. citratum*. *A. citratum* which are species of the Guinean undergrowth forests in Africa. It is distributed in Guinea, Nigeria, Cameroon and Gabon. The variability is inter-specific in nature. The presence of underground rhizomes gives *Aframomum* species an exceptional capacity for resistance when environmental conditions become hostile. To this must be added the capacity of the seeds to preserve their germination power over a long period. In addition, *Aframomum* species are grown in fields or in box gardens for their edible fruits and their multiple uses in traditional pharmacology. In Cameroon, it grows at forest edges.

**Uses**

*Aframomum* species enable communities to satisfy their different needs (Lekané, 2009) [9] and specifically, *A. citratum* fruits are widely used by the population for food, agricultural, medicinal and cultural purposes. *A.*

*citratum* was classified in Guinea among endangered plant species (Diawara, 2000) [10] and in Cameroon as special products. Though there is limited information on *Aframomum* species some studies have shown that they are exported and sold in European markets (Yembi, 2000) [11].

**Nutritive importance**

The works of Lékané (2009) [9] show that the leaves of *Aframomum* spp. thanks to their particular aroma, serve as packaging for different traditional dishes consumed during marriages and other ceremonies. These fruits are eaten fresh by men, monkeys and rodents. The seeds are used as spices in kitchens. In *A. citratum*, the seed is the part mostly used and serves as a condiment to spice various dishes in Bassa communities in Cameroon (Vivien and Faure, 1995) [12].

**Ecological and agricultural importance**

*A. citratum* species are important for soil conservation through their rhizomes and large leaves that protect soils against erosion [13](Eyob *et al.*, 2008) [13]. Nelson *et al.* (2010) [14] demonstrated that *Aframomum citratum* seed extract is a potential antifeedant which can be used as an environmentally friendly insecticide.

**Socio-economic importance**

A fruit of *Aframomum citratum* in 1997 was sold between 10 and 100 FCFA in the markets of Kribi and Ebolowain Cameroon (Van Dijk, 1997) [15]. Lékané (2009) [9] also estimated the cost of fruits the fruit at between 25 and 50 FCFA per unit whereas a 50 kg bag cost between 14,000 and 20, 000 FCFA (Baumeer, 1995) [16]. The sale of these fruits yield up to 2.5% of the total budget of certain municipalities in Cameroon. The small retailer of these fruits has an annual gain of 300,000 FCFA and the wholesaler earns up to 1,000,000 FCFA per year. For this reason, Ingran and Schure (2010) [17] scored *Aframomum citratum* in Cameroon three at a marketable value, indicating that the species is at large-scale trade. The income generated is intended for the economy of households and meets many needs.

**Pharmacological importance**

*Aframomum* species are used for the treatment of multiple ailments (Lékane, 2009). The seed is the only part of *A. citratum* which is used in the traditional pharmacology to cure cough. It also serves as a thickening agent in medicinal preparations (Laird, 2000) [18]. Further studies show that the extract of the seeds of *A. melegueta* has anti-diarrheal activity. *A. angustifolium* provides relaxing and soothing essential oils for massages and baths. Seeds of *A. melegueta* have aphrodisiac properties. Some local populations in Kenya use stem juice extract and its leaves to treat wounds and intestinal infections (Akendengue, 1994) [19]. In addition, *Aframomum* species may play an important role in the treatment of plant pathogens. In addition, *A. citratum* plants are exploited for their use of their aromatic essential oils.

**Investigating the effects of sowing depth on germination and early growth of *A. citratum***

Generally, environmental factors, sowing depths, soil physiochemical properties and some seed factors (like seed dormancy) are the major causes that influence the germination of seeds. The works of Tsombou *et al.* (2016) [20] have shown the existence of tegumentary dormancy in *A. corrorima* and *A. mulugeta* respectively. These authors proposed pretreatments to solve this dormancy problem but the results were not significant for seed germination. Multiplication of seeds of *Aframomum* spp. is very difficult, and this can be related to factors including the soil retention capacity of water, the ability of the embryo to absorb water (Anjah *et al*., 2015a) [5] and the ability of a soil to retain water depends on its texture and topography (Assie *et al*., 2010) [21]. Another problem with these species is seed dormancy which may be general for all *Aframomum* species since in Cameroon, Anjah *et al*. (2015b) [22] reported that seeds of dry *A. melegueta*, have trouble sprouting; Dawid *et al.* (2014) [6] also reported same for *Aframomum corrorima*.

Although several pretreatments exist, works on the elevation of the dormancy of seeds of *A. citratum* are very rare if not non-existent.

Investigations to determine the sowing depth on seed germination, seedling growth and vigor of *A. citratum* seedlings was carried out by Anjah and Christiana (In Press).

**Sowing depth**

The study was conducted in the nursery of the Department of Forestry FASA located in "campus A" of the University of Dschang, Cameroon. A total of 864 seeds of *A. citratum* were used for this work; 432 fresh seeds and 432 dry seeds. 36 polythene bags were filled with soil from different provenances giving a total of 144polythene bags. The polythene bags were laid out in a Randomized Complete Block Design inside a non-mist propagator of 4m x 2m. The 144 pots filled were treated with fungicides (Furaplants) to prevent fungal attack.

Each batch of 36 pots filled was then divided into two groups of 18pots each, in which were sown 108 fresh seeds and 108 dry seeds of *A. citratum* respectively. The dry seeds were treated with sulphuric acid diluted at 50% to enhance germination while the fresh seeds received no treatment. In each bag 6 seeds of *A. citratum* were sown but only one in a hole. These seeds were sown at depths of 0 cm, 3 cm, and 6 cm for all soil provenances. Using a ruler and the edge of an Hb pencil, the depths were determined. The ruler was placed close to the pencil and the different sowing depths marked on the pencil. Manual watering was applied after every two days to the seeded bags using a watering can, so that the medium substrate was kept moist without getting water logged. Germination parameters measured included: Percentage of germinated seeds (PG) and Germination speed GS. The experimental design was the same for fresh and dry seeds.

**Investigating the effects of sowing depths on early growth parameters of *A. citratum***

Since seeds did not all germinate at the same time, averagely 2 seedlings of *Aframomum citratum* emerged from each germination bag, having similar morphological characteristics which were selected to study early growth parameters. Early growth parameters such as average number of leave, average leaf surface area and average height of seedlings, were measured following Association of Official Seed Analysis.

**Effects of sowing depth on germination of *A. citratums***

Results show that germination was affected negatively by increase in sowing depth, since germination speed was highest at sowing depth of 0 cm (4.43) and lowest at sowing depth of 6 cm (0.97). Also, the number of seeds that germinated decreased with increase in sowing depth, and also germination percentage decreased with increased sowing depth for all soil provenances.

**Effects of sowing depth on early growth parameters of *A. citratum* seedlings**

**Number of leaves**

There was a fluctuation in seedling number of leaves during the 8 weeks of observation at different sowing depths. At the end of this study, the highest number of leaves were produced by seedlings from soil at 0cm (11 leaves) and at the same time lowest number of leaves was produced by seedlings at 6cm (2 leaves). Generally, the seeds sown at depths of 0 cm produced seedlings with highest number of leaves, and seeds sown at depths of 6 cm produced seedlings with lowest number of leaves. Statistically, with respect to the different sowing depths a significant difference ($p \leq 0.05$) occurred for each soil provenance as sowing depth increased.

**Shoot height**

There was a significant difference ($p<0.05$) in the decrease of seedling shoot height as sowing depth increased. Meanwhile, seedling shoot height increased throughout the 8weeks of growth observation. The highest seedling height resulted from soil at 0cm (24.03±7.36cm), and the shortest shoot height (2.42±0.67 cm) resulted from soil at 6cm. Summarily, for each soil type, shoot height of seedlings at 0cm were longer than shoot height of seedlings at 6cm.

**Leaf surface area**

It was observed that the leaf surface area showed significant differences (0<0.05) for seedlings at different sowing depths. The leave surface area for seedlings at 0cm had the largest surface area (41.41±11.31cm) and seedlings at 6cm had the smallest leave surface area (9.82±6.33cm). During this research, leaf surface area decreased with increase in sowing depth and increased from one week to the next.

Anjah *et al*. (2015b) [22] reported that *Aframomum* seeds could remain dormant for 2 to 3 years before germinating, but this does not exclude the fact that soil type, sowing depth and other factors like amount of water available to soil has an influence on seed germination. Pretreatment of seeds before sowing can reduce the time the seed takes to germinate and of all methods of pretreatment, the best is seed dipping into sulfuric acid (Niang-Diop, 2010) [4]. During this research, dried seeds which were dipped into sulfuric acid diluted at 50% did not germinate, probably because the concentration of the acid was too high. A seed can germinate if the embryo has the ability to imbibe.

Generally, it has been observed that poor seedling growth results in yield reductions. This may be due to inaccurate seed placement, low and high soil temperatures, soil insects or soil borne disease, soil compaction or smearing, surface crusting after sowing and poor quality seeds Regarding growth, seedling growth is linked to root elongation and nutrient uptake, while growth and elongation of roots are a function of the type of substrates, water content, oxygen concentrations and gas exchange. The non-effect of soil type in number of leaves and in leaf surface area can also be attributed to the fact that in the early stage of growth, the seedlings still depend on nutrients in the seeds reserves (Yerima *et al*., 2015) [23].

## 2. *Equinox giganteus*: Seed pretreatment and sowing depth on regeneration potential of *Equinox giganteus*

### Background

*Echinops giganteus* CD Adams is a perennial deciduous herb endemic to Cameroon and Nigeria. The genus *Echinops* is of the Asteraceae family and consist of about 120 species distributed world-wide (Garnatje *et al.*, 2004) [24]. Its common names are 'globe thistle' (English), 'chadon à fleursglobuleuses' (French). It is erect, pubescent and with a height of about 1.20 m. It has alternate, oblong, lanceolate, pinnately lobed leaves with very pointed acumen at the end of each lobe and the under surface of the leaves are greyish. The capitulum is ball-like surrounded by bracts and scales with whitish florets, pointed styles, hairy achene, pubescent with tiny tuft of whitish silk at the summit (Abdou *et al.*, 2012) [25].

**A picture of *E. giganteus***

### Ecology and Geographical location

The genus *E. giganteus* is distributed worldwide spanning from Eastern and Southern Europe, Asia, North and tropical Africa (Shukla, 2003) [26]. In Cameroon, it is distributed in three regions namely West, North West and South West (Mane and Nature, 2013) [27]. This species is endemic to Cameroon and Nigeria. It grows at altitudes ranging from 950-2400 m (Mane and Nature 2013) [27].

### Uses

*E. giganteus* has been designated a non-forest timber product (NTFP) in the Congo Basin and the part exploited is the root (Tchatat, 1999) [28]. The root is used to treat heart and gastric troubles (Tene *et al.*, 2004) [29]. The root has aromatic properties and has been collected and distilled to obtain essential oils used in synergy with those from other plants to eradicate weevils in stored grains (Pérez *et al.*, 2010) [30]. This species is also of interest to the fragrance and flavour sectors (Menut *et al.*, 1997) [31] which span from medicinal, culinary to industrial uses. The inflorescence and roots of several *Echinops* species have been traditionally employed in the Ethiopian, Cameroonian and Chinese folk medicine in the treatment of haemorrhoids and disorders related to the reproductive system due to their phytochemical properties (Menut *et al.*, 1997) [31].

**Seed pretreatment**

The seeds of E. giganteus were collected from mature mother plants from the wild, dried for two weeks, and preserved in polythene bags before extraction of the seeds. In this experiment to determine the effect of seed pretreatments on the germination and early seedling growth of *E. giganteus* by Anjah *et al.*, (2016) [32] the extracted seeds were subjected to three different pretreatments. These included partial and total manual scarification, roasting gently over low flame, and soaking in water. Partial manual scarification involved the removal of the first layer of pappus, while total manual scarification was by the complete removal of the pappus, leaving only the seed. For the seeds subjected to low flame roasting, three hundred seeds were equally divided into three lots. The first lot was passed over low flame for two minutes, the second for four minutes and the third for six minutes. Roasting was done using an open pot placed over the flame. Pretreatment by soaking seeds in water comprised immersing seeds in tap water at three different durations. The water was maintained at a temperature of 24 °C using mercury in glass thermometer. After dividing the seeds into three lots, the first lot was soaked for 6 hours, the second for 12 hours and the third for 24 hours. At the end of soaking, water was drained from the polythene paper bags by perforation and the respective packages labeled prior to planting. The parameters observed were the latent period (LP), the germination speed (GS) and the germination percentage (PG). The early growth parameters observed were the height, collar diameter, and the root length. On sowing the seeds, it was observed that the latent period was 5 days for seeds sown under partial manual scarification, total scarification, seeds soaked in water for 12 hours and 24 hours. Seeds roasted for 2 minutes, four minutes and those soaked for 6 hours and the control germinated after 8 days. However, the emergence of the epicotyle continued for 17 days. The lowest germination speed was observed in seeds roasted for 6 minutes. Partial and total manual removal of pappus led to the highest germination speed followed by partial manual removal. The duration of soaking in water, partial and total removal of the pappus significantly affected the latent period, cumulative germination percentages and germination speed. The height and collar diameter of the seedlings were highest in the partial removal of pappus, roasting the seeds for six and twelve hours respectively, while seedlings had the highest number of leaves in pretreatments partial removal of pappus, total removal, soaking in water for six and twelve hours respectively. As for the biomass, there were no significant differences in fresh biomass in all the treatments. In this wise, it can be concluded that farmers can effectively use this information in managing a natural regeneration programme for *Equinox giganteus.*

**Sowing depth**

In an experiment by Anjah *et al*., (2016) [33] to investigate the effects of different sowing methods on the germination, early growth and yield of *Equinox giganteus*, it was observed that significant variations occurred. Many farmers have used several methods with different species which include broadcast, sowing single, sowing triple, drilling and variation in distance of sowing. We demarcated a plot of 400 $m^2$, cleared off all existing vegetation using a cutlass. The coordinates of the four corners of the plot were taken using a GPS. This was followed by partitioning into subplots of 6m x 3m using 3 m strips of plank. This gave a total of nine subplots; each separated 30 cm from each other. Tilling using hoes and sterilization of the soil with calomi and nematicide followed suit. Nails were placed on the strips of plank 30 cm apart and ropes tied from one end of the main plots to the other for demarcation.

Mature fruits were collected from under mother tree in the wild, dried for two weeks in natural sunlight and preserved in polythene bags for extraction of seeds.

Three sowing methods were applied which included broadcast, sowing single and sowing triple. For the broadcast, twenty seeds were randomly spread throughout the plot and for the sowing single and sowing triple; seeds were sown at equidistance of 30cm x 30cm at uniform depths. Sowing methods were tagged and nursery care effected. Germination and early growth parameters were monitored daily. Germination parameters were the Latent period (LP), Germination Speed (GS), and Germination Percentage (GP); while early growth parameters were Shoot height, Number of leaves, Collar diameter, Root length, and the Yield.

The results showed that the latent period for seeds sown single and triple respectively was 5 days while that for broadcast was 8 days. Of the 2700 seeds sown, 1167 germinated with an overall percentage of 43.23%. The GP was significant in all the sowing methods at $p<0.05$. Seeds sown triple had the highest germination percentage (60.37), followed by those sown single (37.4) and lastly by seeds broadcast (24.62). GS was not significant in all sowing methods ($p<0.05$); seeds in triple had a speed of (10.69), broadcast (8.30) and single (5.98). As for the early growth parameters, there were no significant differences in the sowing method ($p<0.05$). Despite this, seeds sown in groups had the highest seedling mean of 24.38 cm followed by those broadcast 21.17 cm and lastly by sown single seeds with a mean height of 20.51 cm. Seeds sown triple had the highest collar diameter of 0.64 cm while those broadcast and sown single had the same maximum of 0.6 cm. There was however no significant difference with respect to this parameter. Seedlings resulting from seeds sown triple had the highest number of leaves (4.09) followed by seedlings from seeds sown single and by broadcast. No significant difference however in the number of leaves was observed throughout this work. Also, there was no significant difference among the mean root lengths under the different sowing methods. However seedlings from seeds sown single and triple had the highest mean root lengths, 14.31 and 14.32 respectively while seedlings from broadcast were 13.95. Plant fresh and dry biomass was significant in all sowing methods. Seedlings from seeds sown triple had the highest fresh and dry biomasses followed by broadcast and least by the sown singles.

Thus with the results obtained in this work, with the planting methods having a significant role in germination, early growth and development, farmers can thus adopt sowing the seeds of *Equinox giganteus* in triples per drilled hole or two seeds per hole in a natural regeneration programme.

### 3. *Hibiscus sabdariffa* L: Regeneration potential under established ecosystems background of species

*Hibiscus sabdariffa* is a rosselle annual or sometime perennial herbaceous plant of the family Malvaceae. Itis found in the tropical and subtropical zone notably in Thailand, India, Iran, China, Central America and Mexico. In Cameroon it is commonly called ‘foléré’. This NTFP species is characterized by glabrosity for some individuals with young green and sometime reddish stems and several profuse nodes and branches. It usually grows to a height of between 1 and 2 m and the collar diameter is between 1 to 3 cm. The leaves are usually lobed into 3 to 5, long and crenulated lanceolates. The plant has an alternate phyllotaxy with stipules about 0.5 to 1cm in length. The leaf petioles measure from 4 to 14 cm. The flowers are solitary, bisexual and found at the axils of the leaves with very short peduncles. The petals, red in colour, are about 3 to 5 cm long and the calices of about 5 linear bracts reaching to about 5.5 cm in length. The fruit is a capsule producing about 30 to 40 grains per capsule. *H. sabdariffa* thrives between temperatures of 18 $^{o}$C and 35 $^{o}$C. It is a photo-sensitive plant which flowers well when daylength is less than 12 hours. Rainfall amounts of 800-1600 favours the growth and at least an amount of 100-150 per month during vegetative growth.

**Uses**

*Hibiscus sabdariffa* is an NTFP of the tropics that has contributed to rural poverty alleviation. It is cultivated by the local farmers for bast fibres obtained from the stem (Ogunsanwo and Scotland, 1989) [33]. The fibre obtained from the stem stands at 1.5 m long and is used for cordages and as substitute for the jute in the manufacture of burlap (Duke, 2003) [34]. These fibres can be processed to produce pulp, useful for paper making. All the different organs of *H. sabdariffa* are useful i.e. leaves, the stem, roots, and the flower. In Senegal, the leaves are used in preparing sauce served with rice. The young leaves are also consumed as salad. The calices are dried, stipped overnight and served as a refreshing drink in Cameroon and other countries (‘folere’ in Cameroon, ‘zobo’ in Nigeria, ‘bilenni’ in Mali and Ivory Coast). The extracts of the calices, either concentrated or in dry powder forms are used as colorants in agro industries and pharmaceuticals. In Benin Republic, the grains are used in manufacturing condiments for cooking. In Northern Nigeria, the grains are fermented with other spices to prepare ‘mungzantusa’.

**Assessment of regeneration potential under established ecosystems of *H. sabdariffa***

This except will acquaint farmers on the best ecosystems *H. sabdariffa* can be germinated and grown for best yield and sustainability. The work was carried out in the locality of Tombel situated in the South West Region of Cameroon, at an altitude of 2,064 m, and lying between 40 45N and 90 40 E (www.encater, 2008) [35]. Tombel is highly volcanic with an extinct plutonic mountain characterized by a wet period of nine months of abundant rainfall and 3 months of dryness. It receives an annual rainfall of 2,500 mm and has an average annual temperature of about 21.2 (http://www.pgdm-gtz-cameroun.org) [36]. The work was carried out in the rainy period. The ecosystems were identified and experimental sites leased out by owners.

These included

i) A natural forest.

ii) A cocoa plantation.

iii) A farmland from which crops had been recently harvested.

iv) A fallow land. Field guards were present to ease accessibility into the respective sites.

The sites of the different ecosystems were demarcated into 10x10m plots per ecosystem. Seeds of *H. sabdariffa* were bought from local markets and were sown per plot of each ecosystem at planting distances of 50 cm in drilled holes of 2.5 cm. One seed was dropped per hole and covered slightly with top soil of each ecosystem. The germination parameters accessed were germination percentage, germination rate, germination time, and the coefficient velocity. Measurement of growth parameters of *H. sabdariffa* commenced one month after seeds were sown. 10 uniformly growing seedlings were randomly selected from germination beds and tagged for measurement growth characteristics i.e. stem length, collar diameter, and number of leaves. Eighteen weeks after planting, each plot was divided into subplots in order to evaluate the yield after each harvesting intensity. The subplots were denoted 1, 2, 3 and 4. Subplots 1 for each ecosystem were harvested firstly, constituting 25% harvesting intensity. After an interval of 3 weeks, subplots 2 were harvested i.e. 50%, subplots 3 and 4 respectively, harvested 25 and 28 weeks after planting and constituting 75% and 100% harvesting intensities respectively. The harvesting was done using sharp cutters specially designed. Entire crop for each subplot of each ecosystem were harvested carried to the laboratory where the stems, leaves and fruit components were separated and weighed using an analytical top loading electronic balance (OHAMS) to determine the optimum level of yield and sustainability of this plant in the different ecosystems respectively.

The results showed that the latent period for all ecosystems was 4. The highest germination percentage was 78% for the farmland ecosystem. No significant difference was observed between the farmland (19.4) and plantation (19.1) ecosystems; but these were significantly different from the fallow land ecosystem. The fallow land was not significantly different with the forestland. The mean germination rates were as follows: forest (0.19), farmland (0.19), abandoned fallow land (0.75), and plantation (0.19), while the mean Velocity coefficients in percentage were forest (29.8), farmland (30.6), fallow land (29.8) and plantation (30.6). Growth parameters for *H. sabdariffa* were observed for five months and these values varied amongst the four ecosystems. However, only the plants in the farmland and fallow land ecosystems survived or were able to complete their life cycles from germination, vegetative growth to flowering and production of seeds. Those of the forest and plantation survived just for 4 weeks after germination. After 28 weeks, $P<0.05$, no significant differences were observed between the means of the stem height, leaf number, and stem collar diameter for the surviving plants of the farmland and fallow land ecosystems.

The stems harvested at 25% intensity at subplots 1 had the least weights in both the farmland and fallow lands respectively. These increased for subplots 2, 3 and 4 at harvesting intensities of 50, 75, and 100 percents progressively. The weights of the fruits also progressively increased from 25, 50, 75 and 100 percent harvesting intensities. The farmland and fallow land ecosystems recorded mean stem and fruit weights which were significantly different at $P<0.05$, though stem and fruit yields were higher for farmland (2003 g for stem yield and 1350 g for fruit yield), than for fallow land (1,956 for stem and 1,280 g for fruit yield). The farmland and fallow land recorded leaf weights which were not significantly different at $P< 0.05$.

The results of germination of *H. sabdariffa* agree with those of earlier authors who confirm the latent period to be 4 days. More than half of the total number of seeds germinated for all the ecosystems indicating that the environmental factors, temperature, light, water and oxygen were favourable. The different soil compositions in the different ecosystems had little or no effect on the germination percentages since all recorded high germination percentages. The seedlings under the natural forest and the plantation ecosystem did not survive probably due to the fact that *H. sabdariffa* is a light lover (heliophyte) as observed by Elfy *et al.*, (1980) [37], thus, cannot tolerate the shade of these ecosystems. It is observed that only 2% of the light incident on the forest canopy reaches the forest floor (Edmonds, 1991) [38], thus, the leaves of heliophytes, not adapted to photosynthesize under low light, wither and the entire plant dies. Elfry *et al.* also observed that *H. sabdariffa* exhibits marked photoperiodism as the plants in the farmland and fallow lands produced flowers during the short day period in September with short daylength of 11 hours. *Hibiscus sabdariffa* has two distinct phases of growth i.e. the vegetative and the reproductive. During the vegetative phase, the energy of the plant is concentrated on the development and maturation of vegetative parts like the stem, leaves and roots. At this early phase of growth the plant absorbs water at a rapid rate and often takes in most of nitrogen, potassium phosphorus that is utilized for growth and development. At the reproductive phase, there is formation of flowers and the development of fruit and seed leading to a drop in the number of leaves, slowing down stem height. Plant yield harvested after the 18$^{th}$ week (25% intensity) of growth had the lowest stem, leaf and fruit yields in both farmland and fallow land ecosystems. This varied through the 50, 75 and 100 percent intensities for all the growth features. The leaf yield harvest increased from the 25% to 50%, but after the 50% intensity this dropped probably due to the fact that the number that dropped off the plant was higher than the number that was produced by the plant. At $P<0.05$, the plant yield significantly varied in both ecosystems and as reported by an earlier study by Duke (2003) [35], early harvest of *H sabdariffa* gives low yield while late harvest yields a substantial quantity and quality of stem fibre and fruits. However, higher yield parameters for the farmland, compared to fallow land ecosystem is also probably due to the fact that continuous tillage, in addition to mixing and stirring of soil particles breaks up aggregates and exposes organo-mineral surfaces otherwise inaccessible to decomposers. On the other hand, on abandoned fallow land, the soil texture is not sufficiently aerated and mineral nutrients are not readily available to the plants.

Thus in conclusion, farmers can readily cultivate and readily regenerate *H. sabdariffa* on farmlands and fallow lands.

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# Chapter - 8
# Non-Timber Forest Products of Nagaon District, Assam, India


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# Chapter - 8

## Non-Timber Forest Products of Nagaon District, Assam, India

**Kumar Kritartha Kaushik, Pimpi Sahu and Dr. Ramesh Nath**

### Abstract

Nagaon district of Assam (India) is rich in diversity. North East India is bonafide credible wealthy in forest range and forest products. Plant presents three considerable urgency of human life which are food, clothing, and shelter. In aggregation food for survivability comes from plant products such as fruits, vegetables, nuts, pulses, etc. commonly used in weaving, cloths, fabrics, ropes, threads, bags and nets. Non-Timber Forest Products (NTFPs) are awfully sharing to livelihoods of the society dwelling neighboring the forest field. NTFPs alike wild edible plants are of immense sale, notably in the downtown spaces. This continually rising order of NTFPs is constructing a probable risk of over-utilized of the forest resources.

**Keywords:** Nagaon, non-timber forest products, livelihood

### Introduction

The commencement of a new forest improvement approach in India established in part on non-wood forest resources has fascinated international consideration [1]. The Food and Agricultural Organization [2] defines NTFP as products of biological origin other than wood derivational from forests, other wooded land, and trees farther forests. Nowadays it is universally perceived that non-timber forest products (NTFPs) provide sizable profit to the livelihoods of forest-dependent community, many of whom have finite non-agricultural income-drawing convenience [3, 4]. According to FAO Report [5] "Non-timber Forest Products (NTFPs) are essential means for forwarding underdevelopment subjects for the diminished, forest-dependent public, subsidizing to livelihoods, in conjugation with food guarantee, salary, well-being and viable human progress" Socio-economic seriousness and the price of NTFPs in the business of tropical countries are now strongly standardized. Approximately all tropical countries, the assemblage of NTFPs is an extensive business enterprise [6] and around 500 million folks existing in adjoining woods being relied upon them for their livelihood requirement [7]. India is dawning to analyzing with forest executive approach before in region in section of the Amazon sector [8] and which abode employment and ecological deliberation previously interest increment affairs [9, 10, 11, 12, 13].

NTFPs like fuel-wood, medicinal plants, wild edible vegetables, house construction elements, etc. are an indispensable factor of day-to-day livelihood action chiefly for tribal communities [14]. In consideration of the initial 1990s, the part of NTFPs for viable forest benefit and poverty mitigation has earned heightened consideration [12]. The socio-economic emphasis and the cost of NTFPs in the business of tropical countries are now well recognized [15, 5]. In almost all tropical countries, the collection of NTFPs is a major economic activity [16, 17, 18, 6] and about 500 million people living in or near forests being depended upon them for meeting their livelihood needs [7]. The eradication of non-timber forest products (NTFP) has speculated appreciable implication in international attempts to maintain biodiversity [19, 20]. Therefore, NTFPs are called as the ‘Cinderella’ species since their probability is still to be disclosed and promoted [21, 22].

Removal of non-timber forest products (NTFPs) for sustenance and commerce has a protracted past all over the sphere [12, 23, 24]. In India, about 50 million forest inhabitants live in or along the forest periphery and count on NTFPs for their food care, health care, construction component and cash income [1]. Since NTFPs are not traded through settled retail channels, their market price remnant unrecognized and unheard of and does not come into sight in manufacture and ship stats [16, 25, 26, 27]. The North-Eastern region and Assam specifically is a segment of one of the global 25-biodiversity hot spots [28] and there is a crucial demand to inquiry the rating of biological diversification in this sector with main intensity on guarded spaces. Assam with its 78,523 sq km. geographical area is the second-largest north-eastern state of India and placed between $24^0 2^/$-$27^0 6^/$ N latitudes and $89^0 8^/$ - $96^0$ E longitudes. Out of this absolute geographical area, 30.20% (23,688 sq km) comprises the forest cover of which 14,517 sq km is a heavy forest and 9,171 sq km is open forest in the state [29]. Northeast region of India which constitutes eight states *viz*. Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim is popular for its high floral and faunal diversification. The current district of Nagaon is one of the historically important districts in the state of Assam of north-east India. Nagaon, a district in the center based in the state of Assam in North-East India, is predicted to be one of the largest districts in the state. It broadens at a latitudinal spread of $25^0$45' to $26^0$45' North and $92^0$33'-$92^0$6'' East longitude. It has enclosed a total geographical area of 3,831 sq. km relatively. Predominantly enclosed by thick forests and fertile lands, the potent river Brahmaputra flows forward the northern border of the district. Its major tributaries flowing through the district are the *Kapili* and *Kolong*. Kolong, the major tributary divides the district into Nagaon and Haiborgaon. Nagaon is bounded by the district of Sonitpur and the Brahmaputra in the North, West Karbi Anglong and North Cachar Hills in the south, East Karbi Anglong and the district of Golaghat in the east and the district of Morigaon to the west. The National Highways 36 and 37 converge the district.

**Tenability of non-wood capital**

The frequent inference that NTFP eradication is entirely free from the damaging brunt that attend logging is spurious. Typical eradication of flowers, fruits, and nuts can have inimical environmental collision and can control normal reclamation [30, 31]. More broad-ranging studies of the continuity of NTFP compilation and marketing scheme investigate to assimilate the biological and socio-economic range of the viable concern [32, 33, 34, 35]. Retail coordinated extractive schemes are likely to combat with viability involvement due to inadequacy in facts reservoir, and weak signs and impetus for forest Purchaser Company [36]. Infirmity and crooked rate signs may develop because of lurking or unambiguous endowment, immense transit, and commodity improvement outlay [37] or bureaucratic and civil forces [38]. High market prices and ill-treated high-tech interference can also matter resident annihilation [39].

Even if various reviews have subsidized evidence on the certain or possible trade adeptness of NTFP executive reign [12, 40] more reasoning of innovation in the artistic and civil structure of the forest community body is necessary if we are to further absolutely assimilate our perceptions of impartiality and viability concerns. There is proof that the eradication of NTFPs can share necessarily to native frugality over the intermediate style and can develop life prospects in conditions of livelihood safety and dietary uncertainty belittlement [39, 41]. Many researchers have also cited design in precise geographical sectors [42]. But a bit is known about the aspects that regulate the construct and severity of property exploitation by native people, or why property eradication administration switches over time [43]. Likewise, while a well-fare contract of research has been operated on the business assessment of divergent forest property and administration confer to monetary and alternative touchstone [44, 45, 12]. Comparatively meagerly factual work has been started on how eradication for marketing involves household utilization of forest-based commodities, or how a revolution in domestic establishment stake in employment, money, and land alter forest varieties architecture and profusion [11].

## Livelihood through non-timber forest product

One predominant aspect of livelihood eking scheme for the agricultural humans and wooded area groups is the promotion of the use of non-wooden woodland merchandise. In 1992, delegates to the United countries convention on environment and development, called the Rio earth summit, identified sustainable forest management as a key element in sustainable monetary improvement. In current years interest has been centered on the ability of non-timber wooded area products within the discount of poverty and meal insecurity, consequently improving nutritional and sustainable control of wooded area sources [46]. Forests offer products for one of a kind used for families and commercial degrees [47]. Although NTFPs may not be the most vital income-generating products for neighborhood people dwelling near the forests, they make contributions notably to household income, meals protection, and family healthcare as well as, provision of multiple social and cultural values [48, 49]. In spite of those roles, the main challenge persists inside the accurate evaluation of NTFPs as a revenue factor for the livelihoods of indigenous human beings [50].

## Role of non-timber forest products

The position of NTFPs varies from one region to another depending on the financial and cultural contexts. In developed international locations, for instance, NTFPs are commonly used for cultural and leisure functions, biodiversity conservation, and rural monetary improvement. in growing nations, particularly in Africa and Asia, they're frequently applied for subsistence and profits [51, 49]. In the developing nations, NTFPs are consequently taken into consideration a protection internet that fills the gaps due to a shortfall in agricultural manufacturing or different forms of emergencies [52, 53, 54]. The NTFPs-based actions, if set up by the jurisdiction and other collaborators may be used to increase the monetary and social wellbeing of groups living in and around forestlands [55].

Financial estimates of approximately USD ninety billion annualy have been set for NTFPs international, and about one-1/3 of the equation is fed on inside the neighborhood economic system without coming into the marketplace [56, 57]. Most significantly, the NTFP's contribution to rural family's earnings is sizeable in many countries globally.

## Forest policies in India

State-initiated wooded area management in India dates back to 1855 and the declaration of a constitution of Indian Forests. The forest regulations of 1894, 1927 and 1952, all enacted since the first forest Act of 1865, were in large part directed in the direction of timber production [58, 59]. No matter some cosmetic adjustments, the point of interest of the post-colonial nation's forest rules has additionally been wood, and policies had been inspired by way of sales and business concerns. While Reserved Forests frequently are controlled for wood, firewood and bamboo production on specifically commercial grounds, different classes of state-controlled wooded area lands - variously, 'protected Forests', 'Village forests', 'Zamindari forests' and 'personal forests' amounting to 34 million hectares-have been left to fulfill the forest wishes of nearby humans, normally without the systems of medical management practised within the Reserved Forests or investment to enrich the depleting inventory. The contribution of the misleadingly named 'Minor woodland products' (MFPs, the umbrella term for woodland merchandise aside from wooden and firewood) turned into no longer but liked within the forestry quarter in India, and 'timber' continued to be the major tradeable wooded area item on which control relied to generate revenue. Even though community Forestry in India advanced impressively in the 1980's, it changed into frequently structured across the production of small timber and fuelwood [60]. It turned into only in the 1988 forest policy that definite suggestions for growing NTFPs have been issued. Those coverage guidelines will no longer gain their targets unless they're translated into particular aim-orientated strategies at the kingdom stage forestry, wherein countrywide forest policies are carried out and in which many preceding policy hints have now not been pursued with energy or success.

The forestry area in India is part of the 'Concurrent list' of the constitution, that's to mention that it's miles a subject beneath the twin manipulate of country and central government, wherein nation forestry devices manage and manage the forests within the constraints of a national wooded area policy. Previous to 1970, only a few States had techniques to govern the exploitation of NTFPs, even though the maximum had regulations for timber extraction and advertising and marketing there have been masses of legitimate pastime, or speak, about the significance of what is now called NTFPs. As early as 1961, the record of the Devar commission urged state governments to make provision for in-depth series and neighborhood processing of MFPs. The Committee on Tribal economic system in woodland regions (1967) also endorsed the established order of woodland corporations and Tribal improvement Co-operative agencies for the collection, processing, and advertising of MFPs and the national commission on development of Backward regions (1981) emphasized the necessity of studies on MPFs and the propagation of decided on NTFP species. The national document of the Committee on Forestry and Poverty comfort (1984) likewise endorsed identity of recent MFP assets, tapping techniques, refining chemical change and the introduction of superior forms of flowers yielding so-known as minor wooded area merchandise [61]. However, those hints had very little effect on forest making plans and control in maximum States in which, until these days, the priority turned into an accumulation of revenues via logging of herbal and planted forests.

**Execution and marketing of non-timber forest product**

There are inherent complexities involved in managing a woodland for NTFPs. The goods are diverse, production is unsure, and markets are imperfect. Wherein NTFPs have an excessive industrial value, overexploitation has regularly taken place and the product has emerged as scarce [62, 63], in lots of extra instances, the underdevelopment of a commercial infrastructure is an impediment to powerful NTFP management [64]. Maximum past researches on NTFPs had been specific and performed with regards to either commodity markets or family desires or organic characteristics. Growing a legitimate policy calls for careful analyses of all of the above aspects as they relate to the forests which are regular of a vicinity. To make certain an increasing percent of the market proportion for NTFP gatherers and producers requires information of ways NTFP extraction and advertising and marketing structures have functioned within the beyond and how contemporary structures may be tailored to the demands of the consumer market. One issue diagnosed is that first-rate impediment to the improvement of a replicable version of an extractive device is a lack of individual role model of extraction [36]. it's far tough to understand simply how efficient an NTFP gadget is or is probably. NTFPs are unlike wood manufacturing and management systems due to the fact there is no ‘international metric’ for functions of evaluation, either theoretically or empirically.

The development of policies to dispose of economic and social constraints is crucial if NTFP management systems are to serve a large and diverse body of stakeholders. when the value of products accrues specifically to intermediaries the social objective of NTFP systems might not be maximized [34]. Numerous current research show how creditors of NTFPs very frequently live beneath regimes of financial and social dependence wherein fees and markets are efficiently managed with the aid of land-owners, traders and personal groups. Other studies propose that NTFP trading structures are often riven by means of monopsonistic preparations [65, 66] and are fashioned with the aid of unhelpful or unfair legal regulations at the direct sale of NTFPs with the aid of creditors. The range and unpredictability of traded fees have also been commented on and are extensively visible as an obstacle to the layout of advanced NTFP control systems.

**Table 1:** Dicotyledonous non-timber forest products of Nagaon district of Assam

| Sl. No. | Scientific Name | Common name | Parts used |
|---|---|---|---|
| 1. | *Naravelia zeylanica* | Gorapasoi | Young shoot-tooth brush; Leaf and root as medicine |
| 2. | *Dillenia indica* | Owtenga | Fruit's fleshy calyx as vegetable, mucilaginous seed as a natural shampoo |
| 3. | *Magnolia hodgsonii* | Barhamthury | Wood-as handle of instruments and firewood |
| 4. | *Cissampelos pareira* | Tubukilata | Young shoot tip as medicine |
| 5. | *Tinospora cordifolia* | Shagunilata | Stem as medicine |
| 6. | *Nymphaea nouchali* | BagaVetphul | Flower bud as vegetable |
| 7. | *Nelumbo nucifera* | Padumphul | Flower petal and seeds are edible |
| 8. | *Crataeva religiosa* | Barun | Leaves and frits as medicine |
| 9. | *Flacortia cataphracta* | Ponial | Fruit is edible |
| 10. | *Drymaria cordata* | Laizabori | Young shoot vegetable and medicine |
| 11. | *Garcinia cowa* | Kawri Thekera | Fruit edible and as medicine |
| 12. | *Garcinia lanceaefolia* | Rupahi Thekera | Fruit edible and as medicine |
| 13. | *Garcinia morella* | Kuji Thekera | Fruit edible and as medicine |
| 14. | *Garcinia pedunculata* | Bar Thekera | Fruit edible and as medicine |
| 15. | *Garcinia xanthochymus* | TeporTenga | Frit edible and as medicine |
| 16. | *Abutilon indicum* | Japapatori | Root as medicine |
| 17. | *Sida cordifolia* | Sunborial | Bark as fiber |
| 18. | *Bombax ceiba* | Simalo | Bark as medicine and fruit as fiber |
| 19. | *Abroma augusta* | Gorokhia | Root as medicine |
| 20. | *Zizyphus jujube* | Bagari | Fruit is edible |
| 21. | *Vitis quadrangularis* | Harjura Lata | Young shoot as vegetable, leaf, and stem as medicine |
| 22. | *Leea guineensis* | Owlata | Stem as rope in house building |
| 23. | *Aesculus assamica* | Ramanbih | Seed as medicine |
| 24. | *Mangifera sylvatica* | Ban Aam | Fruit is edible and bark as medicine |

| | | | |
|---|---|---|---|
| 25. | *Rhus chinensis* | Naga Tenga | Fruit is edible and medicine |
| 26. | *Spondias pinnata* | Amara | Fruit and young leaves are edible and medicine, bark as medicine |
| 27. | *Caesalpinia bonduc* | Letaguti | Young leaf and fruit as medicine |
| 28. | *Cassia alata* | Kharpat | Young leaves as medicine |
| 29. | *Abrus precatorius* | Latumoni | Fruit and root as medicine |
| 30. | *Butea monosperma* | Palakh | Bark as medicine and fruit as fiber |
| 31. | *Dalbergia pinnata* | Lalengchali | Bark as condiment |
| 32. | *Pongamia pinnata* | Karash | Leaves as fodder, seed as medicine |
| 33. | *Erythrina variegata* | Madar | Root, bark and leaves as medicine and for ornamental purposes |
| 34. | *Flemingia strobilifera* | Makhioty | Root and bark as medicine |
| 35. | *Mellettia pachycarpa* | Bakal Bih | Root as poison for fish |
| 36. | *Prunus jenkinsii* | TherejuTenga | Fruit is edible, shoot as medicine |
| 37. | *Rubus ellipticus* | Jutulipaka | Fruit is edible, young shoot as medicine |
| 38. | *Rubus lucens* | Jezeru Paka | Frit edible |
| 39. | *Terminalia bellirica* | Bhumura | Fruit as medicine |
| 40. | *Terminalia chebula* | Hilikha | Fruit as medicine and bark as dye |
| 41. | *Syzygium balsameum* | Jaldubuli | Young shoot a medicine |
| 42. | *Syzygium cumini* | Kala Jamu | Fruit is edible, seed as medicine and bark as dye |

**Table 2:** Monocotyledonous non-timber forest products of Nagaon district of Assam

| Sl. No. | Scientific Name | Common name | Parts used |
|---|---|---|---|
| 1. | *Thysanolaena latifolia* | Jaru Ban | Young Shoot-as fodder; Mature stem-as fencing; flower-as broom |
| 2. | *Phragmites karka* | Khagori | Young shoot-fodder; Mature stem in fencing and constructing houses |
| 3. | *Alpinia nigra* | Tora | Leaf-sheath-as rope Young, Soot and rhizome as medicine |
| 4. | *Curcuma aromatica* | Keturi | Rhizome as medicine |
| 5. | *Curcuma caesia* | Kala Halodhi | Rhizome as medicine |
| 6. | *Curcuma amada* | Amada | Rhizome as medicine and condiment |
| 7. | *Etlingera loroglossa* | Karphul | Rhizome as medicine and condiment |
| 8. | *Kaempferia galanga* | Gathiyon | Rhizome-medicine; Young Shoot-vegetables; Flower-ornamental |
| 9. | *Kaempferia rotunda* | Bhumi | Rhizome as medicine |

| | | | |
|---|---|---|---|
| | | Champa | |
| 10. | *Zingiber officinale* | Moran Ada | Rhizome as medicine and condiment |
| 11. | *Musa aurantiaca* | Banaria Kal | Inflorescence-edible |
| 12. | *Musa itinerans* | Banaria Kal | Inflorescence-edible |
| 13. | *Musa nagensium* | Banaria Kal | Inflorescence-edible |
| 14. | *Maranta arundinacea* | Toraalu | Rhizome-edible |
| 15. | *Phrynium pubinerve* | Kawpat | Leaf-wrapper & plate |
| 16. | *Schumannianthus dichotomous* | Patidoi | Stem-as rope |
| 17. | *Crinum asiaticum* | Ban Naharu | Leaf & bulb-medicine |
| 18. | *Dioscorea alata* | Sapara Alo | Underground stem is edible |
| 19. | *Dioscorea esculenta* | Gos Alu | Underground stem is edible |
| 20. | *Dioscorea pentaphylla* | Paspotia Alu | Underground stem is edible |
| 21. | *Commelina benghalensis* | Kanahimalu | Young shoot-medicine |
| 22. | *Arenga pinnata* | MamoiTamul | Stem & leaves sheath-as cultural |
| 23. | *Calamus flagellum* | Raiding Bet | Cane manufacture furniture, Young stem tip as vegetable |
| 24. | *Calamus gracilies* | Suli Bet | Cane-as rope |
| 25. | *Calamus tenuis* | Jati Bet | Cane as furniture and house construction |
| 26. | *Caryota urens* | SewaTamul | Stem in house construction and fencing, young stem tip as vegetable |
| 27. | *Licuala peltata* | Jengu Pat | Leaf as thatching material, fruit is edible |
| 28. | *Livistona jenkinsiana* | TakowTamul | Leaf as thatching material, fruit is edible |
| 29. | *Acorus calamus* | Bos | Corm-medicine |
| 30. | *Alocasia fornicata* | BejKasu | Corm-as vegetable |
| 31. | *Alocasia macrorrhizos* | Man Kasu | Corm-as vegetable, Petiole-as vegetable and medicine |
| 32. | *Alocasia odora* | Dahi Kasu | Petiole-as vegetable |
| 33. | *Amorphophallus bulbifer* | Ul Kasu | Corm-as vegetable |
| 34. | *Colocasia esculenta* | Kola Kasu | Petiole and sub aerial stem as vegetable |
| 35. | *Homalomena aromatic* | Gandha Kasu | Leaf & petiole-as medicine |
| 36. | *Laisia spinosa* | Shengmara | Young shoot as vegetable and medicine |

**Table 3:** Diversity and Utilization of Non-Timber Forest Products (Pteridophytes) of Nagaon district of Assam

| Sl. No. | Scientific Name | Common name | Parts used |
|---|---|---|---|
| 1. | *Diplazium esculantum* | Dhekia Shak | Young leaf as vegetable |
| 2. | *Stenochlaena palustris* | Dhekia Lata | Young leaf edible, mature stem as rope |
| 3. | *Drynaria quercifolia* | Hukan Dhekia | Mature leaf as ornamental |
| 4. | *Dicranopteris linearis* | Kalam Dhekia | Leaf petiole as cultural |
| 5. | *Lygodium flexuosum* | Kapow Dhekia | Young leaf as cultural |
| 6. | *Pteridium aquilinum* | Dhekia Shak | Young leaf as vegetable |
| 7. | *Christella parasitica* | Bihlongoni | Leaf as medicine and cultural use |

**Table 4:** Diversity and Utilization of Non-Timber Forest Products (Fungi) of Nagaon district of Assam

| Sl. No. | Scientific Name | Common name | Parts used |
|---|---|---|---|
| 1. | *Morchella esculanta* | Kathphula | Fruiting body as vegetable |
| 2. | *Agaricus bisporus* | Beng-Sata | Fruiting body as vegetable |
| 3. | *Auricularia auricul* | Kathphula | Fruiting body as vegetable |
| 4. | *Ganoderma* sp. | Kathphula | Fruiting body as vegetable |
| 5. | *Lycoperdon* sp. | Kathphula | Fruiting body as vegetable |
| 6. | *Pluteus cervinus* | Kathphula | Fruiting body as vegetable |
| 7. | *Schizophyllum commune* | Kathphula | Fruiting body as vegetable |
| 8. | *Termitomyces* sp. | Kathphula | Fruiting body as vegetable |

## Management and economic significance of non-timber forest products

Over 50% of wooded area sales and 70% of wooded area export profits come from NTFPs [67]. In India, the principal source of each self-employment and oblique employment in forestry is the gathering, processing, and sale of a huge range of NTFPs. Those encompass bamboo, cane, grasses, oilseeds, fibers, gums, and resins, dyes, medicinal flora, spices, honey and wax, nuts, sandalwood, leaves, and seeds for propagation. Despite the fact that the designation 'minor' may additionally supply the effect that this subsector is of low cost, in 1986 NTFPs accounted for almost 40% of forest department revenues, 75 % of internet export profits from woodland sector revenues, and 75% of net export earnings from wooded area produce. Small-scale wooded area-primarily based corporations, a lot of them reliant on NTFPs, provide as much as 50% of profits for 20-30% of the agricultural labor force in India [68, 69, 16]. Of the total salary employment in the forestry region, NTFPs possibly account for more than 70 % [15]. Greater important is the possibility for self-employment which those corporations provide to the woodland dwellers, recently anticipated at 3.3 million individuals. A current look at in West Bengal shows that many village groups derive as a good deal as 17% in their annual family incomes from NTFP collection and advertising sports [70]. A survey at Bastar, Chhattisgarh, found that while the maximum sustainable yield from 1 hectare of woodland became approximately $10m^3$ every two decades, yielding a net price of Rs. 20,000, non-wood merchandise harvested each year produced an internet income of Rs. 200,000 over the same period [61]. India's state governments earn kind of Rs. 2000 million in step with annum from the NTFP exchange, in the shape of royalty, fees, income profit, licenses and so on.

India's massive and numerous wealth in NTFPs (an envisioned 3,000 plant species yield one or other NTFP), only approximately one hundred fifty non-medicinal plant life are commercially exploited. Inside the absence of particular motion plans at country and countrywide ranges, the modalities of extraction and advertising of many precious products were typically nearby or 'conventional'. Tracking of actual and potential production, use and advertising of NTFPs is missing [15]. Except a 'minor wooded area produce plantation scheme' which has been operational on account that 1985 in numerous States, and which has now not yielded tons minor woodland produce (due to degradation, negative choice of species, lack of usufruct sharing association with creditors), systems of collection, processing, and marketing of NTFPs maintain to perform in a conventional manner in maximum elements.

In phrases of series and advertising arrangements for NTFPs in India, the dominant machine has visible the woodland department (or nation forest organization) buy the accumulated produce from the extractors, and then promote it back at the open marketplace through auction to buyers or industries after basic processing. Products wherein the state wooded area branch has no real interest (generally due to the fact the outputs are small) have usually been leased out to wooded area contractors for exploitation. In maximum cases, the royalties paid by means of contractors are determined by means of crude techniques of predicted manufacturing, without any clinical have a look at or motel to an in-depth inventory of NTFPs on a nearby foundation. Arrangements additionally alternate from year after year for administrative or political concerns. The woodland research Institute in Dehradun has compiled records on NTFPs in India, but this record has not often been utilized by nation forestry organizations, or public or private zone firms, for growing or making value brought merchandise. There are few current incentives for industries to apply NTFPs as uncooked substances.

similarly, it's been proven that the unregulated collection of NTFPs impacts adversely on the regeneration of some susceptible species in India, that woodland-structured families are often exploited by intermediaries [71] and that some NTFPs have been subjected to a current but persistent fall in production.

The brighter aspect of the Indian forest set-up is that most forest legal guidelines and even wooded area policing activities, have no longer encroached at the tenurial rights of NTFP extractors. Apparently, the environmental foyer in India, which has been quite vocal in its opposition to the employment of personal contractors for timber exploitation, has said as an alternative less about the involvement of middlemen inside the advertising of non-wood forest merchandise. It stays the case, however, that the control of NTFP-based sports in India is limited by using problems referring to seasonality, garage, transportation, and occasional volumes of confident manufacturing. on this admire, NTFP structures in India are not in contrast to NTFP structures in some other place [68].

## Occupation and education

The principle profession represents the foremost economic pastime engaged by means of the family head for coins profits and subsistence. Due to the fewer range of livelihood options in rural areas that can complement family earnings and meals deficit, they are therefore predicted to rely greater on forest sources consisting of NTFPs. Families who are engaged in different sectors of the financial system which includes trading and formal employment are much less possibly to be depending on NTFPs compared to their opposite numbers in the farming company [72, 73].

The level of training attained by using the household head is expected to influence the character of his/her monetary activity and therefore the extent of his/her income. This is because education might make it less complicated for households to recognize bad externalities and passive consumer values of natural sources [74, 75]. It's miles assumed that the high degree of education of respondents would cause extraction of fewer forest merchandise considering that schooling opens up opportunity employment possibilities and diverts human beings from subsistence livelihoods activities which include the gathering of NTFPs from the woodland reserve [76, 75].

## Conclusion

NTFPs have an established conventional financial function in most of the islands of the region, particularly for rural groups. They provide a potentially treasured contribution to sustainable livelihoods but the NTFP region has remained marginalized to mainstream monetary activity because of a variety of demanding situations and constraints. NTFP monetary hobby desires to be harnessed and controlled effectively which will seize its capacity contribution to national sustainable improvement, especially for rural livelihoods. Amidst challenges which can be emerging, there are possibilities that the sector provides that ought to be identified and capitalized on.

This studies brought into recognition

i) The critical function that NTFPs do and might play in rural livelihood techniques.

ii) The aid control, advertising and marketing, finance, policy and institutional challenges that need to be conquered for NTFPs to meet their full capability within such livelihood strategies.

Various nearby management agencies, frequently forestry departments, are mandated to manage NTFPs but are challenged through a loss of good enough resources and situations wherein exploitation of the sources occurs on houses past the confines of woodland reserves. In some times, struggle control can be required as shortage of assets promotes opposition and desperation on the part of stakeholders. It is far clear that during order for the NTFP region to be advanced, it has to be analyzed past the slim confines of biodiversity conservation and framed within the broader context of poverty comfort and sustainable livelihoods. Inside this context, the desires of the arena to be addressed must consist of coverage and institutional arrangements, resource control and access, advertising, finance and schooling due to the fact sustainable livelihoods can most effective be completed via governance arrangements that allow powerful control of natural sources while empowering those dependent on such resources. This calls for a policy environment that lets in for participatory based totally processes offering NTFP stakeholders with information, get right of entry to too and a position in the management of the NTFP useful resource base and their personal improvement.

It is miles advocated that stakeholders ought to prioritize technical and financial help programs that might promote off-farm income-generating sports which includes price addition for agricultural produce, handcraft and so forth. Inside the lengthy-run, diversification into formal quarter employment, coupled with schooling and talent improvement, is suggested. This will assist reduce household overreliance on NTFPs for livelihoods and profits. For effective conservation of NTFPs, strategies ought to take into consideration corporations that were determined to have extra stake, which includes the guys and kids, in making plans and enforcing sustainable utilization and control of wooded area resources. Further, interventions aimed toward retaining the forest have to keep in mind both in-situ and ex-situ conservation of the most applied flowers and bushes used for drugs in order to relieve strain at the wild stock. The provision of biogas and kerosene as alternative fuelwood and charcoal is suggested with a purpose to reduce family overreliance on the wooded area timber plant. It is already a recognized fact that for any herbal aid to be controlled sustainably, a sound understanding of the ecology, spatial distribution and abundance of the resource is required. Such statistics might be obtained from a number of assets along with indigenous or local people's information as well as formal scientific inquiry via woodland inventories.

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