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Growth Performance and Conifers Diversity in Achanakmar-Amarkantak Biosphere Reserve, India

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ABSTRACT: Conifers were introduced in the moist deciduous forests of Central India in the 1970s, about 50 years ago. During the IV five-year plan, tropical pine was introduced in central India under the initiative of the Co-ordinated Tropical Pine Project, launched by FRI, Dehradun. The extent of the pine plantation has been decreased in central India due to the discontinuation of its plantations since 1984. The present investigation is focused to assess the composition, current growth status, health and vitality of understory vegetation, economic importance and livelihood dependency of local people of various conifers that were planted in the Amarkantak and East Karanjiya forest ranges that comes under the buffer and transition zone of Achanakmar-Amarkantak Biosphere Reserve, Madhya Pradesh. The scientific names, native range, and IUCN status are duly given in the paper. At that time, a total of 24 conifer tree species from seven genera and four families had been planted; all of these species have been identified and described in this study. Pinaceae is the most common family in the area, followed by Cupressaceae and Araucariaceae. North American nativity has the most species (13), followed by Indian and Australian nativity (3 each), and one each from China, Europe, Tropical Africa, the Mediterranean, and South American nativity. The study area therefore requires immense attention to be utilized as prime site for pine based tourism, local community may find the resin tapping as an alternate livelihood and for that the community needs to be trained and JFMCs be empowered.

Keywords: Biosphere Reserve, Conifers, Gymnosperms, IUCN, Tropical Pines.

INTRODUCTION

Gymnosperms are widely distributed and commonly encountered plants, particularly in the northern hemisphere. Gymnosperms are naked seeded plants, differing from the other group of seed plants, angiosperms (flowering plants), by not having an ovule enclosed in a carpel (Byng, 2015). The word Gymnosperm, "Gymnos" means naked and "Sperma" means seeds, was first used by Theophrastus (300 BC), a pupil of Aristotle, in his famous book "Enquiry into Plants". This term was coined by Theophrastus to describe all plants with unprotected (uncovered) seeds (Pandey *et al.,* 2016). Fertilized ovules develop into seeds on the surface of an integument (interpreted as a scale, bract, or leaf) that are aggregated into cones or cone-like structures, with the exception of Cycas (Cycadaceae) and Ginkgo (Ginkgoaceae). The reproductive structures are usually unisexual and the cones or cone-like structures are usually slow to reproduce, taking up to a year for pollinated ovules to be fertilized and up to another three years to mature (Byng, 2015).Gymnosperms were the most dominant plants in the world during the early Mesozoic era (about 240 million years ago), but only 1057 species remain today. However, some members of gymnosperms (the conifers) are still the dominant vegetation forming groups of plants in many areas of the world, particularly in the temperate boreal forests of the Northern Hemisphere and alpine forests at high elevations, because of their adaptation to cold and dry conditions (Byng, 2015). Many conifer species are also of huge economic importance as timber sources, nuts, oleoresin,

and turpentine oil, with worldwide demand (Biswas and Johri 1997; Sharma *et al.,* 2014; Sharma *et al.,* 2018).

Tropical pines have soft wood with good fiber length and luster. They can survive in different agro-climatic zones up to a certain altitude ranging from 800-1200 m and in climatic, edaphic, and topographic conditions (Ponnuswamy, 1982; Mishra and Raghavan, 2008). In India, pine was introduced as a substitute to meet the paper and pulp industry due to its adaptability and high growth rate. A co-ordinate scheme "Investigation on Fast-Growing Tropical Pines and Conifers was initiated by the Forest Research Institute (FRI) during the IV-Five Year plan (1969-74). The objective of the initiative was to find suitable species of fast-growing tropical pine for different regions of the country. Under this scheme, systematic trials and intensive studies were undertaken in nine States (provinces) of the country including Madhya Pradesh (Chaturvedi, 1982). The first experimental plantation of *Pinus caribaea* was raised in July 1968 at Jagatpur (Amarkantak) over an area of 0.5 ha. Polythene potted plants were planted in 30 cm^3 pits dug after clear-felling Sal (*Shorea robusta*) forest areas (Chaturvedi, 1982).Conifers are also planted as a provenance trail across many hilly tropical environments such as Tamil Nadu's Nilgiri and Gudalur districts, Odisha's Koraput and Phulbani districts, and West Bengal's Kalimpong and Buxa districts etc. as reported by Singh (1982) (Fig. 1), as part of the IV-Five Year plan to compare their survival, growth, and productivity to temperate and sub-tropical environments. In the erstwhile M.P., it was planted in 1982, in several places, including Jashpur Nagar, Pachmarhi, Tamia, and Supkhar areas (Chaturvedi, 1982), but large-scale plantations are being reported only from present-day AABR. Hence, the present study has been largely carried out in this region only. The study is aimed at assessing the conifer's diversity in the region along with their growth performance and adaptability to tropical environmental conditions.

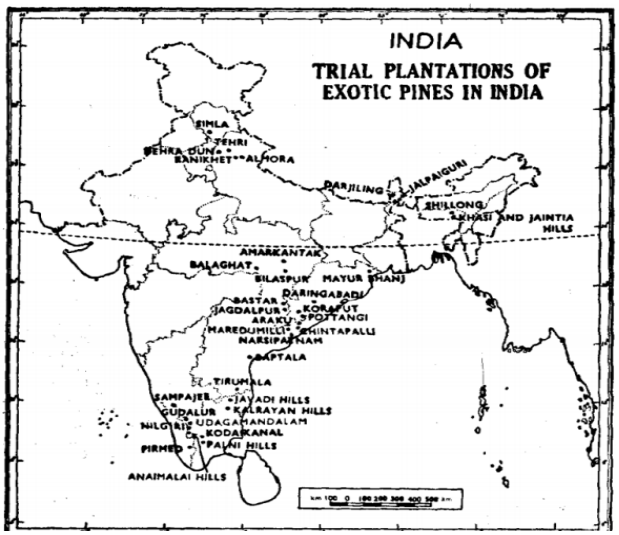

Fig. 1. Plantation location map of various conifers (Source: Singh *et al.,* 1982).

MATERIALS AND METHODS

A. Study site

On March 30, 2005, the Achanakmar-Amarkantak Biosphere Reserve (AABR), one of the rich biodiversity areas of Central India, was declared as the 14th National Biosphere Reserve (BR) of the country. It stretches in a triangular shape from the Maikal hill ranges to the Vindhyan and Satpura hill ranges (junction) of Chhattisgarh (CG) and Madhya Pradesh (M.P.).The BR spanned latitude 22°15' 20°58' N and longitude 81°25' 82°5' E, covering a total geographic area of 383,551 ha (Anonymous, 2007). Further, it is part of the Malayan territory, the Tropical Dry and Moist Deciduous Forest (biome) and the Deccan Peninsular bio-geographical zone of the country. The core zone of this Protected Area (PA) has hills and valleys covered with dense forest with a total geographic area of 55,155 ha and is part of the Bilaspur district (CG) administration (Anonymous, 2007). The buffer and transition zones of the BR with 205,898 ha fall in Bilaspur district (CG), and 122,494 ha in Dindori and Anuppur districts of M.P. (Joshi and Tiple 2010)

In the year 2021 (February–August), the experiment was carried out in several places of the Amarkantak and East Karanjiya Forest ranges. The biodiversity and morphological characteristics of conifers are being documented in various forest stands. The Amarkantak range is in the Anuppur division, whereas the East Karanjiya Range comes under the Dindori Forest Division of Madhya Pradesh, where the State Forest Research Institute (SFRI), Jabalpur, carried out large-scale conifer plantation in the early 1970s. The plantation area extended between Latitude 22°41' and 22°48' N; Longitude 81°42' and 81°43' E (Fig. 2) with an average altitude of 1058 m. The area is endowed with tropical moist (North part) and dry (South part)

deciduous forests, which are very rich in flora and fauna with endemism and genetic variation. The annual rainfall of the district is 1214.33 mm, and July is the wettest month of the year. The minimum temperature of the region varies from 7°C in December to a maximum of 41.7°C in the month of May (Anonymous, 2008). The geology of the area is varied from schists and gneisses with granite intrusion rocks, sandstones, shales, limestone, basalt (lava flow), and bauxite, the rock formations of which the study area is comprised. The soils of the AABR vary in composition and texture, which range from sandy to loamy-clay, generally light brown to brownish-yellow in colour. Due to poor soil drainage, olive green clay zones up to 5 mm depth exist in some places due to poor soil drainage; red soils, relatively fertile soils in the area, are also found in some pockets of the study area. Deposits of alluvial soil are also found on the banks of numerous streams of the Narmada River. Further, black cotton soil also exists in many pockets of AABR (Anonymous, 2010).

B. Floral composition

The Achanakmar-Amarkantak Biosphere Reserve was found to have a diverse floristic assemblage of aquatic, marshy, and terrestrial plants growing in a variety of habitats, including herbs, shrubs, climbers, lianas rhizomes, and trees. More than 324 species of thallophytes (algae fungi and lichen), 44 species of bryophytes, 40 kinds of ferns, more than 1,111 species of angiosperms, and 16 species of gymnosperms make up the Biosphere reserve's Phyto-diversity (Roychoudhury and Gupta 2016). However, in this survey and observation, we have recoded 24 species of conifers that were planted in different forest stands of the Amarkantak and East Karanjiya ranges in the 1970s, and some other pine species were also introduced in this region after that. Both the places are considered notable for its rich biological resources and broad spectra of plant existence.

C. Data collection methods in Pinus stands

(i) Growth data collection. In the present study, field data was collected from the field to determine the growth and yield performance. A quadrate of 10m × 10m was laid, and the total area covered by the total quadrate was about 10% of the total plantation area (i.e. 38 ha). Tree parameters like height and diameter of trees (which are inside the quadrates) were recorded using a data collection format. Some of the unpublished data available in the office of the Range Officer (Research), Amarkantak range, which is related to growth parameters of trees (i.e., for the years 1969-1995), has also been included in the present study. Therefore, in the present investigation, the old data and current data were compiled to reach a good conclusion in relation to the growth (diameter, height) and productivity of the pines.

(ii) Regeneration of pines and other vegetation status. The seedlings and saplings were considered as regeneration parameters (Anonymous, 2017). To determine the regeneration status, 20 quadrates (2m x 2m)were randomly laid to cover the maximum heterogeneity of all the plantation stands covering the Chakratirath, Bhundakona, and Pondi areas of Amarkantak, and Raktidadar, Kabirchabutra, Jagatpur area of East Karanjiya forest range that fall under the buffer and transition zones of AABR, respectively.

(iii) Measurement of tree height and diameter. The height of each tree was measured with the help of Abney's level. Three readings were taken, from different locations, from which the base and top of the tree are visible. The average of these readings provided the height of the tree, which was recorded in meters. Whereas the Girth at breast height (GBH) was measured at breast height (1.37m from the ground level) with the help of the measuring tape and converted in to diameter by using the formula ($G=\pi D$).

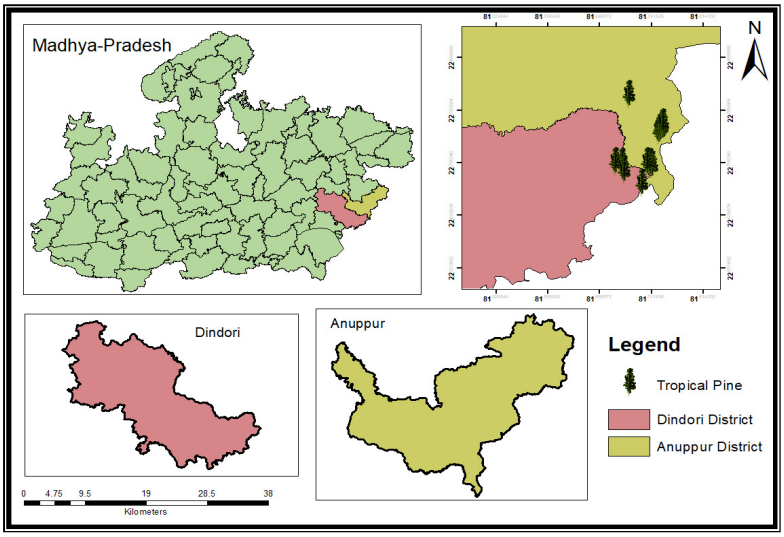

Fig. 2. Location map of the Study area (Arc-GIS).

Image 1: Tropical pine stands at (Raktidadar, East Karanjiya Range) of AABR.

RESULTS AND DISCUSSION

Growth performance study of conifers has been carried out at Amarkantak and East Karanjiya forest range with literature survey and publications related to floral resources of Achanakmar-Amarkantak Biosphere Reserve, plantation data of the State Forest Research Institute (S.F.R.I., Jabalpur) and the working plan Report of Anuppur Forest Division research papers in journals and books available in the Library of the Indian Institute of Forest Management, Bhopal. All the conifers were identified with the help of literature and books authored by Farjon (2017); Vidakovic (1982). The bole diameter and height of these plantations were excellent as compare to temperate Himalayan regions similar to temperate and sub-temperate forests, indicating that these species are suitable for planting in the Amarkantak range in the altitudinal range of 1050-1150 maslas opposed to the East Karanjiya range. This may be due to the altitudinal difference and the microclimate is more favorable to conifer growth in Amarkantak. The resin tapping experiment should be started to know the resin yield. If the resin yield is commercially viable, then only plantations on a large scale will be carried out for the livelihood of the people residing inside and outside of the forest.

A. Extent of Conifers in Amarkantak

As per the Working Plan report (2008-2018), Anuppur, the conifer plantation, was carried from 1969-1982. The total area covered by pine plantation in the Amarkantak range was about 38.82 ha, which was planted in different forest stands of the Amarkantak range (Tables 1 and 2 and Fig. 2). The crown canopy density comes under the moderately dense category as per the observation recorded during 2021. Overall, crown canopy density plays a crucial role in regulating the forests, affecting microclimate, soil conditions and overall forest ecosystem health.

Table 1: Plantation history of Conifers planted in different compartment of Amarkantak range (Source: Working Plan, Anuppur: 2008-2018)

Sr. No.	Plantation Year	Compartment number	Location	Area (ha)
1.	1969	R-237	Bhundakona	0.500
2.	1972	R-237	Bhundakona	3.500
3.	1973	R-237	Bhundakona	8.600
4.	1974	R-237	Bhundakona	4.500
5.	1975	R-237	Bhundakona	5.500
6.	1976	R-237	Bhundakona	2.500
7.	1977	R-237	Bhundakona	4.200
8.	1980	R-237	Bhundakona	2.000
9.	1981	R-237	Bhundakona	1.500
10.	1982	R-237	Bhundakona	0.800
11.	1973	P-216	Pondi	0.520
12.	1975	P-215	Pondi	1.500
13.	1976	P-210	Harai	1.700
14.	1969	P-231	Chakratirath	1.500
Total	38.820			

The list of these 24 conifer species belonging to 7 genera and 4 families, with their native range, habit, and IUCN status, is presented briefly in Table 4 Tables are placed sequentially. In terms of the number of species, the family Pinaceae, with 17 species, was the most dominant, followed by Araucariaceae (3 species), Cupressaceae (3 species) and Taxodiaceae (1 species). The species of North American nativity has the most species (13), followed by Indian and Australian nativity (3 each), and one each from China, Europe, Tropical Africa, the Mediterranean, and South American nativity, respectively. Out of the total documented species, most of them were of Least concern (*i.e.,* 20 species), followed by Endangered (2) Near threatened (1), Vulnerable (1) and category of International Union for Conservation of Nature (Anonymous, 2020) described in Table 4. Globally, the population of many conifers has been decreasing drastically due to various causes. For example, like the population of *Araucaria araucana*, which decreases due to illegal logging, catastrophic fires, etc., this species is not only placed in the endangered category of IUCN but also in Appendix-I of CITES and as a Natural Monument in Chile, which gives it legal protection against logging (Farjon, 2017). In the present study, there are only two mature individuals recorded, *i.e*., *Araucaria araucana* is still present in the old nursery area. Looking at the current status of these conifers, only option left is to propagate and multiply to plant in these forest stands, and there is a need to conserve these endangered species. In Amarkantak range, *Pinus greggii* was also planted. This species was considered important due to its genetic plasticity and adaptation to eroded and poor soils (Dvorak and Donahue, 1993). Further, it is also listed in the vulnerable category of the IUCN Red List category of Threatened Species. *Pinus greggii* is widely used worldwide in reforestation programmes for the recovery of watershed areas. This tree is drought, pest and disease tolerant, as reported by Musálem and Martínez (2003). Therefore, it can be recommended as because of high growth rates in plantation trials (López *et al.,* 1999; Salazar *et al.,* 1999). These characteristics favor the use of *Pinus greggii* in commercial plantations; hence, it can be planted in greater amounts in marginal lands and open forest patches of the Amarkantak range.

B. Growth pattern

The present floristic account of the Achanakmar-Amarkantak Biosphere reserve is highly significant as it provides the current and latest status as well as morphological description of coniferous plant wealth occurring within the Biosphere reserve for future usefulness to foresters and botanists in the planning of conservation and management strategies. As tropical pines can grow in a wide range of soil and climate, suitable sites have been chosen across different places of the Amarkantak forest range with an elevation of about 1000 m and an annual rainfall of 1200-1800 mm. The below mentioned (Table 2) showed the distribution of the species in different areas and showed the growth parameters of pines. The physical features of the species found in the area are more or less the same in comparison to the species found in the western and eastern Himalayan ranges of India as well as other temperate areas of the world. However, aspects like cone size and seed formation differ greatly, and hence the regeneration is found to be nil in the plantation stands. However, *Pinus roxburghii*, *Pinus kesiya* and *Pinus oocarpa* produce moderately fertile seeds from February, May every year. Therefore, it is also suggested that during management practices, care should be taken to conserve the rare species from getting destroyed and cleared off.

The main observations of the present investigation are mentioned below (Table 2 & Fig. 3).

- *Pinus caribaea* and *Pinus oocarpa* showed good height growth with values between 30-35 m and 28-32 m.
- Due to its good site quality and higher land elevation, *Pinus roxburghii* attains the best diameter growth out of all the species (especially in Bhundakona area of Amarkantak Range).
- Viable seeds are produced only in *Pinus kesiya*, *Pinus roxburghii* and *Pinus oocarpa*. However, due to rapid forest fire in the summer season, seedling establishment of these species is a major problem. This could be one of the major reasons for pine stand degradation in this area.
- Six different pine species were all introduced to the Pondi area in 1973. Only one of these *Pinus roxburghii* grow successfully, but plantations of the other five species *i.e* (*Pinus patula, Pinus kesiya, Pinus caribaea, and Pinus taeda*) utterly failed. Pondi is located at 906 m amsl, which is lower than other locations where other tropical pines are well-established, and the heavy anthropogenic pressure on this area may be the cause of this.
- In the BALCO Bauxite mine area, four species of pine were planted, but currently only two species, *Pinus roxburghii* and *Pinus kesiya,* have survived with poor growth. However, the height and diameter growth are the lowest as compared to other areas of pine plantation existing.
- In Bhundakona, all three varieties of *Pinus caribaea* were planted, including *Pinus caribaea var. bahamensis* (Bahamas origin), var. *hondurensis* (Mexico origin), and *var. nicargua* (nicargua) were tested to observe their behavior in small scale field trials. Out of these, var. *bahamensis* showed the most promising results in this area.
- Growth performance of *Pinus pinaster* is also very poor because this species belongs to Mediterranean climate region, however, in Amarkantak the factors of

locality like microclimate, site quality is not suitable to establish this species.

• In *Pinus patula* trees planted at Chakratirath and Kabirchabutra it was found that most of the tree stems having a wavy outgrowth.

Growth performance comparison with other places of tropical pine plantations

Das (1982) reported that *Pinus caribaea* var. hondurensis attain best height growth in the Kalingia Research Garden (820 m amsl) of Odisha after 10 years of plantation trial as compared to *Pinus caribaea* var. bahamensis. Whereas the stem form of *Pinus caribaea* var. bahamensis at Daringbadi (945 m amsl) was found to be excellent. Similar observation has also been recorded in the present experiment after 50 year of plantation at Amarkantak (1050 m amsl) that both the variety of *Pinus caribaea* attain maximum height. The results of the current study corroborated those from Chaturvedi (1982). In several high altitude tropical environment of India, Pandey (1982) reported on the growth performance of various tropical pines. According to his investigation, *Pinus patula, Pinus elliotti, and Pinus kesiya* were found to thrive well at Kodaikanal and Ooty (Tamil Nadu). In Jalpaigudi (West Bengal), Chaibasa (Jharkhand) and in Jagdalpur(Chhattisgarh) only *Pinus cariabea* can be flourish well if good soil should be provided. *Pinus oocarpa* has shown good growth in upland areas of Southern part of India *i.e* Koraput (Odisha), Araku (Andhra Pradesh) and Gudalur (Tamil Nadu). Mishra and Raghvan,2008 conducted feasibility study of tropical pine plantations in Koraput and revealed that *Pinus caribaea* var. hondurensis shown good survival rate of more than 70 % . The Changmai, Thailand (FRI-750) provenance of *Pinus kesiya* showed good growth performance as well as survival. However, other provenances such as Khasi & Jaintia Hills(Assam), Philippines showed poor survival rate (less than 40%). Only *Pinus kesiya* trees produces viable seeds in sufficient amount. In the present study area *Pinus kesiya* along with two other species i.e *Pinus roxburghii* and *Pinus oocarpa* also produces viable seeds in each year.

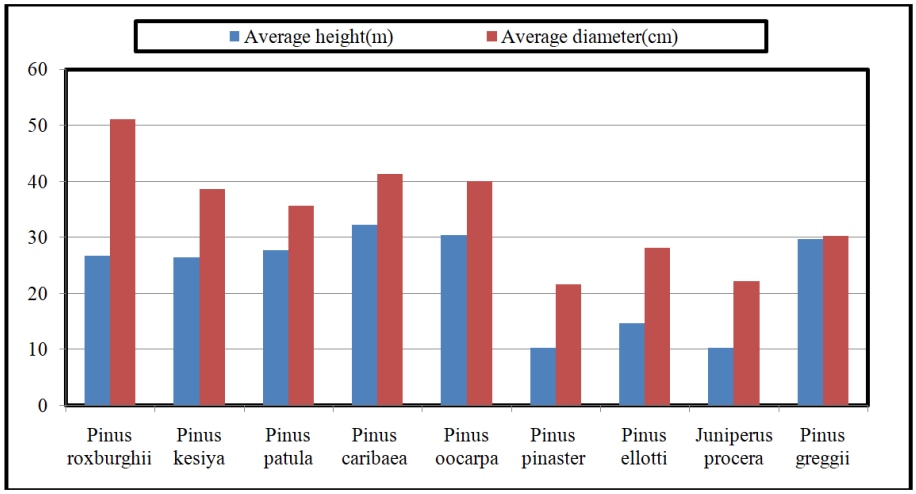

Fig. 3. Current growth data of diverse pine species planted inside of forest areas.

The dominant understory vegetation consists of shrubs like like *Colebrookea oppositifoila*, *Pogostemon benghalensis* (Table 3). Vegetation of *Colebrookea oppositifoila* growth was much flourishing in R-237 compartment (Bhundakona) due to higher elevation as compared to other areas and also mixed plantation of *Pinus greggii*, *Pinus kesiya*, *Pinus caribaea* and these species tends to be the unpremeditated factor for promoting the growth of ground vegetation. The leaf litter of pines contains phenolic compounds that are inhibitory to conifer seed germination, primary root growth, and ecto-mycorrhizal growth (Mallik, 1987, Pellissier, 1993, Pellissier, 1994). Due to this reason, the natural regeneration is completely check as because of the litter decomposition rate is slow this may become physical barrier of seedling establishment. However, it is very interesting to note that in study area natural regeneration of *Pinus kesiya* and *Pinus roxburghii* was found excellent compared with other conifers existing in Bhundakona (Compartment number R-237),and these two species producing viable seeds. It was found that in Compartment number P-216 (Pondi) fire incidence phenomenon was observed very common due to anthropogenic and other social factors and this area is very poor in understory vegetation also.

Table 2: Current growth data of pines.(This comes under Buffer and Transition zone of AABR)2021.

Name of species	Provenance	Year of Trial	Compartment number and place	Age at Measurement	Average height(m)	Average diameter(cm)	GPS location	Altitude (m)
Pinus roxburghii	Supkhar	1969	P-231, Chakratirath, Amarkantak Range	52	25.7	42.97	22^0 41.854` $081^0$ 43. 806`	1029
Pinus roxburghii	Supkhar	1973	P-216, Pondi, Amarkantak Range	48	12.2	26.74	22^0 48. 26` $081^0$ 42. 36`	936
Pinus roxburghii	Supkhar	1974	R-237, Bhundakona, Amarkantak Range	47	26.7	*51.12	22^0 45. 467` $081^0$ 44. 834`	1108
Pinus roxburghii	Supkhar	1983	R-836 Raktidadar, BALCO, East Karanjiya Range	38	10.5	25.46	22^0 41. 870` $081^0$ 41. 609`	1070
Pinus patula	Kenya	1969	P-231, Chakratirath, Amarkantak Range	52	27 .9	35.65	22^0 41.742` $081^0$ 43.936`	988
Pinus patula	Kenya	1972	R-237, Bhundakona, Amarkantak Range	49	27.2	34.89	22^0 45.242` 081 $^0$44.748`	1119
Juniperus procera	Ethiopia	1969	P-231, Chakratirath, Amarkantak Range	52	10 .4	22.28	22^0 41.742` $081^0$ 43.936`	977
Pinus kesiya	Shillong range	1973	R-237, Bhundakona, Amarkantak Range	48	26.4	38.57	22 ^{0}45. 145` 081 $^0$44. 672`	1104
Pinus kesiya	Shillong range	1983	R- 839, BALCO, East Karanjiya Range	38	10.2	20.69	22^0 42. 029` $081^0$ 41. 279`	1073
Pinus kesiya	Shillong range	1969	P-232, Kabirchabutra, East Karanjiya Range	52	28	31.83	22^0 40.365` $081^0$ 43. 397`	1029
Pinus greggii	Hidalgo, Mexico	1974	R-237, Bhundakona, Amarkantak Range	47	18.5	28.65	22^0 41. 893` $081^0$ 43. 699`	1022
Pinus greggii	Hi dalgo, Mexico	1971	R- 835, Khurkhuri dadar, Karanjiya Range	52	30.7	30.24	22^0 41. 044` $081^0$ 42. 129`	932 m
Pinus ellotti	South missisipi and South georgia	1974	R-237, Bhundakona, Amarkantak Range	47	14.7	28.20	22^0 45. 313` $081^0$ 44. 732`	1107
Pinus caribaea var.bahamensis, hondurensis and nicargua	Cuba and Oxonbahamas	1973	R-237, Bhundakona, Amarkantak Range	48	**32.2	41.38	22` 45' 403 081` 44' 822	1092
Pinus caribaea var.bahamensis and hondurensis	Cuba and Oxon bahamas	1969	P-231, Chakratirath, Amarkantak Range	52	29	39.79	22^0 41. 832` $081^0$ 43. 827`	1029
Pinus pinaster	Cuba	1970	P-231, Chakratirath, Amarkantak Range	51	10.4	21.64	22^0 41. 899` $081^0$ 43. 694`	1027
Pinus oocarpa	Honduras and Guatemala	1973	R-237, Bhundakona, Amarkantak Range	48	30.4	40.11	22^0 45. 579` $081^0$ 44. 854`	1010

***Maximum diameter, ** Maximum height**

Table 3: Checklist of Understory vegetation in pine stands.

Habitat	Local name	Botanical name	Compartment number and place	Family
Herbs				
1	Bhangra	*Hemigraphis latebrosa*	R-237, Bhundakona	Acanthaceae
2	Bhat kataiya	*Solanum viriginiamum*	R-237, Bhundakona	Solanaceae
3	Mithipati	*Scorparia dulcis*	R-237, Bhundakona	Plantaginaceae
4	Patchouli	*Pogostemon benghalensis*	R-237, Bhundakona	Lamiaceae
5	Ageratum	*Ageratum conyzoides*	R-237, Bhundakona & P-231,Chakratirath	Asteraceae
6	Bakchan	*Amorphophallus bulbifer*	R- 835,Khurkhuridadar	Araceae
7	Banmuli	*Euphorbia fusiformis*	P-231,Chakratirath	Euphorbiaceae
8	Chirota	*Cassia tora*	R-237, Bhundakona	Fabaceae
9	Gangarua	*Cyperus brevifolius*	R-237, Bhundakona	Cyperaceae
10	Sarpagandha	*Rauwolfia serpentina*	P-231, Chakratirath	Apocyanaceae
11	Satavar	*Asparagus racemosus*	P-231, Chakratirath	Asparagaceae
Shrubs				
1	Ameda	*Colebrookea oppositifolia*	R-237, Bhundakona	Lamiaceae
2	Kurchi	*Holarrhena pubescens*	R-237, Bhundakona	Apocynaceae
3	Duranta	*Duranta rapens*	P-231,Chakratirath	Verbenaceae
Climbers				
1	Dudhibel	*Vallaris solanceae*	R-237, Bhundakona	Apocynaceae
2	Amrola (red)	*Ampelocissus latifolioa*	R-237, Bhundakona	Vitaceae
Pteridophytes				
1	Jatashankar	*Dryopteris sparsa*	R-237, Bhundakona	Dryopteridaceae
2	Murgakes	*Ophioglossum reticulatum*	R-237, Bhundakona	Ophioglossaceae
Trees				
1	Patvan/bistendu	*Diospyrous montana*	R-237, Bhundakona	Ebneaceae
2	Amaltas	*Cassia fistula*	R-237, Bhundakona	Fabaceae
3	Barri	*Casearia elliptica*	P-231,Chakratirath	Flacourtiaceae

D. Economic importance

The economic importance of various conifers is relatively high in terms of its economic return because they produce oleoresin. The principal species of Pine which are tapped for oleoresin production including *Pinus elliottii* (in Brazil, Argentina, South Africa); *Pinus massoniana* and *Pinus kesiya* (in People's republic of China); *Pinus pinaster* (in Portugal); *Pinus merkusii* (in Indonesia); *Pinus oocarpa* (in Mexico and Honduras); *Pinus caribaea* (in Venezuela); *Pinus sylvestris* (in Russia); *Pinus halepensis* (in Greece); and *Pinus radiata* (in Kenya) and *Pinus roxburghii*, mainly found in India and Pakistan as per William 2002; FAO, 1995. The principal products obtained from oleoresin are rosin and turpentine oil. Through the distillation method, the aromatic turpentine oil and transparent rosins are separated. Turpentine oil is utilized in the manufacturing of paints, fireworks, insecticides, and disinfectants (Anonymous, 2003). The turpentine oil industry has become one of the major sources of raw materials for organic chemicals. Because, turpentine oil is a natural product that can easily be obtained from living pine trees without destructing and degrading the habitat with sustainable harvesting methods. The use of rosin is in adhesives, electric isolation, paper, soldering flux, varnish, printing ink, and match industries. In the printing ink industry, rosin gives adhesiveness, surface smoothness, hardness, ant blocking and other properties, synthetic rubber and chewing gum (Wiyono *et al.,* 2006). To improve the economic viability, assessment of the resin quality, skill development, and involvement of local community in pine management are equally important for the sustainable management of conifers in this area.

E. Livelihood dependency and sustenance

The area is a tourist attraction, and lakhs of tourists visit every area of the AABR. The local community is involved in collecting and selling pinecones in the local market at a price of 10–20 INR cone-1, which helps in improving their economic conditions. There is a need to develop skills in people to convert these cones into handicraft items. The pine needles (leaves) are of socio-economic importance to the fringe villages. They collect the leaf litter to meet their fuel requirements for cooking food and to cover the house roof as thatching material. However, in the Himalayan region, the tapping of the resin is an economically viable source of income-generating activity. Even though this study area has similar potential if large scale plantation were carried out, it is still not being tapped into pine plantation stands. One reason could be a lack of knowledge and skill to tap into the resin.

Table 4: A Checklist of conifers along with Native range and IUCN status planted in Achankmar – Amarkantak Biosphere Reserve (Source: Farjon, 2017, SFRI Data).

Sr. No.	Species name	Family	Common name	Location	Native Range	IUCN status
1.	*Araucaria bidwillii* Hook.	Araucariaceae	Bunya pine	Nursery area	Australia	Least Concern
2.	*Araucaria araucana* (Molina) K.	Araucariaceae	Monkey puzzle/Chilean pine	Nursery area	Argentina, South America	Endangered
3.	*Araucaria cunninghamii* Aiton ex A. Cunn	Araucariaceae	Hoop pine	Nursery area	Australia	Least Concern
4.	*Cedrus deodara*(Roxb.) G.Don	Pinaceae	Himalayan cedar	Nursery area	India	Least Concern
5.	*Pinus caribaea* Morelet *var.bahamensis,var.hondurensis,var.caribaea*	Pinaceae	Carribbean pine	Nursery area and Forest	North and Middle America	Least Concern
6.	*Pinus elliotti* Engelm.	Pinaceae	Slash pine	Nursery area and Forest	North America	Least Concern
7.	*Pinus greggii* Engelm.	Pinaceae	Greggs pine	Nursery area and Forest	North America	Vulnerable
8.	*Pinus kesiya* Royle ex Gord.	Pinaceae	Khasi pine	Nursery area and Forest	India	Least Concern
9.	*Pinus montezumae* Shaw.	Pinaceae	Montezuma pine	Nursery area	North America	Least Concern
10.	*Pinus oocarpa* Schiede.	Pinaceae	Egg cone pine	Nursery area and Forest	North America	Least Concern
11.	*Pinus patula* Schlecht. & Cham.	Pinaceae	Jelecote pine/Mexican weeping pine	Nursery area and Forest	Mexico, North America	Least Concern
12.	*Pinus ponderosa* Douglas ex C. Lawson.	Pinaceae	Western yellow pine	Nursery area	North America	Least Concern
13.	*Pinus psedostrobus* Lindl.	Pinaceae	False Weymouth pine	Nursery area	North America	Least Concern
14.	*Pinus roxburghii* Sarg.	Pinaceae	Chir pine/long leaved Indian pine	Nursery area and Forest	Indian Himalaya	Least Concern
15.	*Pinus serotine* Michx.	Pinaceae	Pond pine	Nursery area	Coastal Plain of North America	Least Concern
16.	*Pinus radiata* D.Don.	Pinaceae	Monterey pine	Nursery area	North America	Endangered
17.	*Pinus leiophylla* Schiede ex Schltdi & Cham.	Pinaceae	Smooth leaved pine	Nursery area	North America	Least Concern
18.	*Pinus brutia* Ten.	Pinaceae	Calabrian pine	Nursery area	Mediterranean region	Least Concern
19.	*Pinus pinaster* Aiton.	Pinaceae	Maritime pine	Nursery area	Europe	Least Concern
20.	*Pinus taeda* L.	Pinaceae	Loblolly pine	Nursery area	North America	Least Concern
21.	*Juniperus procera*Hayata.	Cupressaceae	African pencil cedar	Nursery area and Forest	Tropical Africa	Least Concern
22.	*Thuja orientalis* L.	Cupressaceae	Oriental Arbor –vitae	Nursery area	China	Near Threatened
23.	*Callitris intratropica* R.T. Baker & H.G Smith	Cupressaceae	Cypress pine	Nursery area	Australia	Least Concern
24.	*Taxodium mucronatum* Ten	Taxodiaceae	Mexican cypress	Nursery area	North America	Least Concern

Image 2: *Pinuso ocarpa* Stem Bark

Image 3: *Pinus montezumae* Stem Bark

Image 4: *Pinus caribaea* Stem Bark

Image 5: *Pinus gregii* Stem Bark

Image 6: *Pinus roxburghii* female cone

Image 7*: Pinus kesiya* female cone

Image 8 : *Pinus oocarpa* female cone

Image 9: *Pinus greggii* female cone

Image 10: Male cone of *Pinus roxburghii*

Image 11: *Pinus patula* canopy

Image 12: Collection of pine cones and dry leaves

Image 13: Local Tribal dependency on Pine species

Image 14: *Juniperus procera* leaves

Image 15: Regeneration of *Pinus roxburghii* on forest floor

Image 16: Regeneration survey

Image 17: Estimation of tree height with help of Abneys level

Image 18: *Colebrookea oppositifolia*

Image 19: Stem bark of *Cedrus deodara*

CONCLUSIONS

Nature cures man made injuries itself, if we allow it. In the Amarkantak around 38.820 ha of conifers were planted in 1969−1982, but nowadays the area extent of those plantations in the region has been reduced due to various biotic and abiotic disturbances. So, the need of the hour is to plant more fast-growing conifers in this area to re vegetate and convert it into a tourist attraction spot for ecotourism industries. The seeds of various conifers should be collected, artificially raised in forest nurseries, and planted in eroded and degraded forest areas where the sites are suitable and these conifers have grown well. Therefore, it is essential to work for proper management practices and conservation strategies for the maintenance of pine species diversity as this area is very suitable for conifer growth. To improve the economic viability, assessment of the resin quality, skill development, and involvement of the local community in pine management are equally important for the sustainable management of conifers in the study area.

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