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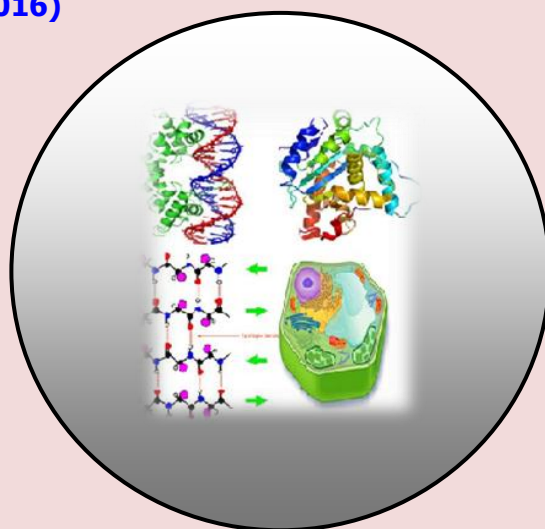
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# **Ethnobotanical, Pharmacological and Antimicrobial Importance of *Pinus roxburghii* Sargent: A Review**

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## **ABSTRACT**

*Pinus roxburghii* Sargent, a common gymnosperm found in the Himalayan region of the Indian subcontinent. It is extensively used among the local tribal communities inhabiting in the mountainous region. All parts of the plant have medicinal properties and its medicinal properties are mentioned in the Ayurveda, Unani and Siddha systems of medicines for the treatment of fever, cough and cold, gynaecological disorders, urinary problems and diseases of ear, skin, throat etc. In addition the plant is also used as timber for roofing purpose, thatching and house building material. This plant is also a rich source of bio active compounds such as catechin, quercetin, gallo catechin,  $\alpha$ -Pinene, 3-Carene, caryophyllene, various phenolic acids, lignans, stilbenes, sugars etc, most of which act as strong antioxidant and thus have medicinal importance. The review highlights the traditional use of *Pinus roxburghii* Sarg. amongst the people of Indian subcontinent and adjoining Himalayan region along with its pharmacological and antibacterial properties in relation to its explored bioactive compounds. The plant can be well utilized as a cheap source of harvesting compounds leading to production of dietary and health supplements for the population of Indian subcontinent.

**Keywords:** *Pinus Roxburghii* Sargent, Antioxidant, Antibacterial and Flavonoids.

## **INTRODUCTION**

The conifers form a unique distinctive group among the gymnosperms and are largely confined to the hills and mountains of the tropics, subtropics, temperate and alpine climatic zones. Among the conifers, pines or the genus *Pinus* forms the largest extant group and consists of more than 100 species worldwide (Gernandt et al., 2005). The genus is widely distributed in the northern hemisphere of the globe except *Pinus merkusii* which has natural habitat below the equator in the Sumatra Island (Das et al., 2017). Chir Pine or *Pinus roxburghii* is the most common among the six indigenous pine species that occur in India. In nature it occurs in forests ranging from 70° east to 93° east longitudes and between 26° North and 36° North longitudes between 450m and 2300m altitudes of Siwalik Himalayas and its river valleys from Pakistan in the west to Arunachal Pradesh in the east covering a distance of 3200km (Ghildiyal et al., 2009). The species mostly occurs in subtropical and warm temperate monsoon regions of Himalayas. In India, the chirpine forest covers a total area of 869000 hectares extending from Jammu and Kashmir, Haryana, Himachal Pradesh, Uttarakhand, parts of Sikkim, West Bengal and Arunachal Pradesh (Gupta et al., 2009). They are also distributed in regions where there is snowfall

in winter and summer temperature can be as high as 40° C thus making its distribution in wide range of climatic condition (Mukherjee Roy et al., 2004)

### MORPHOLOGY

**Habit:** Chir pines are large trees and attain a height of 30 to 50 meters with trunk reaching a diameter up to 2 meters and up to 3 meters on some exceptional cases. The bark is reddish brown and thick and deeply fissured at the basal region and becomes thinner and flaky on the upper zones of the trunk (Kheyrodin, 2016). Barks are greater than 3cm thick at maturity. (Brown et al., 2011).

**Branching and eaves:** The tree is branched and the branches are of two types namely the long shoots and the dwarf shoots. The long shoots arise in the form of a lateral bud from the axil of a scale leaf on the main stem and are characterized by the presence of an apical bud enclosed by bud scales. The dwarf shoots are borne on the long shoots and grow from the axil of a scale leaves and are characterized by the presence of two scaly leaves in opposite phyllotaxy followed by 5-13 spiral cataphylls arranged in 2/5 phyllotaxy. The dwarf shoots bear two types of leaves namely the needle like foliage leaves in bunches of three and scale leaves of protective nature. (Bhatnagar and Moitra, 1996). The leaves are green, long, needle like, and enclosed by a sheath at the base. The leaves arise in groups of three, flabellate, triangular in cross section, having a dimension of 20-30cmx1.5mm. They are finely toothed, light green in colour and persist for a year and half on an average (Shuaib et al., 2013).

**Roots:** The plants exhibit extensive tap root system whose laterals branch up to 4 meters from the main tree and spreading around 1 meter within the soil surface. The plants exhibits two types of roots namely the root of unlimited growth on which roots of limited growth or the short roots developed. The short roots are infected with mycorrhizal fungi (Bakshi et al., 1965).

**Reproductive structures:** *Pinus roxburghii* is monoecious. Male and female reproductive structures occur in the form of cones on separate branches of the same plant. The male cones replace the dwarf shoots and occur in clusters of around 140. The male cones comprise of a central axis on which microsporophylls remain arranged in a spiral fashion each of which contains a pair of abaxial sporangia.

The female cones replace the long shoots and arise in pairs. Each female cone has a central axis with spirally arranged microsporophylls (ovuliferous scales) numbering about 80 to 90 which arise at the axil of bract scales. At maturity the bract scale and ovuliferous scales fuse together to form the seed scale complex. It is a woody structure and bears a pair of ovules on the adaxial surface. The ovules are inverted and the micropyle faces the axis of the female cone. The exposed part of the ovuliferous scale is called apophysis and the tip is called umbo (Bhatnagar and Moitra, 1996). The seeds are 8-12mm long having wings of dimension 2.5cm. The seeds mature in the months of October-November (Kaushik et al., 2010).

### USES IN TRADITIONAL MEDICINES

The name of *Pinus roxburghii* is mentioned in the pages of Ramayana hinting its importance in prehistoric times (Balapure et al., 1987). The plant has a long history of traditional medicinal use and mentioned in the Ayurveda as Sarala, Pita – Vriksha (Kumar, 2014). It is used for the treatment of various ailments such as dyspepsia (agnimandya), distension of abdominal gases (Adhmana), leprosy (kustha), diseases of throat (kantharoga), worms (Krimiroga), skin (Tvakroga), ear (Karnasula), excessive sweating and foul body odour (Sveda-daurgandhya), blisters and boils (Pidaka), itchy lesions (Kandu) and many others and mentioned in the ayurvedic pharmacopoeia of India. Shrivestaka, the oleoresin of the plant is mentioned in the Kashyapasamhita. It forms an important ingredient of dhupakalpadhyaya or treatment through fumigation (Bhinde and Joshi, 2015). The plant is used for the management of fever, diarrhoea, cough, anaemia and disorders caused by mothers (matrajanyadosha) (Pravin et al., 2015). Sarala Nirryasa The exudate of *Pinus roxburghii*, known as Sarala Nirryasa is one of the components of Kasisadi ghrita and is used in ayurvedic system for the treatment of nadivrana or tubercular breast sinus (Pandey et al., 2017). It also forms a constituent of Saribadyarista, an ayurvedic formulation which is used for treatment of Psoriasis (Ferdous et al., 2016). The oil of the plant is as a hepatoprotective agent (Dey et al., 2013; Kshirsagar et al., 2011). The exudate is used to cure 'krimiroga' or the disease of worms and microorganisms (Soni et al., 2017). Oil, barks and resins of the plants are also used for 'Sthaulyahara' or antiobesity (Murali et al., 2017). It also finds its application in treatment of leucorrhoea (Dhiman, 2014) and psychosomatic disorders (Rout et al., 2013). The plant also forms one of the constituents of topical application for the cure of melasma (Chavan et al., 2017).

In ayurveda, the plant forms one of the constituents in fumigation ingredient or Dhupa which are used for treatment of inflammations, mucous and keeping away mosquitoes and insects (Gazala., 2015). As a fumigant, the plant is also used for the treatment of wounds (Vishnuprasad et al., 2013). The plant is used in Unani system medicine as Qatil-e-Deedan (vermifuge), Daf-e-Humma (Antipyretic), Mudir-e-Baul (diuretic), Muhallil-e-Auram (Anti-inflammatory), Muhammira (rubefacient) and Dafe Ufoonat (antiseptic) (Zubair et al., 2014). In Unani system, the plant is also used for the treatment of gynaecological disorders (Kumar, 2014) and in polyherbal formulation in Unani for induction of labour during childbirth (Sultana et al., 2015). It is also one of the constituent of Habb-e-Suranjaan, a formulation used as analgesic (Suhail et al., 2017). Polyherbal formulations in Unani medicine with *Pinus roxburghii* as one of the constituents have shown to have antinociceptive effect (Azmat et al., 2006).

*Pinus roxburghii* finds extensive medicinal use among the rural people of the Indian subcontinent as well as in other parts of Asia. They are traditionally used for the treatment of indigestion (Kala, 2005), gastric troubles (Hasan et al., 2013), healing of wounds (Abbasi et al., 2010; Thapa., 2012), antidotes (Nasim et al., 2013), treatment of diarrhoea, tuberculosis (Ahmed et al., 2013). The plant is also used as antiseptic, diaphoretic, diuretic, rubefacient, stimulant and vermifuge (Chopra et al., 1986). The gum of the plant is also used as purgative, emmenagogue, aphrodisiac, anthelmintic, analgesic and carminative (Khan et al., 2012), antiseptic and expectorant (Puri et al., 2011). The wood of the plant is aromatic and haemostatic. It acts as liver tonic and is useful for the treatment of diseases of eyes, ears and pharynx, ulcers, haemorrhages, haemoptysis, flatulence, liver, skin, giddiness and pruritus (Kaushik et al., 2012). The ethnomedicinal and non-medicinal uses of the plant across the Indian subcontinent and neighbouring regions are illustrated in Table 1 and Table 2 respectively.

#### PHARMACOLOGICAL ACTIVITY

Based on the wide spread traditional use of *Pinus roxburghii* detailed investigations of the pharmacological activities are performed by various groups of researchers. Studies reveal that the wood oil of the plant acts as a hepatoprotective agent (Khan et al., 2012) while bark extract is also reported to possess anticonvulsant activity (Kaushik et al., 2012a). The flavonoids isolated from the bark extracts also exhibit alpha amylase activity and can be effectively used for the management of diabetic disorders (Kaushik et al., 2015a). The flavonoids present in the bark extracts exhibit analgesic and anti-inflammatory activity in tested models (Kaushik et al., 2012b). Kaushik et al., 2015b, also reported that petroleum ether and chloroform extract of the bark possess anticancer activity against IMR-32 human neuroblastoma cancer cell line.

#### ANTIMICROBIAL ACTIVITY

Qadir et al., (2014), reported that the essential oil of *Pinus roxburghii* possess antibacterial property and was effective against *Proteus vulgaris* and *Escherichia coli* bacteria. Hassan et al., 2009 observed antioxidant activity of the essential oil of the stem against *Staphylococcus aureus* and *Bacillus subtilis*. The essential oil also inhibited the activity of *Aspergillus candidus*, *Aspergillus versicolor*, *Aspergillus flavus*, *Aspergillus niger* and *Trichoderma viridae*. Chaudhary et al., 2012, reported that the chloroform extract and volatile oil of the stem wood of the plant showed inhibition against *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Bacillus subtilis* while amongst fungus the activity of *Candida albicans* was inhibited. Zafar et al., 2010, reported that the essential oil extracted from the needles showed inhibition of the growth of *Bacillus subtilis* and *Staphylococcus aureus*. The needle oil of the plant totally inhibited the growth of three fungal species namely *Aspergillus candidus*, *Aspergillus versicolor* and *Aspergillus niger* while partial inhibition in growth was observed for *Aspergillus terreus*, *Aspergillus flavus* and *Trichoderma viridae*. Salem et al., (2014), reported that the essential oils extracted from bark, wood and needle were inhibitory to human pathogenic bacteria namely *Bacillus subtilis*, *Sarcina lutea*, *Escherichia coli* and *Staphylococcus aureus* while the essential oil of barks and needles were effective against *Ralstonia solanacearum* and *Pectobacterium carotovorum*. Parihar et al., 2006, reported that the aqueous and alcoholic extracts of various parts of the plant showed inhibitory activity towards *Agrobacterium tumefaciens*, *Salmonella arizonae*, *Salmonella typhi* and *Staphylococcus aureus*. It was reported by Khalid et al., 2016, that the chloroform and methanolic extract of the female cones showed maximum inhibitory activity against fungus *Alternaria alternata* and *Fusarium solani* respectively. The methanolic extracts of female cones and needles also showed maximum inhibition against *Xanthomonas oryzae* while *Pseudomonas alcaligenes* was maximally inhibited by methanolic extract of female cones and chloroform extract of the needles.

Bissa et al., 2008 reported that the female cone and needle extracts showed maximum inhibition against *Klebsiella pneumoniae* whereas bark extracts were effective against *Agrobacterium tumefaciens*. *Salmonella typhi* was also inhibited by the extract off male cone.

#### CHEMICAL CONSTITUENTS

Wide array of ethno botanical, ethno medicinal and microbial activities of *Pinus roxburghii* suggests that the plant is a rich source of biologically active constituents. Studies indicate that all parts of the plants have been explored, utilized and consequently investigated for biological activities. Simultaneously exploration of chemical constituents has also been done by various groups of researchers with a motive to correlate the chemical constituents with their biological activity. It was found that the essential oil of the plant is rich in terpenes, terpene alcohol, esters and other hydrocarbons (Hassan et al., 2009; Zafar et al., 2010; Satyal et al., 2013; Qadir et al., 2014; Labib et al., 2017b). The bark and needle of the plant are rich in flavonoids, flavonoid glycosides, phenolic acids, lignans, stilbenes, fatty acids, fatty alcohols, sterols and terpenyl alcohols and steryl esters (Wilfor et al., 2009; Naeem et al., 2010; Kaushik et al., 2015a; Labib et al., 2017b).  $\alpha$ -Pinene constitutes the major component of the essential oil extracted from the various plant parts of *Pinus roxburghii* whose percentage can be as high as 60.8 (Qadir et al., 2014). In addition to it, caryophyllene and carene also forms important constituent of essential oil. In barks, catechin and quercetin forms the important flavonoid constituent (Wilfor, 2009). Other flavonoids isolated from the barks includes kaempferol, rhamnetin, myrecetin (Naeem et al., 2010), taxifolin (Labib et al., 2017a), galocatechin (Wilfor et al., 2009). The detailed chemical constituents of various plant parts and essential oil of *Pinus roxburghii* is given in table 3. It is noteworthy that most of the compounds isolated from the essential oils and bark of the plant acts as antioxidants and have tremendous beneficiary effect in maintaining the physiological redox balance of the human system (Pietta, 2000; Rice-Evans, 2001; Grassmann, 2005; Gonzales-Burgos and Gomez-Serranillos, 2012).

#### DISCUSSION

Dependency on plants by humans for the cure of physical ailments has a long history. The earliest evidence of the association of herbal medicine with humans often refers to that of the grave of Neanderthal man dating back to 60000 years in which pollens and fragments of different medicinal plants were observed (Hart 2005). Medicinal herbs were discovered from the mummified remains of the 5300 years old ice man from Swiss Alps (Capasso 1998). The first documentation of the study of herbs for medicinal use was done by Sumerians 5000 years ago. Use of herbs as medicines were also common amongst Egyptians in 1000BC (Falodun 2010). Thus uses of herbs for care and cure of diseases gradually got assimilated within the culture and tradition of human civilization. Ancient India also had a strong belief on the use of herbs for treatment and is very well documented in the Ayurveda. The herbal remedies are still being practiced and is very popular among various groups throughout the globe. 75-80% of the world's population specially in the developing countries depends on herbal remedies for their primary health care (Kamboj, 2000). With the introduction of modern day medicines, the application of herbal medicine somewhat got marginalized but recent years experienced a revert back of the usage of herbal medicine mainly due to the side effect of modern day drugs (Pan et al., 2014). This has led to global pharmaceutical industries explore herbal resources as a potential starting material for new drug discovery based on natural product (Seidel, 2002). Presently 80% of the drugs are natural products or derivatives of natural products (Gordaliza, 2009) and the global market of the use of herbal medicine for healthcare practices is estimated to be around US\$ 107 billion by the year 2017 (Gelayee et al., 2017). India possesses one of the richest traditions of herbal medicine and the rural population uses an estimate of 25000 plant based formulation as folk medicines (Verma et al., 2008). The total number of recorded medicinal plant in India is around 20000 of which 7000-7500 plants are used by traditional medical practitioners for curing various diseases (Pandey et al., 2013). Due to increasing popularity, it is estimated that the demand of herbal raw drugs is 5, 12,000 MT while the estimated exports of herbal drugs and extracts is 1, 34,500 MT for the year 2014-2015. It is also estimated that 1, 67,500 MT of Herbal Raw Drugs are consumed by rural households in India per year (Website: National medicinal plant board, Ministry of Ayush, Govt of India, 2018). This is accompanied by a budget allocation of INR 10044 crore for the Department of AYUSH in the 12th five year plan (2012-2017) which was 235 % more than the expenditure of 11th Plan (Sen et al., 2017). India is a biodiversity hotspot due to its varied phytogeography and climatic condition and houses a large number of medicinal plants. The Himalayas occupy 15% of the country's area and accounts for one third of endemic species found in the subcontinent (Kumar et al., 2011).

The gymnosperms constitute a remarkable proportion of the vegetation of Himalayas out of which undoubtedly *Pinus roxburghii* forms a dominant representative. This is because it has a wide climatic adaptability and occurs in the tropical, sub-tropical and temperate regions of the Himalayas. Ethno botanical surveys by various groups of researchers indicate that the plant plays a major role in the life of the communities in rural area of Indian subcontinent and adjoining areas both in terms of folk medicine and other household activities. The plants also positively impact the economic condition of rural peoples of the area. Hence the plant has been integrated in the day to day life of the people. In addition to it, in-depth phytochemical analysis of different plant parts by various groups proves that the plant is a rich source of antioxidant compounds and exhibits various pharmacological and antibacterial activity. Presently not much effort has been made to extract the various pharmacologically active compounds and eventually leading to production nutraceuticals and dietary supplements. Thus the plant can be well utilized in extracting compounds of pharmacological and antioxidant potential. All these findings hints at the tremendous potential of the plant as a cheap source of antioxidants which can be bio prospected as a cheap available source for the management of large number of diseases which result due to disruption of antioxidant homoeostasis in the living system. As the plant is abundant along the Himalayan region, bio prospecting this plant will directly benefit a large number of population of Indian subcontinent and adjoining areas. The ever-growing pharmaceutical industry of the country requires playing a pivotal role in selecting *Pinus roxburghii* as a source of developing cost effective source for production of dietary supplements and medicines which would directly be of use of the booming population of the Indian subcontinent.

**Table 1. Ethnomedicinal uses of *Pinus roxburghii* Sarg. across Indian subcontinent and adjoining countries.**

S. No.	Region	Vernacular /Sanskrit Name	Plant part and their uses	Reference
1.	Himalayan region of Asian subcontinent	Chir	<b>Leaves:</b> Used for the treatment of sprains. <b>Resins:</b> Used for treatment of boils, heel cracks. <b>Wood:</b> Diaphoretic and stimulant, used for treatment of cough. <b>Wood and Oleoresins:</b> Used for treatment of snakebites and scorpion stings. <b>Oil:</b> Used for the treatment of flatulence, chronic bronchitis, typhoid. <b>Bark:</b> Used for the treatment of skin diseases.	Kaushik et al., 2013.
2.	Indian Himalayas	Chir, Hindko	<b>Resin:</b> stomachic and remedy for gonorrhea, buboes, abscesses. <b>Wood:</b> Diaphoretic, remedy for burning of body, cough, fainting and ulceration. <b>Oleoresin:</b> Used for snakebite and scorpion stings along with wood. <b>Oil:</b> Useful in chronic bronchitis, cures flatulence and constipation. <b>Bark:</b> Used for colouring leather.	Chaturvedi et al., 2011.
3.	Ziro valley, Arunachal Pradesh, India	Chir, Dhupi, Salla	<b>Seeds:</b> Used for treating indigestion.	Kala, 2005.
4.	Bhattiyat Block, District Chamba, Himachal Pradesh	Chil	<b>Leaves/Needles:</b> Used to increase urine flow and treatment of kidney stones.	Rani et al., 2014.
5.	Himachal Pradesh, India	Chir	<b>Resin:</b> Used for the treatment of boils, bone fracture, cracks in sole of feet, leprosy, skin diseases, snake bites, sprains, swelling, ulcers and urine complaints.	Samant et al., 2007.
6.	Kanda Range, Chopal forest division, Himachal Pradesh, India	Chir, Sarala	<b>Roots:</b> Paste is used to cure joint pain. In dry state it is used for the treatment of asthma. <b>Stem bark:</b> Used for management of bone fracture.	Singh et al., 2018.

7.	Kangra district, Himachal Pradesh, India	Chir	<b>Wood and leaves:</b> Fuel, bronchitis, gangrene of lungs	Upadhyay, 2013.
8.	Renuka forest division, Sirmaur district, Himachal Pradesh, India	Chir	<b>Saw Dust and aerial parts:</b> Used for the treatment of asthma.	Yadav et al., 2014.
9.	Una & Hamirpur district, Himachal Pradesh, India	Chir	<b>Leaves:</b> Fever, loss of appetite, <b>Seeds:</b> Bronchitis, tuberculosis, bladder infection, <b>Oil:</b> muscular pains	Chand et al., 2016.
10.	Jammu & Kashmir, India	Sarala	<b>Whole Plant:</b> Skin disease, inflammation and ulcer	Srivastava et al., 1986.
11.	Kajinaag Range, district Baramulla, Kashmir, India	Chad	<b>Seeds and Gums:</b> Used to relieve from general weakness after childbirth.	Mala et al., 2012.
12.	Kathua, Jammu and Kashmir, India	Chir	<b>Oil:</b> Turpentine oil used in pharmaceuticals. Turpentine expectorant used to treat chronic bronchitis and gangrene of lungs. Used as carminative to treat haemorrhage in tooth sockets and nose.	Kumar et al., 2012.
13.	Rajouri, Kashmir, India	Chir	<b>Seed and Stem:</b> Boils, bone fracture, cracks of skin, skin diseases, leprosy, snake bite, sprains, swelling, ulcers, urine complaints. Edible, fuel, timber, agricultural tool.	Pant et al., 2008.
14.	Sewa river catchment, district Kathua, Jammu and Kashmir, India	Chir, Chil	<b>Resin:</b> Used as expectorant in chronic bronchitis, gangrene of lungs, carminative, prevention of hemorrhage in tooth sockets and nose.	Khan et al., 2009.
15.	East Godavari district, Andhra Pradesh	Pinachettu	<b>Stem Bark:</b> Used for treatment of rheumatoid arthritis.	Suneetha et al., 2016.
16.	Tamil Nadu, India	Devadaru	<b>Leaf:</b> Used for treatment of stomach disorder.	Jayaprasad et al., 2011.
17.	Almora district, Uttarakhand, India	Chir	<b>Seed and Needles:</b> Used for the treatment of fracture in cattle. <b>Resin:</b> Used for the treatment of broken horns of cattles.	Shah et al., 2008.
18.	Bageswar Valley, Uttarakhand, India	Salla	<b>Resin:</b> Used to treat skin disease, snake bite and scorpion stings.	Singh et al., 2014.
19.	Chamoli District, Garhwal Himalaya, Uttarakhand, India	Kulain, Chir	<b>Oleoresin:</b> Used for the treatment of crack <b>Saw dust:</b> Used in the treatment of asthma and bronchitis.	Bhandari et al., 2016.
20.	Champawat and Pithoragarh district, Uttarakhand, Central Himalayas, India	Salla	<b>Resin:</b> Used to treat sprains and wounds. Used for treatment of fracture.	Negi et al., 2002.
21.	Garhwal Himalaya, Uttarakhand, India	Kulai/Cheer	<b>Resin:</b> Used as crack cream, Pollen Dust: anti-cancer and antitubercular.	Uniyal et al., 2005.
22.	Jakholi Block, Rudraprayag district, Uttarakhand, India	Cheed, kulian	<b>Root:</b> Used for treatment of Tuberculosis <b>Resin:</b> Used for cracked feet, cuts and bone fracture.	Singh et al., 2017.
23.	Kalimath Valley, District Rudraprayag, Uttarakhand, India	Kulain	<b>Resin:</b> Used to cure joint pain, cracks and body aches.	Semwal et al., 2013.

24.	Kedarnath wildlife sanctuary, Garhwal Himalayas, India	Chir	<b>Saw dust:</b> Used for the treatment of asthma & bronchitis. <b>Aerial parts:</b> Used for healing cracked toes.	Bhat et al., 2013.
25.	Kumaun Himalayas, India	Chir	<b>Wood:</b> Used in snake bite and scorpion sting <b>Resin:</b> Used to heal crack.	Mehra et al., 2014.
26.	Mornaula Reserve Forest, Uttarakhand West Himalaya, India	Chir	<b>Resin:</b> Used in treatment of Pimples.	Pant et al., 2009.
27.	Narendra Nagar Block, Tehri Garhwal, Uttarakhand, India	Chir	<b>Needles:</b> Used to increase urine flow.	Dangwal et al., 2011.
28.	Raipur Block, Dehradun district, Uttarakhand, India	Cheer	<b>Resin and Leaves:</b> Used for healing of cracked feet.	Deoli et al., 2014.
29.	Ramnagar, Kotabagh and Ramgarh Blocks, Nainital district, Kumaun Himalayas, India	Chir	<b>Plant:</b> Used to treat era, throat, blood and bronchitis disease. <b>Resin:</b> Used to treat scorpion bite.	Parihar et al., 2014.
30.	Surkanda Devi Hill, Uttarakhand, India	Chira, Kulain	Medicinal	Arya et al., 2016
31.	Tehri Garhwal, Uttarakhand, India	Chir	<b>Wood:</b> Antiseptic and haemostatic, foul ulcers, asthma, gonorrhea, epilepsy	Chauhan et al., 2017.
32.	Uttaranchal (Uttarakhand ), India	Chir	<b>Ethnoveterinary:</b> Used to treat bone fracture, sprains, foot and mouth disease, burns, internal injury, external parasites, broken horn, diarrhoea, indigestion, gastric trouble, itching, rheumatism, food poisoning and pimples.	Pande et al., 2007.
33.	Uttarkashi, Uttarakhand, India	Chir	<b>Resin:</b> Used as crack cream, anti-cancer <b>Pollen dust:</b> Anticancer and antitubercular.	Negi et al., 2011.
34.	Abbotabad City, Pakistan	Chirr	<b>Seeds and gums:</b> Used as stimulant, antispasmodic , anti-pathogen astringent and diuretic.	Sabeen et al., 2009.
35.	District Abbotabad, Pakistan	Chir	<b>Resin:</b> Applied topically to control bleeding.	Abbasi et al., 2010.
36.	Azad Jammu and Kashmir, Pakistan	Chir	<b>Bark:</b> Considered as emollient, stimulant, antiseptic, anthelmintic, liver tonic, diaphoretic, diuretic. <b>Resin:</b> Used for the treatment of skin diseases and acts as blood purifier.	Rashid et al., 2015.
37.	District Kotli, Azad Kashmir, Pakistan	Chir	<b>Juvenile apex:</b> Used for the treatment of diarrhoea. <b>Whole plant:</b> Shade is beneficial to tuberculosis patient. <b>Wood:</b> Used for timber & fuel. <b>Leaves:</b> Used for thatching. <b>Resin:</b> Used in soap Industry.	Amjad et al., 2014.
38.	Koli Peer National Park, Azad Kashmir, Pakistan	Chir	<b>Leaves and Bark powder:</b> Used for the treatment of dysentery. <b>Resin:</b> Used for the treatment of Ulcers, tumours, bleeding wounds, cough, snake bite.	Amjad et al., 2017.
39.	Bhawalpur district, Pakistan	Chir	<b>Areal part:</b> Used as antiseptic, diuretic, vermifuge treatment of kidney and bladder complaints, cough, colds, influenza, tuberculosis, wounds, sores, burns, boils and ulcers.	Nisar et al., 2014.



40.	Chagharzai Valley, district Buner, Pakistan	Nakhtar	<b>Wood:</b> Timber and Fuel. <b>Resins and Leaves:</b> Stimulant, stomachic and diuretic.	Sher et al., 2011.
41.	Nandiar Khuwarr catchment, district Battagram, Pakistan	Nakhtar	<b>Resin:</b> Used as a stimulant in ulcer, skin diseases, snakebites and scorpion stings.	Haq et al., 2011.
42.	Cholisthan desert, Pakistan	Chir	<b>Whole Plant:</b> Used for treatment of parasitic disease (mange).	Farooq et al., 2008.
43.	Barroha, Bhara Kahu and Maanga, Islamabad, Pakistan	Cheer	<b>Gum:</b> Used to cure back ache. <b>Young shoots:</b> used to cure measles.	Rauf et al., 2012.
44.	Jalalpur Jattan, district Gujrat, Punjab, Pakistan	Chir	<b>Bark and Resin:</b> Used to treat burns, scalds, boils, cough and gastric troubles	Hussain et al., 2010.
45.	District Malakand, Pakistan	Nakhtar	<b>Shoot, seed, wood:</b> Antidote, emollient, vermifuge.	Barkatullah and Ibrar., 2011.
46.	Hazar Nao forest, Malakand district, Pakistan	Nakhtar	<b>Resin:</b> Used for the treatment of ulcer, skin diseases, snake bite.	Murad et al., 2011.
47.	Kaghan Valley, Manshera district, Pakistan	Chir, Hindko	<b>Resin:</b> Stomachic, treatment of gonorrhea, hair remover. <b>Oil:</b> Used for the treatment of chronic bronchitis, flatulence.	Hussain et al., 2006.
48.	Lower Kaghan Valley, district Manshera, Pakistan	Chir	<b>Resin and Needles:</b> Used as emollient, aromatic, antiseptic, deodorant, anthelmintic, digestive, diuretic, expectorant, anodyne, purgative, rubefacient, vermifuge. It finds use to cure cough and cold.	Shoaib et al., 2017.
49.	Margala Hills National Park, Pakistan	Chir	<b>Seeds and Gums:</b> Used as stimulant, antispasmodic, astringent, diuretic and antipathogenic.	Ahmad et al., 2009
50.	Patriata, New Murree, Pakistan	Chirr	<b>Juvenile apex:</b> Used for the treatment of diarrhoea.	Ahmed et al., 2013.
51.	Galliyat, NWFP, Pakistan	Chirr	<b>Wood:</b> Used to cool burning sensation of body, snakebite, scorpion sting. <b>Resin:</b> Used for the treatment of snake bite and scorpion sting also used as antiseptic.	Ahmed et al., 2004.
52.	Kohistan Valley, NWFP, Pakistan	Nakhtar (Pushtoo), Hindko, chir	<b>Resin:</b> Stimulant used for treatment of ulcer, snakebites, and scorpion stings. It also acts as blood purifier.	Jan et al., 2009.
53.	Lodhran, Punjab, Pakistan	Chir	<b>Bark and Resin:</b> Used for burns and scalds, boils, cough and gastric troubles.	Ismail et al., 2010.
54.	Pearl Valley, Rawalakot, Poonch district, Azad Jammu and Kashmir, Pakistan	Chir	<b>Leaves and bark powder:</b> Used for the treatment of dysentery <b>Resin:</b> Used for the treatment of ulcer, tumour, bleeding, cough, snake bite and wound.	Shaheen et al., 2017.

55.	Lilownai Valley, district Shangla, Pakistan	Nakhtar	<b>Whole plant:</b> Used in ulcer and snake bites.	Shah et al., 2012.
56.	Tehsil Charbagh, Swat district, Khyber Pakhtunkhwa, Pakistan	Nakhtar	<b>Resin:</b> Used for treatment of pimples and antidiabetic. <b>Seed:</b> Used as sex tonic.	Khan et al., 2015.
57.	Madyan Valley, Swat district, Pakistan	Nakhtar	<b>Gum:</b> Used to treat skin diseases and heart diseases.	Ahmad et al., 2013.
58.	South Waziristan and Bajaur Agency, Pakistan	Nakhtar	<b>Latex:</b> Used for the treatment of skin problems in cows, buffalo and sheep.	Aziz et al., 2018.
59.	Macchegaun, Nepal	Rani Salla	<b>Resin:</b> Resin is applied to cut boils.	Joshi et al., 2011.
60.	Kali Gandaki, Bagmati and Tadi Likhu Watersheds, Nepal	Rani Salla	<b>Resin:</b> Used externally to cure boils.	Joshi et al., 2007.
61.	Baitadi and Darchula districts, Nepal	Khote salla, Rani Salla, Sarala	<b>Resin:</b> Used for treatment of cough and gastric troubles	Kunwar et al., 2009.

Table 2. Non medicinal uses of *Pinus roxburghii* Sarg.

S.No.	Region	Vernacular/Sanskrit Name	Uses	Reference
1.	Allai Valley, Pakistan	Chir	<b>Wood:</b> Fuel, timber, thatching.	Haq et al., 2012.
2.	District Kotli, Azad Kashmir, Pakistan	Chir	<b>Wood:</b> Used for timber & fuel. <b>Leaves:</b> Used for thatching. <b>Resin:</b> Used in soap Industry.	Amjad et al., 2014.
3.	Kot Manzaray Baba Valley, Pakistan	Nakhtar	<b>Wood:</b> Timber, fuel, furniture.	Zabihullah et al., 2006
4.	Gokand Valley, Buner District, Pakistan	Nahtar	<b>Wood:</b> Timber, construction purpose. <b>Branches:</b> Fuel wood. <b>Resin:</b> paints and varnishes. <b>Needles:</b> Making ropes.	Khan et al., 2003.
5.	Poonch Valley, Azad Kashmir	Chir	<b>Timber:</b> Making furniture, bridges, beam. <b>Cones:</b> Fuel.	Khan et al., 2011.
6.	Kotli District, Azad Kashmir	Cheer	<b>Stem:</b> Fuel.	Ahmad et al., 2012.
7.	Kaghan Valley, Mansehra District, Pakistan	Chir	<b>Stem:</b> Wood obtained from stem is used for construction and furniture making. Resin extracted from wood is used as varnishes.	Awan et al., 2011.
8.	Salarzai Valley, District Buner, Pakistan	Nakhtar	Medicinal, fuel wood, thatching, shelter, roofing.	Sher et al., 2014.
9.	Margallah Hills National Park, Islamabad, Pakistan.	Chir	<b>Wood:</b> Timber. <b>Resin:</b> Fuel.	Jabeen et al., 2009.
10.	Dir Kohistan Valley, Khyber Pakhtunkhwa,	Chir/Nakhtar	<b>Wood &amp; Leaves:</b> Fuel, thatching, timber, sheltering.	Jan et al., 2014.

Pakistan				
11.	Dir Kohistan Valley, NWFP, Pakistan	Nakhtar (Pushtoo)	<b>Wood:</b> Used as timber, fuel and furniture.	Jan et al., 2009.
12.	Gandruk VDC, Nepal	Sallo	<b>Wood, leaf root:</b> Used as fuel, wood and electricity pole.	Adhikari et al., 2010.
13.	Nepal	Rani Salla	<b>Resin and Wood:</b> Used as incense.	Manandhar, 2004.
14.	Bagmati and Langtang watershed, Nepal	Rani Salla	<b>Wood:</b> Used as firewood and for constructions of doors, beds etc.	Joshi et al., 2005.
15.	Shaktikor VDC, Chitwan District, Nepal	Metang	<b>Seeds:</b> Edible.	Rijal, 2011.
16.	Shimla Hills, Himachal Pradesh, India	Chir, Dhupasarala	<b>Wood:</b> Turpentine obtained from wood finds its application in pharmaceutical preparations, disinfectants, insecticides, varnishes and perfumery.	Singh et al., 2014.
17.	Indian subcontinent	Chir	<b>Resin:</b> used in stages of batik technique of fabrics.	Maulik et al., 2014.
18.	Uttarakhand, India	Chir	<b>Leaves:</b> used for the extraction of a green dye.	Akhtar et al., 2012.
19.	Bhagirathi Valley, Uttarakhand, India	Chir	<b>Wood:</b> Wood is used for furniture making.	Uniyal et al., 2002.
20.	North Cachar Hills, Assam, India	Hmar, Biate, Vaiphei	<b>Wood:</b> used for timber, furniture making and firewood.	Sajem et al., 2008.
21.	Kashmir, India	Chir, Dhup	<b>Wood:</b> Used for the preparation of sleepers, carpentry works, firewood and tanning purposes.	Dar et al., 2006.
22.	Lobha Range, Kedarnath Forest Division, Garhwal Himalayas, India	Kulain	<b>Seeds:</b> Edible at maturity.	Ballabha et al., 2013.

Table 3. Chemical constituents in various plant parts of *Pinus roxburghii* Sarg.

Plant Part	Chemical Constituent	Reference
<b>Essential oil</b>	$\alpha$ -Thujene (0.2%), $\alpha$ -Pinene (60.8%), Camphene (1.0%), $\beta$ -Pinene (30.2%), L-beta-Pinene (1.8%), Limonene (0.9%), Terpinolene (0.1%), Transpinocarveol (0.1%), $\alpha$ -Terpineol (1.6%), L-Bornyl acetate (0.3%), $\beta$ -Caryophyllene (1.1%), $\alpha$ -Caryophyllene (0.4%), $\delta$ -Cadinene (0.4%).	Qadir et al., 2014.
<b>Cone essential oil</b>	(E)-Caryophyllene (26.8%), Terpinen-4-ol (16.2%), $\delta$ -3-Carene (6.8%), $\alpha$ -Humulene (5.0%)	Satyal et al., 2013.
<b>Needle essential oil</b>	(E)-Caryophyllene (31.7%), Terpinen-4-ol (30.1%), $\alpha$ -Humulene (7.3%), $\alpha$ -Terpineol (5.0%)	Satyal et al., 2013.
	$\alpha$ -Pinene (29.3%), $\beta$ -Myrcene (1.1%), 3-Carene (14.2%), Terpinyl acetate (1.0%), $\alpha$ -Terpineol (4.5%), Borneol acetate (2.2%), $\alpha$ -Longipinene (1.2%), Caryophyllene (21.9%), Caryophyllene oxide (3.1%).	Zafar et al., 2010.
<b>Bark essential oil</b>	(E)-Caryophyllene (34.5%), Eugenol (11.4%), Linalool (6.4%), $\alpha$ -Humulene (5.7%), $\alpha$ -Terpineol (4.9%), Terpinen-4-ol (4.1%).	Satyal et al., 2013.
	$\alpha$ -Thujene, $\alpha$ -Pinene, Camphene, 1-isopropyl-4-methylenebicyclo[3.1.0]hex-2-ene; 1,2,4-Trimethylbenzene, 3-Carene, Isocineol, $\alpha$ -Terpinene, p-Cymene, O-Cymene, D-Limonene, Eucalyptol, trans-Bicyclo[4.4.0]Decane $\tau$ -Terpinene, 2-Methyldecane, Terpinolene, n-Undecane, n-Nonanal, $\alpha$ -Thujone, Fenchol, L-trans-Pinocarveol, Camphor, Isoborneol, p-Acetyltoluene, 1-Terpinen-4-ol, p-Cymen-8-ol, $\tau$ -Terpineol, Myrtenal, n-Decanal, cis-Carveol, Acetophenone, 2,4-dimethyl, Cuminaldehyde, n-Nonaic acid.	Labib et al., 2017b.
<b>Stem essential oil</b>	$\alpha$ -Pinene (41.9%), Camphene (0.9%), 3-Carene (16.3%), o-Cymene (0.4%), p-Cymene (1.9%), Limonene (1.7%), $\beta$ -Phellandrene (0.7%), $\gamma$ -Terpinene (0.2%),	Hassan et al., 2009.

	1-Terpinen-4-ol(0.2%), $\alpha$ -Terpineol(1.8%), Borneol acetate (1.1%), Terpinyl acetate (0.8%), Farnesene (0.6%), Caryophyllene (12.3%), Butanoic acid, -methyl-,2-phenylethylester (0.3%), Caryophyllene oxide (1.0%), farnesyl acetate (0.2%).	
<b>Xylem Resin</b>	$\alpha$ – Pinene (22.8%), Camphene (0.4%) , $\beta$ -Pinene/sabinene/C11 (14.1%), $\Delta$ -3-Carene (50.6%), $\alpha$ -Phellandrene (0.1%), $\beta$ -Phellandrene (0.7%), $\alpha$ -Terpinene (0.4%), $\gamma$ - Terpinene (0.5%), Limonene (0.9%), Terpinolene (3.8%), Longipinene (0.2%), Longicyclene (0.2%), Sativene (0.1%), Longifolene (3.4%), $\beta$ -Caryophyllene (0.2%), $\alpha$ - Terpinyl acetate (0.3%). (% abundance)	Coppen et al., 1988.
<b>Bark</b>	1,3,7-Trihydroxyxanthone, 2,4,7-Trihydroxyxanthone, Flavan-3-ol, Taxifolin, Quercetin, 5,7-Dihydroxy-4'-methoxy dihydroflavonol-3-O-rhamnoside, Isorhamnetin-3-O-rhamnoside, Isopimaric acid, 3-Methoxy-14-Serratene-21-one, Ursolic acid, Methoxyprotocatechuic acid, 3,4- Dihydroxy benzoic acid, p-Hydroxybenzoic acid, Octacosyl ferulate, Ellagic acid.	Labib et al., 2017a.
	3,3',4',5,7-Pentahydroxyflavone (quercetin)	Kaushik et al., 2015a.
	$\Sigma$ Sugars and sugar alcohols (17.0)	
	$\Sigma$ Simple acids:3,4-Dihydroxybenzoic acid (0.22), 3,4- Dihydroxycinnamic acid (0.31), $\Sigma$ -ferulate (1.44),	Wilfor et al., 2009.
	$\Sigma$ Lignans: Pinoresinol (0.35), Secoisolariresinol (0.37).	
	$\Sigma$ Stilbenes: Dihydro-monomethyl pinosylvin (0.01%),	
	$\Sigma$ Flavonoids: Catechin (13.3), Taxifolin (2.65), Quercetin (0.09), Quercetin derivative (10.3), Catechin and gallactocatechin (10.3).	
	$\Sigma$ Fatty acids: C14:0 acid (0.05), C16:0 acid (0.29), C17:0 acid (0.05), C18:1 acid (0.30), C18:2 acid (0.25), C22:0 acid (0.16), C24:0 acid (0.20).	
	$\Sigma$ $\alpha$ , $\Omega$ -fatty acids: 1, 22-dioic-22: acid (0.01).	
	$\Sigma$ Fatty alcohol: C22:0 alcohol (0.05), C24:0 alcohol (0.18).	
	$\Sigma$ Resin acids: Pimaric acid (0.45), Sandaracopimaric acid (0.10), Isopimaric acid (1.54), Dehydroabietic acid (1.21), Abietic acid (1.32), Neoabietic acid (0.18), x-Hydroxy-dehydroabietic acid (0.15).	
	$\Sigma$ Monoglycerids: C24:0- Monoglyceride (0.05).	
	$\Sigma$ Sterols and triterpenyl alcohols: Campesterol (0.07), Sitosterol (0.52), Sitosterol glucopyranoside (1.01).	
	$\Sigma$ Steryl esters (0.73), $\Sigma$ Triglycerides (0.33).(mg.g <sup>-1</sup> )	
	Kaempferol (3.04%), Rhamnetin (1.0%), Quercetin (10.01%).	Naeem et al., 2010
<b>Needles</b>	Myrecetin (1.0%), Quercetin (4.2%).	Naeem et al., 2010

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