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Commentary

Chir Pine Forests of Western Himalaya are Under Stress Because of Combined Effects of Resin Extraction, Recurrent Fire and Climate Change: A View Point

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ABSTRACT
Pine (*Pinus* sp.) resin is a non-wood forest product used for multiple purposes worldwide since ancient times. Out of five Pine species occurring naturally in India (Himalayas), only *Pinus roxburghii* is tapped for resin using Rill method in Uttarakhand and Borehole method in Himachal Pradesh. The earlier faulty Cup-and-Lip method of resin extraction has been completely abandoned in this region for a few decades. The advantages and disadvantages associated with these two methods regarding the vulnerability of Pine trees to forest fire and consequent windfall have been discussed. In Uttarakhand, Pine forests spread over 4.12 lakh ha face colossal loss every summer due to recurrent fire of anthropogenic origin. Over the years, the faulty resin tapping practices are making trees vulnerable to forest fire and windfall. Further, climate change and human-caused forest fire has put the Pine forests under ever greater stress that has affected their natural structure and functioning and the ecosystem services, causing a considerable loss to the environment and economy of this region. The lack of enforcement of rules for resin tapping laid by the Forest Department has been highlighted as the main factor behind the vulnerability of the trees to fire and their subsequent windfall. This article examines the combined effects of resin extraction, forest densification, fire, and climate change on the Chir Pine forests of the western Himalayan region and underscores some research questions to be answered involving well-designed studies for managing these forests for ecosystem services and human well-being.

Key words: Forest fire, Resine, Climate change, Forest management, Himalaya

INTRODUCTION

Resins are prime among non-wood forest products (NWFPs), the most widely used and traded NWFPs. Pine (*Pinus* sp.) resin is an NWFP used for multiple purposes worldwide since ancient times. India ranks sixth among the world's top ten resin-producing countries (Handique et al. 2020). Out of the 187 species and varieties of Pine, 80 species are tapped for resin worldwide. Out of five Pine species occurring naturally in India (Himalaya), viz., *P. roxburghii, P. wallichiana*, *P. gerardiana*, *P. kesiya*, and *P. armandi*, only *P. roxburghii* (commonly called as long leaf Pine or Chir Pine) is tapped commercially for resin. Pine oleoresin (locally called *Lisa* in Uttarakhand) yields two industrially important products—volatile turpentine oil (about 70%) and solid transparent material rosin (about 17%) those are used for various industrial and medicinal purposes (Negi 1992). In the Himalayan region, resin extraction as a source of revenue has been reported since 1911 (Yogi et al. 2021). In Uttarakhand, resin tapping began in 1890 and was extended to J&K and Himachal Pradesh in 1940 and 1945, respectively (Singh and Asokan 1984). Uttarakhand, Himachal Pradesh and Jammu & Kashmir are major resin-producing states of India, producing around 8,000 to 9,000 tons of raw Pine resin annually, with an average yield of 2.5 kg resin/tree. Of the decadal (2010-11 to 2018-19) average production of Pine resin in Uttarakhand and Himachal Pradesh the former contributes only 22%, and the remaining 78% by the latter (Yogi et al. 2021). In Uttarakhand, Pine forests spread over 4.12 lakh ha face colossal loss every summer due to recurrent anthropogenic fires (man-made accidental and intentional) (Semwal and Mehta 1996), often associated with global warming (Negi 2019). In recent decades, the western Himalayan region has experienced rapidly increasing temperatures and decreasing monsoon precipitation

(Norris et al. 2020), with winter warming occurring faster (Bhutiyani et al. 2007). Extended periods of warm temperatures, changing monsoon patterns, including a lack of pre-monsoon rainfall and drought-like conditions increases the fuel loading in the forests of this region, making the Chir Pine forests particularly vulnerable to forest fire (Singh et al. 2016). Resin tapping is a common practice from the Chir Pine trees in Uttarakhand and Himachal Pradesh to make rosin, turpentine, and pine oil used for various industrial purposes. Over the years, the faulty resin tapping practices are making trees vulnerable to forest fire and windfall, climate change and human-caused forest fire have put the Pine forests under ever greater stress that has affected their natural structure and functioning and the ecosystem services causing a considerable loss to the environment and economy of this region. Further, in 1980, the Supreme Court banned cutting trees situated above 1,000 m amsl, which has given rise to the densification of Pine forests, thus adding to the inflammability of these forests.

This article examines the combined effects of resin extraction, forest densification, fire, and climate change on the Pine forests of the western Himalayan region. It underscores some research questions to be answered involving well-designed studies for managing these forests for environmental protection and human well-being.

RESIN TAPPING TECHNIQUES: COMPARATIVE ADVANTAGES AND DISADVANTAGES

In the past, the old faulty French "Cup-and-Lip" method practiced in European and Asian countries was used for resin tapping in the Himalaya. In this method, the tree's outer bark is scraped off with the adze (a local instrument) to a smooth surface of 60 cm long, 15 cm wide, and 25 cm above the point where the lip is fixed, and the channels are freshened at definite intervals. Even though a channel depth of 2.5 cm is prescribed, very often the tapper exceeds the depth of the channels in the hope of getting more resin or partly due to inherent hacking action using freshening tools, which makes it difficult to control the depth of the blazes. Thus, deep cuts around the bole results in loss of timber quality at the butt end log and trees become less resistant to wind storms (Sharma et al. 2018). Also, because of the slow healing of deeper blazes/wounds a second cycle of tapping is not possible that results into abrupt fall in the resin production (Tiwari 1994). Because of these disadvantages, this method was discontinued in 1990s (Chaudhari et al. 1988).

In Himachal Pradesh and Uttarakhand, two resin tapping methods are currently in vogue: Rill method and Borehole method. (i) Rill method is an improved method, standardized at Forest Research Institute, Dehradun, to overcome the disadvantages of the earlier used Cup-and-Lip method (Verma 1983). In the Rill method, a bark piece of 45×30 cm at 15 cm above the ground level is removed, and the thickness of the bark is left ~2 mm (Tiwari 1994). Now, one inclined rill (5-6 mm wide and deep) is made on either side of the central groove through which resin flows into a cup fixed at the base of the blaze and 32 such rills are made in 8 month cycle every year in one blaze. Each time, a 1:1 mixture of dilute sulphuric acid (20%) and dilute nitric acid (20%) is sprayed on the freshly cut rill. The Rill method is considered less destructive as it involves minimum cutting depth, which saves heartwood from damage and does not reduce the timber value of the wood (Chaudhari 1995). The technique provides fast healing of the blaze, which reduces the tapping cycle and increases the tapping life of the trees. The technique saves trees from fire and windfall, yields about 50% more resin per tree than the old Cup-and-Lip method, and generates more employment. (ii) Borehole method involves drilling holes of 2.5 cm diameter into the tree bole 10 cm above the ground to a depth of 10-15 cm, and sprayed with 1-2 ml of the stimulants (mixture of sulphuric acid and ethephon, i.e., 2-chloro-ethyl phosphonic acid). There is less stress on tree health due to the small size of the hole, and the hole heals fast. This economical technique compared to the other methods protects trees against fire, insects, pests, and diseases. A vital feature of the method is that a closed collection apparatus prevents premature solidification of resin, thereby maintaining oleoresin flow for up to six months (October–April) without wounding the stem. Due to reduced oxidation and contamination, the end product is of higher quality and fetches higher prices in the market. The crown fire incidents are also lower because there is no hard resin accumulation on the main stem. Also, there is no damage to the merchantable part of the tree. This technique can effectively conserve and manage Pine forests (Sharma et al. 2018).

In Himachal Pradesh till 1984, the old faulty "Cup-and-Lip" method was used for resin tapping, which was replaced by the Rill method completely in 1991 (Chaudhari 1995). The H.P. forest department is promoting the Borehole method for resin extraction, while Uttarakhand has also conducted trials using this method. There is still ambiguity regarding the resin yield using the Rill and Borehole methods, which must have hindered the Uttarakhand Forest Department from using the latter method. Meena and Akash (2023) reported that oleoresin yield varied significantly in the Borehole method, with 8.36 L per tree, compared to the Rill method, with 2.36 L in three months. Experiments at the Forest Research Institute, Dehradun, have reported 5.13 kg/blaze/year resin yield in the Rill method as compared to 1.5 and 3.1 kg/blaze/year by the other two traditional methods, viz., Silva Hill Basula and Bark chipped method, respectively (Chaudhari et al. 1988). However, Sharma et al. (2006) and Kedarnath (1971) found the resin yield slightly higher in the Rill method than in the Borehole method. Substantial research has gone into the effect of resin tapping on various aspects of resin production across diameter classes of trees, tree mortality, cone, and seed production (higher in tapped trees), relative humidity, soil moisture, and soil temperature, etc. (Lohani 1985). Coppen and Hone (1995) found that a tree age of 15-20 yrs, tree girth of 1.1 -2.9 m, and height of 23-45 m is ideal for resin tapping.

RESIN YIELD AND LACK OF ENFORCEMENT OF EXTRACTION PROTOCOL

Most studies in Uttarakhand found the resin yield of Pine trees ranging from 0.25 and 8.0 kg/tree/year (average 3 kg/tree/year), which is on the lower side as compared to that of *P. ellottii* (3-8 kg/tree), *P. yunnanensis* (2-12 kg/tree), and *P. halepensis* (1-13.5 kg/tree) (López-Álvarez et al. 2023). In lower altitudes of the Himalayan region, the maximum resin yield was obtained in May and the lowest in October. Rosin obtained from the Borehole method is of better quality and fetches a higher price as it is free from impurities. In contrast, the Rill method rosin is yellow to dark yellow in colour due to open tapping and impurities. Tree height, needle colour, needle length, cone length, number of seeds/cone, and bark thickness show a significant positive correlation with oleoresin yield in *P. roxburghii* (Lekha 2002, Nimkar and Sharma 2007, Sood et al. 2019), but negatively correlated with relative humidity and rainfall (Sharma et al. 2018). Therefore, phenotypic tree characteristics (viz., radial growth, morphology of stem or leaves, needle length and thickness, mean leaf angle, LAI, crown ratio, bark and phloem thickness etc.) correlated with the resin yield of several Pine tree species globally, including *P. roxburghii* (Rawat et al. 2014, Li et al. 2022) must be selected for resin tapping to avoid the damage to Pine trees those are not suitable for resin tapping to avoid the vulnerability of forests to forest fire and tree fall due to wind storms. Resin tapping can weaken the structural integrity of trees, allowing fire to burn into the wood. The Forest Rule Book says that only trees that are at least 40 years old and have a diameter above 40 cm can be used for resin tapping and tapped four feet above the ground (Sharma et al. 2018). However, contractors do not follow the rules and regulations, causing the drying up of Pine trees and massive damage to forest wealth in the hands of unskilled labourers. As per the standard, only three kg of resin per year can be collected from a tree with a three-foot circumference. For 100 kg of resin extraction, at least 30 Pine trees are needed because a tree gives 0.5 L of resin weekly. Starting with a girth of 1.2 m and spacing each successive channel with an interval of 12 cm of bark in between, it should be possible to tap the trees for 35 years, omitting all considerations of occlusion (Anonymous 2014). However, contractors have been extracting resin more than stipulated amounts, even from younger trees. The inspection of some forest divisions of Almora and Bageshwar by Forest Officials of Uttarakhand in June 2023 revealed that at least 20 to 30% of trees used for resin extraction were found to be underage trunks that had smaller diameters (Azad 2023). Experiments conducted at FRI, Dehradun, in 1965 to find out the effect of resin tapping on trees below 90 cm girth using the Cup-and-Lip method recorded the tree mortality from 15-33% during three years in 15-20 cm diameter class (Lohani 1985). Also, the application of overdose and higher concentration of acid on the barks used as a freshener, and improper size of the blaze had adversely affected the growth of trees, and even the tapped surface area is not healing, resulting in the death of trees in many places (Attri et al. 2020). It is also noticeable that a certain quantity of resin flows down the old channels and saturates the earth, needles, and chips at the base of a tapped tree, making the forest floor vulnerable to fire. As per the Forest Rule Book, the needles and chips need to be swept clear to a distance of 1-2 m from the tapped trees, and the saturated earth is dug up and burnt or otherwise destroyed to keep the fire away. So, if the rules are enforced, there would be fewer losses to Pine trees due to forest fires.

In Uttarakhand, the old and outdated method of resin tapping (Cup-and-Lip Method) in the past has caused severe damage to the Pine trees and forests. Even after decades of discontinuing this method, the Pine trees are still vulnerable to fire as the channels made for resin tapping have yet to heal fully. Further, such trees are weakened again by resin tapping on the same trees using the Rill method and made vulnerable to fall due to windstorms and forest fire (Personal observation in June 2024 in Uttarakhand). The resin oozing out from these wounds is deposited at the base of the blaze. Often, these blazes are close to the ground (~ 15 cm) and catch fire, and the wounded part of the tree continues to burn even after the surface fire is over. Thus, the fire sometimes turns to crown fire as the saplings growing nearby close to mother trees or drooping branches of neighbouring trees catch fire during hot summer. Densification of forests due to the regeneration of Chir Pine and other associate species has enormously added to the fuel loading of the forest floor. This is one important aspect that needs to be studied in detail. According to some authors, low-intensity fire increases resin flow by inducing the differentiation of resin ducts and reducing resin viscosity. However, others have shown that the effect of fire is not reflected in resin yield (Zas et al. 2020). This observation requires further studies to establish the link between forest fire and resin production, as it can promote the interests of the resin collectors.

FOREST FIRE AND CHIR PINE

In recent years, Uttarakhand has stood out as the most forest fire-affected State. According to FSI, the highest number of fire alerts (3338) between April 23 and 30, 2024, have been recorded in Uttarakhand- the highest in India. In Uttarakhand, 0.17% of the total forest cover comes under the extremely fire-prone category, 1.60% under very highly fire-prone, 9.32% under highly fire-prone, 21.66% under moderately fire-prone and 67.25% under less fire-prone category (Anonymous 2019). The State reported all-time low damage due to forest fire during the COVID-19 epidemic, with a mere 172 ha area burnt in 2020, thus clearly pointing out human's dominant role in forest fires. According to some media reports from Uttarakhand, till May 2024, 1145 ha of forest was damaged due to fire, with an estimated loss of Rs. 25 lakh (@ Rs. 2183/ha), which is surprisingly a very low figure. The Govt. of Uttarakhand has set norms for estimating loss from forest fire; in case of surface fire, the loss is calculated @ Rs. 3000/ha for Pine forest, @ Rs. 2000/ ha for Sal forest and @ Rs.1000/ha for mixed forest (Upadhyay 2021). In case of crown fire, these values are @ IRs.1200/ha for Pine forest, IRs. 664/ha for Sal forest and IRs. 336 /ha for mixed forest. Similarly, for plantations, IRs. 20 is fixed for loss of one-year-old plant, IRs. 22 for two-year-olds, IRs. 25 for three-year-olds, IRs. 28 for four-year-olds, and IRs. 32 for those above five years of age. A recent study coordinated by ICFRE, Dehradun (Anonymous 2023) has reported the monetary loss of tangible goods of forests ranging between IRs. 9,595 and 3,52,752/ha forest (mean= IRs. 1,30,387/ha) due to low and medium severity forest fires of 2019 in Uttarakhand. Thus, it can be pointed out that despite this issue of grave national concern, the actual monetary loss to ecosystem goods (viz., timber, medicinal and aromatic plants, wild edibles, fodder, leaf litter etc.) and services (carbon sink value, habitat loss value, soil and water conservation, etc.) of forests continues to be unaccounted in loss estimation due to forest fire.

In Uttarakhand, Chir Pine forms extensive forests at lower altitudes from 500–1500 m, occupying about 16% (4,12,000 ha) of the total forest area. The Pine leaves falling every summer (pre-monsoon, March-May) on the forest floor are highly inflammable due to the presence of oleoresin and catch fire when there is a prolonged pre-monsoon drought and high atmospheric temperature (Negi 2019).Kala and Subbarao (2018) estimated that 1.37 - 2.37 million\ tons of Pine needles are annually dropped by Pine forests in Uttarakhand. The deposition of Pine needles on the forest floor and their slow decomposition increases fuel loading, making the forest floor vulnerable to forest fire. While its needles tend to catch fire easily because of their high resin content and high oxygen content in the loose litter, the thick bark (>1.5 cm) required ~15 minutes to kill the cambium of *P. roxburghii*, protects cambium from heat (Gumber et al. 2022). Fule et al. (2021) reconstructed fire regimes using tree-ring methods in the Chir Pine forests of Uttarakhand and reported that fires were widespread (mean fire intervals <6 yr), but of low severity, so most mature trees of this thick-barked species survived numerous burns. Fule et al. (2021) also found that despite the high fire frequency, fires were mostly asynchronous, indicating a bottom-up pattern of local ignitions. They observed that resin tapping of the Pines interacted with surface fire by allowing the fire to burn into the wood of some tapped trees and weaken their structural integrity to the point of breakage and concluded that the effects of anthropogenic fire and interactions with resin-tapping merit further investigations in this region. Chir Pine's characteristics, like dominance, gregarious distribution, and resistance to fire, have made it a biotic climax species that hinders the natural succession of Oak forests. It replaces the climax Banj Oak (*Quercus leucotrichophora*) forests in the mid-hills that governs the region's hydrological cycle (Singh and Singh 1992). During the colonial period, Oak forests were often cut down to produce charcoal that allowed the Chir Pine to spread further and be promoted commercially, mainly for lumber and resin. Das et al. (2021) analyzed satellite imagery data between 1991 and 2017 and found that dense Banj Oak forests have undergone substantial degradation and loss of area. In contrast, Chir Pine forests have expanded, mainly by replacing degraded Banj Oak stands that are likely to reduce biodiversity and ecosystem resilience. In the repeatedly burnt areas, some inferior weeds e.g., *Lantana camara* (shrub), *Anaphalis* spp., *Echinops cornigerus*, *Eupatorium odoratum, Imperata cylindrica, Parthenium hysterophorus* (herbs) etc. proliferate that does not allow other native species to grow. Such changes in forest composition have certain negative implications on the ecosystem services of these forests and wellbeing of local people (Joshi and Negi 2011).

WAY FORWARD

In conclusion, the Chir Pine forests of Uttarakhand are under stress due to faulty practices of resin extraction in combination with anthropogenic fire induced by long periods of drought and atmospheric warming, as witnessed in the summer of 2024. Hitherto, no research has been conducted to establish the interconnection between these factors responsible for the degradation of the Chir Pine forests of this region. With the increase in resin demand in India, which is expected to grow @ 7% during the forecast period 2022-30 for eco-friendly and bio-based products such as bio-fuels, fragrances, ink, adhesives, disinfectants, and coatings etc. (https://straitsresearch.com/report/pine-chemicals-market/india) the Uttarakhand and Himachal Pradesh are likely to tap more resin from Pine forests for earning revenue. Further, because of the Supreme Court's ban on tree cutting above 1000 m asl, forest stands are getting densified with small individuals who need more bark development before they are killed by fire. Moreover, they provide a ladder for crown fire. If Pine's natural forest structure is not revived, it would change the nature of forest fire, shifting from surface fire to crown fire, which is more destructive and would require different adaptation strategies. Pine cannot resprout, so once the trees are damaged by fire, they cannot revive, unlike resprouting Oaks. Thus, are the Pine trees stressed and more vulnerable to wind storms and fire? Sharma et al. (2018) have pointed out that the available devices for tapping resins are less efficient and time-consuming and have problems being handled by the workers involved in tapping resin. They cause more injury to the trees with low yield. There is a need to popularize the Borehole method of resin tapping. Improved tapping techniques and devices will minimize tree injury and help in the sustainable production of resin.

This article raises a few questions on the vulnerability of Pine forests to fire vis-à-vis the resin tapping practices that need to be answered by conducting well designed studies: (i) How much the trees tapped using the Cup-and-Lip method in the past are vulnerable to forest fire and weakening of basal part of the tree trunk to withstand windstorm as the resin channels/wounds are not still healed up. Many such trees can be found in the forests those catch fire that continues for a longer duration even

Plate 1. Pine trees tapped and wounded close to the ground using Cup-and-Lip method in the past are quite vulnerable to catch surface fire and turn it into crown fire and subsequent wind fall

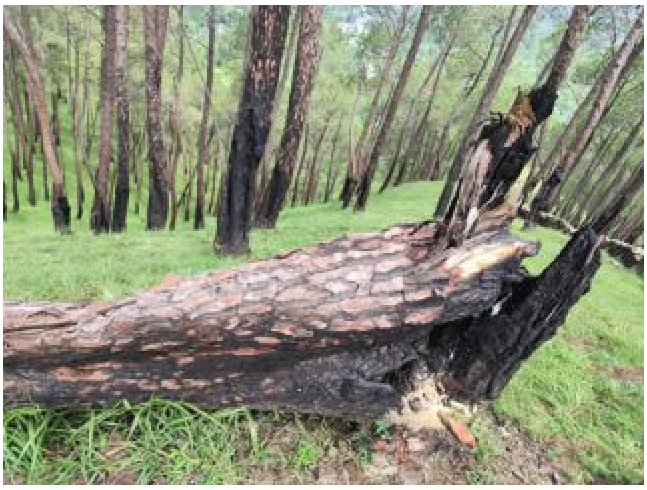

Plate 2. Pine tree fallen due to combined action of resin tapping and wind storm (note in the background some more vulnerable trees to forest fire and wind storm are seen)

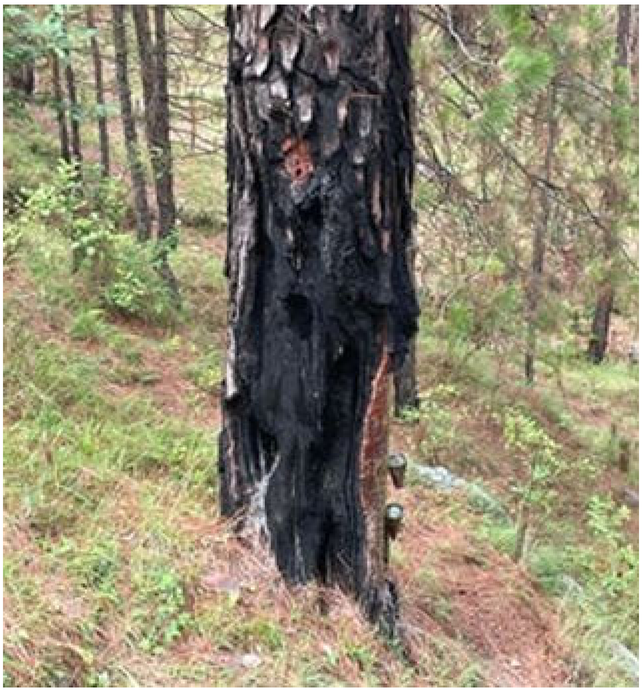

Plate 3. Pine tree tapped for resin using Cup-and-Lip method earlier and now using Rill method has weakened the tree base considerably (note in both the methods tapping is close to ground making the tree vulnerable to forest fire and subsequent wind fall)

Plate 4. Borehole method (blue holes) trials on the already tapped tree for resin using Rill method by Forest Department Uttarakhand

after the surface fire is over, thus making the trees vulnerable to a wind storm and fall (Plate 1 & 2). (ii) Does the Rill method applied on the already wounded Pine trees tapped using Cup-and-Lip method is making the trees more vulnerable to forest fire and weakening them to fall due to windstorm. (iii) What is the possibility of turning the surface fire to crown fire when resin tapping is done right from close to the ground, sometimes only about 1 feet, facilitated by the densification of forest stands (Plate 3). (iv) What are the limitations of the Borehole method over the Rill method of resin tapping that hinder its adoption in Uttarakhand (Plate 4). (v) Does a warmer atmosphere yield more resin and its connection with man-made intentional fire, particularly resin tappers, and (vi) The overall comparative advantage of the Borehole method over the Rill method on account of its easy application, economic efficiency, recovery of resin and vulnerability of trees to forest fire. Research is also required to examine whether trees subject to resin extraction become more vulnerable to fire than those not extracted for resin. Do they grow slowly; have smaller needle leaves and other morphological characters, etc. to identify the stress caused by resin extraction and fire to devise mitigating measures. Maintaining Chir Pine natural community - open type with grass cover is required as human dependence continues with them for many ecosystem goods and services.

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