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1. Pine resin tapping techniques used around the world

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Abstract. Pine tapping techniques used around the world for resin production differ widely, both in terms of methodology and pine species tapped. Results obtained in comparing three commercial operations in China, Brazil and Indonesia showed that it is possible to improve tapping operation yields in terms of labor efficiency and amount of pine trees tapped per year. Further developments are needed to establish more sustainable tapping operations, essentially based on detailed understanding of how pine trees produce resin. These advances may result in reduced interventions per season and mechanization of some of the activities, which could be coupled to the selection and propagation of pine species and individuals that show higher resin yield.

Introduction

By *tapping technique* we understand the commercial activity performed at a global level to produce pine resin, raw material that through different industrial processes is converted into gum rosin, turpentine and their derivatives. These renewable products are used for example in the

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manufacture of adhesives, printing inks, coatings and emulsifiers, to mention a few of a wide range of applications they find in our daily life.

More than 90% of the pine resin production in the world is concentrated in three countries: China, Brazil and Indonesia. India, Argentina, Mexico, Nepal, Russian Federation, Portugal, Spain, Cuba, Vietnam, Madagascar, Fiji, Honduras, South Africa, Colombia, Malaysia and Uruguay are also producers of pine resin. In 2010, the total world production of pine resin reached the amount of 1,114,000 metric tons.

More than 80 species of pine trees have been tapped for the production of resin in the world. Almost three quarters of it are produced from natural pine stands mainly from *P. massoniana*, *P. yunnanensis* and *P. merkussii*; the other quarter derives from planted stands, mainly of *P. elliottii* and various species of *P. caribaea*.

Four tapping techniques are applied for the production of pine resin. The “Chinese method” is applied in China and in other producing countries in South East Asia. The “American method” is used in South America and Europe. Other two very old techniques are also currently being used: the “Hugues or French method”, for example, in Indonesia and Mexico, and the “Mazek or Rill method”, mainly in India.

A comparison of three of these methods in selected areas in China, Brazil and Indonesia, showed that the tapping techniques need to be improved, to enhance tapping efficiency in view of future shortage of forest resources and hand labour. These improvements should come through the introduction of the present scientific knowledge about oleoresinosis, mechanization of some to the pine tapping activities, operation management and, of course, the selection of high resin producing pine trees to form new stands.

Pine resin producers

The top producer of pine resin is China, with and annual production of 830,000 metric tons. It is followed by Brazil an Indonesia, with production volumes in the order of 180,000 metric tons per year. Other producers of pine resin are India, Argentina, Mexico, Nepal, Russian Federation, Portugal, Spain, Cuba, Vietnam, Madagascar, Fiji, Honduras, South Africa, Colombia, Malaysia and Uruguay, totalling all of them together about 100,000 metric tons per year. This adds to a world total current production of pine resin of about 1,114,000 metric tons per year (Table 1). During the year of 2007 and because of good market and weather conditions, China produced a total of 1,116,000 metric tons of pine resin.

Table 1. Evolution of the world yield of pine resin (1990-2010) in major producing countries (in thousands of metric tons).

YEAR	CHINA	BRAZIL	INDONESIA	OTHERS	TOTAL
1990	408	52	56	407	923
1991	457	53	73	331	914
1992	559	55	80	294	988
1993	580	63	101	291	1,035
1994	500	73	95	271	939
1995	513	72	70	254	909
1996	533	82	82	219	917
1997	707	79	102	197	1,085
1998	507	103	69	148	827
1999	520	105	90	133	848
2000	527	103	80	105	815
2001	596	102	70	103	871
2002	723	95	87	93	998
2003	776	113	85	89	1,063
2004	841	93	84	77	1,095
2005	901	100	69	98	1,168
2006	933	106	90	90	1,219
2007	1,116	106	81	90	1,393
2008	795	106	78	95	1,074
2009	754	94	74	97	1,019
2010	830	105	74	105	1,114

Species tapped for pine resin production

During the history of pine tapping activities around the world, about 80 pine species have been tapped for the production of resin. Today more than 90% of the resin produced comes from five pine species (Table 2): *P. massoniana*, *P. yunanensis*, *P. elliottii*, *P. caribaea* and *P. merkussii*. Also *P. kesiya*, *P. oocarpa*, *P. pinaster*, *P. roxburgii* and *P. tabuleiformis*, are tapped for the production of pine resin.

Table 2. Main pine species currently tapped for the production of resin.

SPECIES	CHINA	BRAZIL	INDON ESIA	OTHER	TOTAL	%
P. massoniana	610,000				610,000	54.7
P. yunnanensis	150,000				150,000	13.4
P. elliottii	60,000	50,000		30,000	140,000	12.6
P. caribaea	10,000	45,000		30,000	85,000	7.6
P. merkussii			69,000		69,000	6.2
Other species		10,000	5,000	45,000	60,000	5.5
TOTAL	830,000	105,000	74,000	105,000	1,114,000	100.0

In the 1960's 50% of pine resin was obtained in the USA from *P. palustris* and *P. elliottii* [1]. At that time also *P. pinaster*, *P. halepensis*, *P. sylvestris*, *P. oocarpa*, *P. pseudostrobus* and *P. longifolia* where tapped in France, Russia, Spain, Portugal, India, México and Greece. Since the second half of the XIX century and approximately every five decades, the pine tapping activity has shifted from one place to the other of the globe, because of labour costs and shortage of forest resources. The chemical industry has slowly adapted to the shift in source of pine resin over these periods of time.

Natural versus planted pine forests

Pine trees grow naturally in the northern hemisphere and Indonesia, whereas they are planted for commercial use in the southern hemisphere. When we analyse the tapping techniques used worldwide, it is important to know if the forest where the activity develops is natural or planted. An operation developed in a natural forest is associated with hand labor formed by individuals that extract pine resin and sell it to an industry, either directly or through a trader. If the operation is carried out in a planted forest, as for example in South America, in most of cases it is performed by an enterprise that hires the personnel required to tap the pine trees, and takes care of the operation following standard management procedures.

These two different ways of proceeding will be directly related to the tapping techniques used during the operation. Natural pine forests tapped for pine resin by individuals (often peasants) are related to the use of archaic and inefficient tapping techniques. The modern pine tapping technique, like the "American method", is generally applied in planted forests (or natural managed forests) by enterprises whose aim is to produce pine resin commercially and sell directly to the industry. In many cases, industries that convert pine resin into gum rosin and turpentine own or participate in these tapping enterprises.

Tapping techniques

Around 1850, Pierre Hugues develops the first pine resin tapping technique in the Landes de Gascogne, France, system that is applied even nowadays, for example, in Indonesia. In 1869, Steele is granted an US patent [2] in which he describes the basis of the fish bone tapping technique. Later, the technique was going to evolve, through some modifications performed in the 1950's by Mazek Fialla in Europe, and become known today as the Rill method, applied in India. We can identify four tapping techniques currently used around the world (Figure1):

- ***Chinese method.*** A downward-pointing V-shaped groove is cut every day, deep enough to reach the secondary xylem. The first groove is cut about 1.2 m above the ground, and subsequent grooves are cut below it. The groove reaches roughly half way around tree's circumference. No chemical stimulant is used. This method is used mainly in China.
- ***American method.*** A horizontal groove is cut every 15 to 18 days. The grooves are cut upward, the first at 20 cm above the ground. Only the bark and phloem are removed. The length of the grooves is about one-third of the tree's circumference and the height varies from 2 to 3 cm. A stimulant paste with 18 to 24 percent sulphuric acid (H_2SO_4) is applied. In the paste formulation, stimulants are also used as chemical adjuvants, such as, for example, CEPA (2-chloroethyl-phosphonic acid, an ethylene precursor) or salicylic acid. This method is used, for example, in Brazil, Argentina, Portugal and Spain.
- ***Hugues or French method.*** Slices of 8 to 10 cm wide are cut into the trunk every 10 to 15 days, reaching the secondary xylem. The cut surface may extend to 1.8 m from the ground after two years of extraction. This method was developed in the mid-nineteenth century in France and is now used mainly in Indonesia.
- ***Mazek or Rill method.*** V-shaped grooves, 2 to 3 mm wide are cut every 3 to 7 days. The grooves are cut upwards. A stimulant of 50 percent H_2SO_4 and 50 percent hydrochloric acid (HCl) is applied in the form of a spray. This method is currently used in Indonesia and India.

Other extraction methods, such as the borehole [3, 4] or Eurogem [5, 6] closed-blaze method, in which the oleoresin is collected in a closed recipient, have been tested but not yet significantly applied at commercial scale.

Figure 1. Pine resin tapping techniques.

Chemical stimulation

The historical development of the “American method”, as the only modern tapping technique recognized today, starts in the early 1920’s, with the research of Eloise Gerry [7] in the USA, aiming at understanding the production of pine resin. At about the same time, the concept of chemical stimulation was developed in Russia. By chemical stimulation we understand the use of chemical products applied to the pine tree to enhance the production of pine resin. Since the first US patent granted to Hesseland in 1936 [8], a series of products have been tested. In 1967, R.W. Clements [9] was granted a US patent that described the first chemical stimulant in paste form. Prior to this, the products where sprayed on the wound that was opened to let pine resin flow. In this case, the active product added to the stimulant paste was sulphuric acid (H_2SO_4).

Later, in another US patent, Wolter [10] described the formulation of a stimulant paste whose active ingredient, besides sulphuric acid, was CEPA (2-chloroethylphosphonic acid). After being applied on the wound, CEPA migrates deep into the pine stem where, under appropriate chemical conditions, is decomposed, generating ethylene. The presence of ethylene triggers resin production by the pine tree [11, 12]. More recently, salicylic acid has been successfully tested as an active ingredient in stimulant paste for pine tapping [13], and is currently used commercially in some areas of Brazil.

Case study – comparison between three tapping techniques

With the aim of comparing the efficiency of different tapping techniques, we selected three different commercial operations in China, Brazil and Indonesia, during the 2007/2008 season crop [14]. The characteristics of these three locations are shown in Table 3. The summary of data collected at the end of the crop season for each location is shown in Table 4, whereas labor efficiency is depicted in Table 5.

Table 3. Characteristics of the locations of pine tapping operations.

Location	CHINA	BRAZIL	INDONESIA
Density (trees/hectare)	700	800	350
Pine species	*P. elliottii*	*P. elliottii*	*P. merkusii*
Age (years)	12	12	45
Type of forest	planted	planted	natural
DBH (cm)	~ 15	~ 25	~ 35

Table 4. Yield and technical characteristics of the tapping operations.

Location	CHINA	BRAZIL	INDONESIA
Tapping technique	**CHINESE**	**AMERICAN**	**MAZEK**
Faces tapped per tree	1	2	2
Pine resin (kg/year)	2.00	3.00	2.25
Streak frequency (days)	1 or 2	15	3
Stimulation	No	Paste w/ H_2SO_4	Spray H_2SO_4 + HCl
Season	5 / 6 months	9 months	12 months
Yield per time (g/day)	11.2	19.7	5.8
Yield per area of streak (kg/m^2)	25	40	0.7
Years in production	5 to 7	~ 20	2 to 3
Streak depth	xylem	cambium	xylem

Table 5. Labor efficiency and yield in the different tapping operations.

Location	CHINA	BRAZIL	INDONESIA
Eficiency of labour			
Trees tapped per worker	1,500	7,000	1,000
Hectares tapped per worker	2.18	8.75	2.81
Metric tons produced per worker	3	35	4.6
Amount of resin per tree area tapped			
Yield of pine oleoresin in kilograms per square meter tapped per year	25	40	~ 1

Future developments

The case study described shows that the efficiency of the operation of producing pine resin depends on the technique applied, the characteristics of the pine forest being exploited, and the hand labor available. A poor tapping technique results in the rapid exhaustion of the forest resource, and if it is applied to natural growing forests with poorly trained labor force, the operation is unsustainable.

Pine resin is a renewable raw material demanded by the chemical industry for the formulation of products that we use in our daily life. Its sustainable production has to be linked to:

- Application of knowledge about the mechanisms of resin production by pine trees to improve tapping methods;

- Using techniques that require less intervention, i.e., strategies that demand less interaction of the worker with the pine trees during the production season. To that end, different forms of mechanization of some of the operations have been sought during the past decades, but no one has reached the level of commercial application.
- Selection and propagation of pine species, hybrids, and individuals that show higher resin yield.

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