Izvirni znanstveni članek / Original scientific paper

RESIN YIELD OF *Pinus nigra* AND *Pinus sylvestris* IN THE SLOVENIAN KARST
DONOS SMOLE ČRNEGA BORA (*Pinus nigra*) IN RDEČEGA BORA (*Pinus sylvestris*) NA KRASU V SLOVENIJI

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ABSTRACT

The aim of our research was to study the impact of various environmental factors on the resin production of pines in the Slovenian Karst. Five plots were established – three in *Pinus nigra* (Arnold) stands and two in *Pinus sylvestris* (L.) stands. On each plot, the 19-20 most vigorous dominant or codominant trees with a minimum diameter at breast height (DBH) of 20 cm were selected and their resin yield analysed in 2012. Resin yield in *P. nigra* was considerably higher than that in *P. sylvestris*. The average resin yield per tree during the study period of 102 days was 1.144 kg for *P. nigra* and 0.612 for *P. sylvestris*. There were substantial differences in resin yield among individual trees in the study period: 0.336-2.487 kg for *P. nigra* and 0.249-1.270 kg for *P. sylvestris*. The resin yield in *P. nigra* was considerably higher for the trees with larger DBH, while this was not the case in *P. sylvestris*. Tree species was the most important factor in resin yield. Increased precipitation resulted in higher resin yields on most plots, whereas better site productivity positively affected resin yield on all *P. nigra* plots but not on *P. sylvestris* plots.

Key words: black pine, Scots pine, resin production, resin yield, Slovenian Karst

IZVLEČEK

Namen naše raziskave je bil proučiti vpliv različnih dejavnikov na proizvodnjo borove smole na Krasu v Sloveniji. Za ta namen smo določili 5 raziskovalnih ploskev, in sicer tri ploskve v sestojih črnega bora (*Pinus nigra* Arnold) in dve v sestojih rdečega bora (*Pinus sylvestris* L.). Proizvodnjo smole smo spremljali v letu 2012, ko smo na vsaki ploskvi izbrali 19 – 20 dominantnih ali kodominantnih dreves z minimalnim prsnim premerom 20 cm. Analiza je pokazala, da je proizvodnja smole pri črnem boru značilno večja kot pri rdečem boru. Povprečna količina smole na drevo v času periodičnega spremljanja 102 dni je pri črnem boru dosegala 1,144 kg in pri rdečem boru 0,612 kg. Variabilnost v proizvodnji smole je bila znotraj vrste velika, pri črnem boru med 0,336 – 2,487 kg in pri rdečem med 0,249 – 1,270 kg. Pri črnem boru je bila količina proizvedene smole v pozitivni povezavi z debelino drevesa, medtem ko pri rdečem boru te odvisnosti nismo potrditi. Na količino smole pri črnem boru pozitivno vpliva produktivnost rastišča. Ugotovili smo, da na smoljenje črnega bora pozitivno vpliva količina padavin, medtem ko višje dnevne temperature dnevni donos smole zmanjšujejo.

Ključne besede: črni bor, rdeči bor, smolarjenje, donos smole, Kras

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1 UVOD
1 INTRODUCTION

Resin tapping dates back to Gallo-Roman times and began in Gascony, France. The practice was prosperous until the beginning of the world economic crisis of 1929, after which the demand for resin started to decline (Piškorić, 1992). This time-honoured and labour-intensive practice is performed by incising, i.e. damaging, the outer layers of the bark of a pine or some other conifer in order to collect the resin or sap. The two main components of resin are turpentine and gum rosin. Rosin is widely used to produce adhesives, paper sizing agents, printing inks, detergents, etc., while turpentine is usually the raw material for varnishes, perfume, disinfectants, cleaning agents, etc. (Wang et al., 2006).

The total world production of resin products has remained fairly stable since the 1960s and reached its maximum in 2007, when production was approximately 1,050,000 tonnes of gum rosin and 170,000 tonnes of turpentine. The most valued type of turpentine, Iberian turpentine, is of a very high quality and by 15-20% (and up to 50%) more expensive than turpentine from other parts of the world. However, its use is currently limited by its low production (La resina, 2009). China is presently the largest producer of gum rosin globally with more than 70% of the total production, followed by Latin America (notably Brazil) with 10% and Indonesia with 7% (Cunningham, 2009).

The demand for resin derivatives in Europe is growing, but European production amounts to less than 10% of its consumption. The largest European producers are France, Portugal, Spain and Greece, while the largest consumers are Germany and the Netherlands, followed by Spain and France (La resina, 2009). However, resin tapping in Europe has declined considerably as a consequence of the introduction of synthetic resins and low-price resin from countries such as China and Brazil. In Spain, the number of resin tappers has decreased considerably in recent years, though in some areas, such as Segovia, resin tapping has been successfully preserved (La resina, 2009).

Several pine species are used for resin tapping worldwide: *Pinus massoniana* Lamb. in China; *P. elliottii* Engelm. in Brazil, Argentina and South Africa; *P. oocarpa* Schiede ex Schltdl. in Mexico and Honduras; *P. merkusii* Jungh. & de Vriese in Indonesia and Vietnam; *P. roxburghii* Sarg. in India and Pakistan; *P. caribaea* Morelet in Venezuela; and *P. radiata* D. Don. in Kenya (Coppen and Hone, 1995). In Spain, France and Portugal, the main resin-tapping pine species is *P. pinaster* Aiton, while in Central Europe and in the Adriatic region, resin tapping has traditionally been carried out on *Pinus nigra* Arnold and *Pinus sylvestris* L. (Bojanin, 1967).

In Slovenia, the first serious attempts at resin tapping started in the Primorska region in 1938, where resin tapping of both *P. nigra* and *P. sylvestris* began according to the French method. In 1946, the first resin-tapping experiments were carried out in Prekmurje and Dravsko polje using the German method, and from there, this method continued to spread into the Karst region. In that period, resin tapping in Slovenia increased every year. The annual resin yield was 84.5 tonnes in 1947, 119.3 tonnes in 1948, 105 tonnes in 1949, 140 tonnes in 1950 and 148 tonnes in 1951 and 1952 (Kiauta, 1953). At that time, *P. sylvestris* was mainly used for resin tapping along with the short-term modified German method (also named the Chorin-Finowtal method) (Pejoski, 1952). The seasonal resin yield per individual tree in Slovenia at that time was 1.06 kg for *P. sylvestris* and 1.33 kg for *P. nigra* (Pejoski, 1953). Near the town of Sežana, the reported average seasonal resin yield per single tree was 1.4 kg for *P. nigra* (Simić, 1953). For comparison, the average seasonal resin yield per single tree in similar conditions and for the same species on the Croatian island of Brač was 0.58 kg at that time.

At the present time, large areas of once desolate Slovenian Karst are covered by plantations of predominately *P. nigra*. They cover a surface area of more than 16,500 ha (Diaci et al., 2014) and are considered ecologically and mechanically unstable. They are threatened by fire and fungal diseases, and their wood productivity is low. An important goal of forest management plans is the gradual transformation of these stands into ecologically more stable broadleaved forests with improved productivity. However, alongside timber production provided through the final cutting, it is also possible to generate additional income from non-timber forest products. In this respect, resin tapping in the Slovenian Karst region, once well established but now completely abandoned, is an option worth considering by a forest owner in the years prior to the final cut of a pine plantation.

The main goals of our study were to determine the total amount and differences in resin yield between *P. nigra* and *P. sylvestris* as well as the influence of environmental factors, site productivity and tree diameter at breast height (DBH) on total resin production.

2 METHODS

2 METODE

Five plots were established near the town of Sežana in the Karst region of Slovenia. Of these five plots, three were placed in *P. nigra* stands and two in *P. sylvestris* stands (Fig. 1). On each plot, the 19-20 most vigorous dominant or codominant trees were selected. For each selected tree, DBH, GPS coordinates and tree vigour were measured or assessed. According to Smith et al. (1997), the size of the crown and its density indicate vigour; therefore, four crown vigour classes were used: 1 – full vigour, 2 – good to fair vigour, 3 – fair to poor vigour, and 4 – very poor vigour. All trees included in the research sample belonged to either vigour class 1 or 2. The altitude and plant association of each plot were also assessed. The predominant association on the plots was *Seslerio-Ostryetum*, followed by *Seslerio autumnalis-Quercetum petraeae* (Table 1).

The amount of harvested resin was correlated with environmental data from the nearby Godnje meteorological station (45.75530 N, 13.839775 E). The station is located at an altitude of 316 m and, on average, 3 kilometres from individual research plots. Meteorological data of individual days (minimum, maximum and average air temperature 2 m above the ground; precipitation; and sun duration) were used to calculate averages of individual tapping periods (3-6 days). These mean values were correlated with the resin yield in the corresponding period (25 tapping periods in total). Mean values of climatic parameters are shown in table 2.

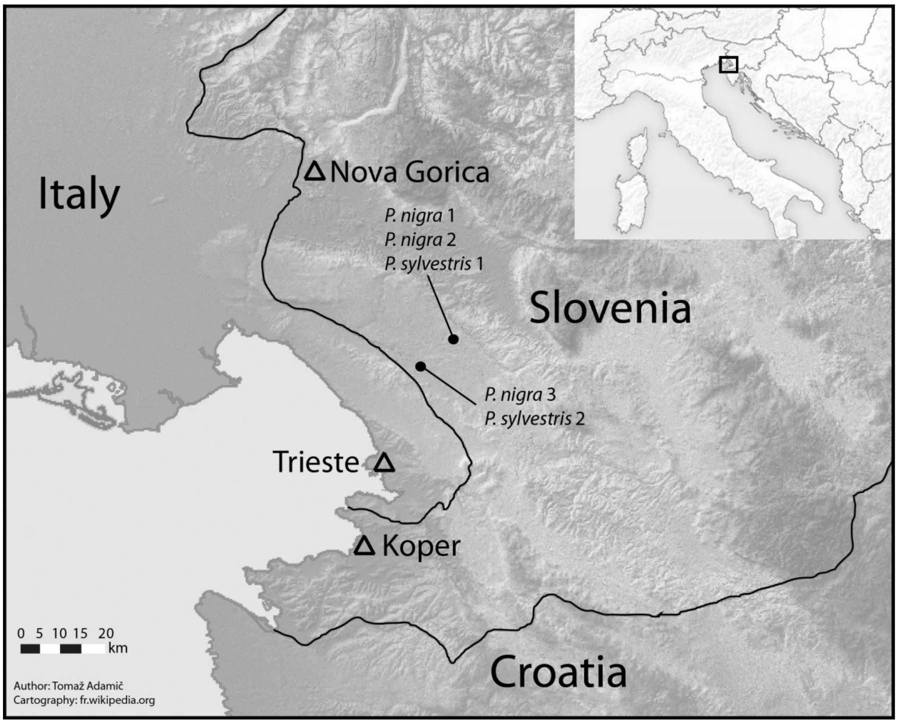

Fig. 1: Locations of the studied plots

Slika 1: Lokacije raziskovalnih ploskev

Table 1: Main characteristics of the studied plots

Preglednica 1: Glavne značilnosti raziskovalnih ploskev

Plot *Ploskev*	No. of trees *Št. dreves*	Plant association *Rastlinska združba*	Coordinates *Koordinate*	Altitude *Nadmorska višina*	Distance to meteo. station *Razdalja do meteo. postaje*
P. nigra 1	19	*Seslerio-Ostryetum*	N 45.78489° E 13.85494°	290 m	3.5 km
P. nigra 2	19	*Seslerio-Ostryetum*	N 45.78177° E 13.85765°	290 m	3.3 km
P. nigra 3	20	*Seslerio autumnalis-Quercetum petraeae*	N 45.75681° E 13.80976°	263 m	2.3 km
P. sylvestris 1	20	*Seslerio-Ostryetum*	N 45.78053° E 13.85376°	280 m	3.0 km
P. sylvestris 2	19	*Seslerio autumnalis-Quercetum petraeae*	N 45.75396° E 13.80308°	273 m	2.9 km

Based on our preliminary tests from 2011 that showed virtually negligible resin yields before mid-June, we started incising the trees in mid-June 2012 and ended at the end of September 2012 when the weather cooled. We used the Slovenian method, which is almost identical to the German method, in which 1.5-2 cm wide incisions are made in 8-10-day intervals. The main difference is that the incision width is smaller in the Slovenian method (0.5-1.5 cm). The method was further adapted with the use of tools – instead of the traditional, bent resin-tapping knife, a straight carpentry chisel was used. This enabled more effective work, particularly with knotty wood and thick bark. At the bottom of every wound's vertical channel, we carved out a bed for a pot that was then nailed to the stem. After removing the thicker parts of the rhytidome, cleaned bark was stripped off in the shape of a triangle and one wound per tree was incised. The wound covered about 40 per cent of the tree perimeter (Fig. 2). It should be noted that no stimulating paste was used in the experimental process. The harvest cycle ranged between 3 and 6 days. One of the reasons for choosing a short tapping period was that the obtained resin was also chemically analysed (data not shown). The resin was stored more quickly and thus the evaporation of turpentine was reduced. In each cycle, resin was collected and weighed and new incisions were carved simultaneously. The resin was collected with a spoon and stored in containers. Weighing was carried out with a Gorenje KT05NS kitchen scale with an accuracy of one gram.

To study the impact of site conditions on resin yield, the site productivity of the plots was assessed. Five dominant or codominant trees from each plot were cored with an increment borer to determine their age. Prior to analysis, the cores were prepared with established

Table 2: Climatic variables from the nearest meteorological station at Godnje (approx. 3 km from the research plots) for the period from 17 June to 28 September 2012

Preglednica 2: Meteorološki parametri območja raziskave, pridobljeni z bližnje meteorološke postaje Godnje (oddaljenost 3 km od raziskovalnih ploskev), za obdobje med 17. junijem in 28. septembrom 2012

	Mean values of tapping periods *Povp. vrednost med obhodi*	**Total period** *Celotno obdobje*
Average air temp. (° C) *Povprečna temp. zraka (° C)*	22.45	/
Max. air temp. (° C) *Maks. temp. zraka (° C)*	29.26	/
Min. air temp. (° C) *Min. temp. zraka (° C)*	16.98	/
Precipitation (mm) *Padavine (mm)*	9.16	229
Sun duration (h) *Sončno obsevanje (h)*	40.73	1018.2

Data from the archives of the Slovenian Environmental Agency (ARSO, 2018)

Fig. 2: Initially carved triangle 14 days after bark removal (photo: Brecelj, 2011)

Slika 2: Smolina v obliki trikotnika 14 dni po odstranitvi skorje (foto: Brecelj, 2011)

dendrochronological methods (Stokes and Smiley, 1968). The counting of annual rings was performed with a Nikon SMZ80 stereoscopic microscope with 10× magnification. For describing the site productivity of *P. nigra* plots, site classes (Gatzojannis, 1999) were used and a site index (Halaj et al., 1987) for *P. sylvestris* plots.

To assess the correlation between resin yield and the various environmental factors (air temperature, amount of precipitation and sun duration), Pearson's correlation was used. When considering the potential impact of tree species and the diameter of the tree on resin yield, analysis of covariance (ANCOVA) was contrived, where 'tree species' was a fixed factor and diameter at breast height (DBH) was used as a covariate. All computations were performed with Microsoft Excel 2013 and IBM SPSS Statistics 25.0 software.

3 RESULTS
3 REZULTATI

The maximum resin yield of a single tree in the study period of 102 days was 2.487 kg for a *P. nigra* tree on plot *P. nigra* 3, where the best site conditions (site class 1) were recorded. The minimum resin yield produced per tree was 0.249 kg for a *P. sylvestris* tree on plot *P. sylvestris* 2. While the average resin yield was very similar on both *P. sylvestris* plots, it was more variable on the *P. nigra* plots (Table 3).

The analysis of covariance showed that the covariate, diameter at breast height, was significantly related to resin yield, $F = 17.10$, $p < 0.001$ (Table 4). Moreover, the value of b for the covariate ($b = 23.3$, $p < 0.001$) means that resin yield increases with DBH. However, further analysis showed that resin yield was significantly related to DBH only in *P. nigra* (Pearson's correlation: 0.462**) and not in *P. sylvestris* (Pearson's correlation: 0.089 n.s.) (Figure 4). There was also a significant effect of 'tree species' on resin yield after controlling for the effect of DBH, $F = 18.00$, $p < 0.001$ (Table 4). The average resin yield in the study period was considerably higher for *P. nigra* (1.144 kg/tree) compared to *P. sylvestris* (0.612 kg/tree) (see Table 3 and Figure 3).

The resin yield correlated with most of the studied environmental factors on *P. nigra* plots, while on *P. sylvestris* plots no such correlation was detected (Table 5). The correlation between resin yield and average daily air temperature was statistically significant (P<0.01) for the two plots with the highest resin yield – *P. nigra* 2 and 3. For these two plots, there was also a statistically significant correlation between resin yield and average, maximum and minimum air temperatures (Table 5). All of these correlations were negative, which means that resin yield decreased with increasing air temperature (the average air temperature during our study was 22.5 °C on all plots, with the maximum temperature

Table 3: Average (x̄), maximum (max.) and minimum (min.) resin yield per tree for all plots during the study period (102 days)

Preglednica 3: Aritmetična sredina (x̄), maksimum (max.) in minimum (min.) donosa smole na drevo po posameznih ploskvah v obdobju periodičnega spremljanja 102 dni

	x̄ (kg)	Max. (kg)	Min. (kg)	DBH (cm) *Prsni premer (cm)*	Site productivity *Produktivnost rastišča*
P. nigra 1	0.942	1.923	0.421	39.95±9.70	Site class 3 (A)
P. nigra 2	1.116	2.434	0.336	32.84±7.06	Site class 2 (A)
P. nigra 3	1.361	2.487	0.597	39.45±5.78	Site class 1 (A)
P. sylvestris 1	0.632	1.270	0.283	31.25±6.95	SI 25 (B)
P. sylvestris 2	0.590	1.139	0.249	30.63±2.79	SI 25 (B)
P. nigra total	1.144	2.487	0.336	37.41±8.19	/
P. sylvestris total	0.612	1.270	0.249	30.94±5.29	/

A: Gatzojannis, 1999; B: Halaj et al., 1987

Table 4: F-ratios of the analysis of covariance
Preglednica 4: F-vrednosti analize kovariance

Source of variation *Vir variacije*	*F*
Diameter at breast height *Prsni premer*	17.10***
Tree species *Drevesna vrsta*	18.00***

n.s. P>0.05; * 0.01<P< 0.05; **0.001<P<0.01; *** P<0.001

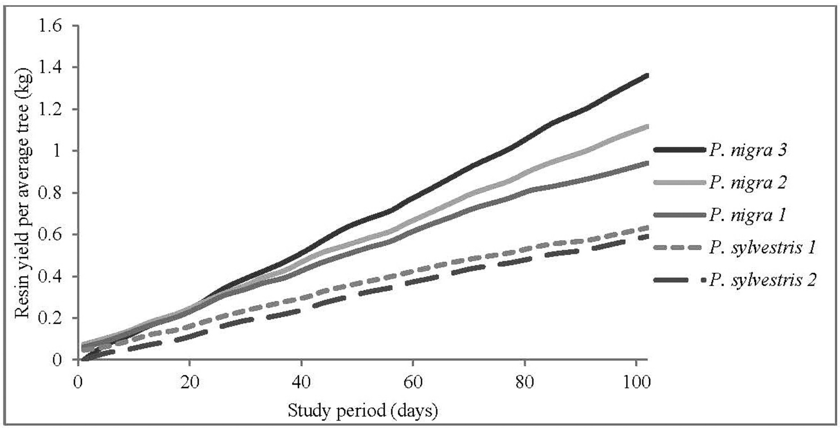

Fig. 3: Cumulative resin yield per average tree on each plot

Slika 3: Skupni povprečni donos smole na posameznih ploskvah

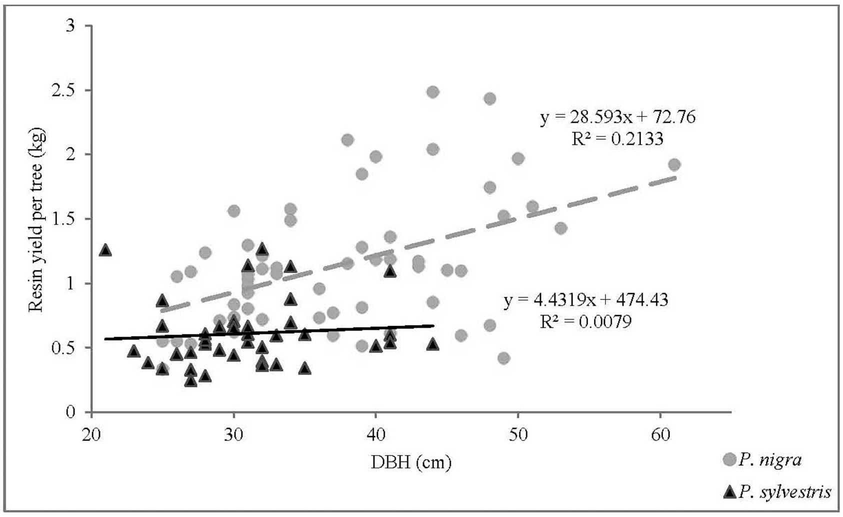

Fig. 4: Scatter plots of resin yield per tree as a function of DBH with regression lines fitted

Slika 4: Donos smole glede na prsni premer drevesa

Table 5: Correlations (Pearson's correlation) between resin yield and various environmental factors

Preglednica 5: Odvisnost (Pearsonov koeficient korelacije) med donosom smole in različnimi okoljskimi dejavniki

	Average air temp. *Povprečna temp. zraka*	Max. air temp. *Maks. temp. zraka*	Min. air temp. *Min. temp. zraka*	Precipitation *Padavine*	Sun duration *Sončno obsevanje*
P. nigra 1	-0.094n.s.	-0.097n.s.	-0.169n.s.	0.072n.s.	-0.100n.s.
P. nigra 2	-0.592**	-0.510**	-0.660***	0.423*	-0.361n.s.
P. nigra 3	-0.547**	-0.497*	-0.530**	0.560**	-0.025n.s.
P. sylvestris 1	-0.202n.s.	-0.210n.s.	-0.282n.s.	-0.135n.s.	-0.094n.s.
P. sylvestris 2	-0.067n.s.	-0.084n.s.	-0.103n.s.	0.145n.s.	0.209n.s.

reaching as high as 36 °C) (ARSO, 2018). The amount of precipitation had a positive effect on resin yield on plots *P. nigra* 2 and 3. Sun duration had no detectable effect on the resin yield in any of the studied plots.

4 DISCUSSION
4 RAZPRAVA

The available data on the average annual resin yield per single tree are relatively scarce and even those that exist are about various tree species and various site and climate conditions. In Segovia, Spain, the annual average resin yield per single *Pinus pinaster* tree was 3.54 kg between 1998 and 2002 and 3.37 kg between 2003 and 2007 (La resina, 2009), while in the Almazan and Burgo de Osma areas, the annual resin yield for *P. pinaster* in the last century was quite stable at around 2.5 kg/tree (Bravo et al., 2010). In the Karst region of Slovenia, for *P. nigra* the recorded average annual resin yield per tree was 1.33 kg (Pejoski, 1953) and 1.4 kg (Simić, 1953), whereas for *P. sylvestris* it was 1.06 kg (Simić, 1953). The average annual resin yield per single tree in our study was somewhat lower (Table 3), which is especially true for *P. sylvestris*, while for *P. nigra* the differences were smaller, particularly if we only look at our most productive plot (*P. nigra* 3), where the average annual resin yield (1.361 kg) was comparable to that from 60 years ago. The differences are likely a consequence of the different duration of resin-tapping seasons – our study period lasted for only 102 days, while those of the other mentioned studies were up to 6 months. On the other hand, our shorter tapping period of 3-6 days in comparison with the German method (8-10 days) and the Spanish-Portuguese method (15-21 days) could have contributed to the increased yield, since continuous incision and fresh wounds probably accelerate resin production. But again, in most other studies, various stimulating pastes were used, while in our analysis we did not use them. Thus, direct comparisons and differences between experiments remain difficult to explain. However, we can conclude that the adapted method used in this study can be successfully applied should resin tapping start again in the Karst region, even if it is only a complementary activity for forest owners.

Various methods for increasing resin yield have been considered, including genetic improvement (La resina, 2009), fertilization, wounding and fungal inoculation (Knebel et al., 2008), the use of stimulant pastes containing active components such as sulphuric acid and an ethylene precursor (CEPA) (Rodrigues et al., 2008; Pio and Valente, 1998), prescribed burnings

(Cannac et al., 2009), metal adjuvants (Rodrigues et al., 2011), and others. In the study by Novick et al. (2012) on *Pinus taeda* L., better soil nutrient availability, i.e. fertilization, increased resin flow, although the authors acknowledged that the majority of similar studies observed that fertilization had no effect on resin flow. The reasons for some trees producing considerably greater quantities of resin than others are still not entirely known. In our study, more precipitation resulted in higher resin yields on most plots (Table 5). This is in line with the findings of Rodriguez-García et al. (2015), who concluded that water availability during the summer positively affected resin yield. In contrast, Gaylord et al. (2007) found that the highest resin flow of *Pinus ponderosa* trees occurred when water stress was the highest and photosynthesis was low. The amount of precipitation can also affect other tree secretions such as gum arabic, for which more precipitation immediately prior to the tapping season resulted in a higher yield for *Acacia senegal* (L.) Willd. trees in western Sudan (Ballal et al., 2005). It is possible that our results showed a negative correlation between resin yield and air temperature owing to the fact that the temperature range was too small to reflect an otherwise potentially positive correlation.

For *P. nigra*, DBH had a significant impact on resin yield. Thicker *P. nigra* trees mostly had higher resin yields compared to thinner ones. This is in line with the findings of Rodríguez-García et al. (2014), who established that the tree diameter of *P. pinaster*, along with the percentage of live crown, stand density and soil quality, strongly influenced resin yield. The same was also confirmed by Davis and Hofstetter (2014), who found that the resin flow of *P. ponderosa* rapidly increased with tree diameter but plateaued when tree diameter exceeded 40 cm. Interestingly, although plots *P. nigra* 3 and 1 contained trees of almost the same average DBH (39.45 and 39.95 cm, respectively), *P. nigra* 3 had a considerably higher resin yield. This is possibly due to the better site productivity of plot *P. nigra* 3 (site class 1) compared to plot *P. nigra* 1 (site class 3). The site classes of all three *P. nigra* plots coincided well with their respective resin yields (Table 3). The site productivity of both *P. sylvestris* plots was, on the other hand, the same (SI 25), which likewise coincides with the fact that differences in resin yields between these two plots were also much smaller. Wang et al. (2006) similarly acknowledge the impact of site productivity on resin yield, as they cite that the profit from resin increases with increasing site index (SI).

We can conclude that the adapted method from our study can be used for resin tapping in the Slovenian Karst region. The study findings could be interesting to small and medium-sized forest owners in the region, since resin tapping could mean a viable source of additional income. Our aim was not a study of the market for resin derivatives, which is a story by itself. However, the resin yields of *P. nigra* from our study are generally similar to those of commercial resin tapping in the region in the past.

5 SUMMARY

5 POVZETEK

Prvi resni poskusi smolarjenja v Sloveniji so se začeli šele leta 1938, in sicer na Primorskem. Smolo so pridobivali iz dreves črnega (*Pinus nigra*) in rdečega bora (*Pinus sylvestris*) po t.i. francoski metodi, leta 1946 pa so po nemški metodi opravili tudi prve poskuse smolarjenja v Prekmurju in na Dravskem polju, od koder se je metoda razširila tudi na Kras. Letna proizvodnja smole v tistem obdobju se je vsako leto povečevala, in sicer od 84,5 tone v letu 1947 do 148 ton v letih 1951 in 1952. Sezonski donos smole na posamezno drevo v Sloveniji v tistem času je bil 1,06 kg za rdeči in 1,33 kg za črni bor.

Danes imamo na slovenskem Krasu več kot 16.500 ha nasadov, pretežno črnega bora, ki veljajo za ekološko in mehansko manj stabilne sestoje. V času preoblikovanja teh sestojev v ekološko bolj stabilne gozdove listavcev bi v smislu proizvodne funkcije pred končnim posekom dreves lahko razmišljali o dodatnem donosu oz. dohodku, ki bi ga prinašala proizvodnja smole. Namen naše raziskave je bil preučiti vpliv različnih dejavnikov na proizvodnjo borove smole na Krasu v Sloveniji. Na treh ploskvah v sestojih črnega bora in dveh v sestojih rdečega bora smo spremljali proizvodnjo smole v letu 2012. Na vsaki ploskvi smo izbrali 19 – 20 dominantnih ali kodominantnih dreves z minimalnim prsnim premerom 20 cm. Postopek smolarjenja smo opravili po slovenski metodi, ki je skoraj identična nemški, pri kateri je širina zareze med 1,5 – 2 cm, medtem ko je pri slovenski med 0,5 – 1,5 cm. Druga razlika je v uporabi orodja, namesto tradicionalnega ukrivljenega smolarskega noža smo uporabili ravno tesarsko dleto.

Povprečna količina pridobljene smole na drevo v času periodičnega spremljanja 102 dni je pri črnem boru dosegala 1,144 kg in je bila značilno večja kot pri rdečem boru (0,612 kg). Variabilnost v proizvodnji smole je bila znotraj vrste velika, pri črnem boru je znašala med 0,336 in 2,487 kg, medtem ko je bila pri rdečem boru med 0,249 in 1,270 kg. Z analizo smo potrdili, da je proizvodnja smole pri črnem boru v pozitivni povezavi z debelino drevesa ($r = 0,462$; $p < 0,01$). Za rdeči bor tovrstne povezave nismo potrdili. Na količino

smole pri črnem boru pozitivno vpliva tudi produktivnost rastišča, medtem ko tovrstne povezanosti zaradi manjših razlik v produktivnosti rastišč pri rdečem boru nismo ugotovili. Potrdili smo pozitivno povezavo med količino smole pri črnem boru in količino padavin, medtem ko višje dnevne temperature dnevne donose zmanjšujejo. Z analizo smo ugotovili, da je v poskusu uporabljena metoda pridobivanja smole učinkovita in potencialno uporabna za smolarjenje na slovenskem Krasu ter da donos smole pri črnem boru bolj ali manj dosega komercialne donose v regiji iz preteklosti. Izsledki raziskave bi bili lahko zanimivi in uporabni za manjše in srednje velike lastnike gozdov, ki bi jim proizvodnja smole lahko pomenila dodatni vir zaslužka.

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