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Resin-Tapping Production in *Pinus pinaster* Ait. Stands in Galicia (NW Spain): Effects of Location, Number of Faces, Wound Width and Production Year

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Abstract: Resin or gum is secreted by conifers, mainly members of the genus *Pinus*, in response to physical and/or chemical stimulation, which can be induced by tapping live trees, i.e., by making repeated wounds in the trees. Resin production could potentially complement timber production (the main economic activity) in pine stands in Galicia (NW Spain). In addition, the particular characteristics of Galician woodlands (smallholdings, sloping land, presence of shrubs, high density of trees) imply different yields and costs than in pine stands dedicated to resin production in other parts of Spain. Therefore, a specific regional management model that is different from the traditional model established for other resin producing areas in the Iberian Peninsula is required. In this study, resin tapping was applied in each of the three years before the trees were felled, in two different locations, with one or two faces tapped and wounds of two different widths (12 and 16 cm) made across the face(s). Tapping two faces yielded more resin than tapping a single face, thus confirming the study hypothesis. When only one face was tapped, the plot location acquired greater importance, with production being higher in the location characterised by a higher mean annual temperature. Increasing the width of the wound did not always increase the amount of resin obtained per tree, which depended on the number of faces open: when two faces were tapped, increasing the width of the wound increased resin production in both locations in each of the three years of the trial. The weather conditions in each year masked the effect of the tapping season, and production did not follow any particular trend over time. The importance of the local weather conditions in the study areas and the environmental conditions in each year are discussed. The study findings are important for decision-making regarding the treatment and selection of areas for resin extraction.

Keywords: Atlantic pine; maritime pine; timber; compatibility; Iberian Peninsula

Citation: García-Méijome, A.; Rozados Lorenzo, M.J.; Fernández Blanco, E.; Martínez Chamorro, E.; Gómez-García, E. Resin-Tapping Production in *Pinus pinaster* Ait. Stands in Galicia (NW Spain): Effects of Location, Number of Faces, Wound Width and Production Year. *Forests* **2023**, *14*, 128. https://doi.org/10.3390/f14010128

Academic Editor: Joana Ferreira

Received: 14 November 2022
Revised: 16 December 2022
Accepted: 5 January 2023
Published: 10 January 2023

1. Introduction

The distribution area of maritime pine (*Pinus pinaster* Ait.) includes the western Mediterranean basin and the Atlantic coasts of Portugal, Spain and France [1]. In Spain, maritime pine is the second most common tree species in terms of surface cover, with monospecific stands occupying an area of 1,200,000 ha [2]. The species is mainly used for timber and resin production, recreational purposes and soil protection [1]. Although many pine species are not suitable for resin production, *Pinus pinaster* produces good quality resin in reasonable quantities [3]. At present it is the only species from which resin is extracted in the Western Mediterranean region [4].

Pine resin is a renewable product that is purified and distilled to produce turpentine and rosin, which have diverse industrial applications, including the manufacture of a variety of other products [5,6]. Resin is extracted from live trees via repeated wounds (or grooves) made in the stem by four tapping techniques currently used around the world [7]: the "American method", the "Chinese method", the "Hugues or French method" and the "Mazek or Rill method". Although the "American method" is the only modern tapping technique recognized today, it is not used in all resin-producing countries. In the "American method" horizontal grooves are cut across the tree every 15–18 days, in an upwards direction, and the bark and phloem are removed to produce a wound through which the resin flows [8]. A paste containing sulphuric acid is often applied to the wound to stimulate resin flow, although in recent years trials have been conducted to test the effects of reducing the amount of acid or of using different stimulants [9,10]. Currently, more than 90% of the global resin production is concentrated in three countries, which use different tapping methods: China (the "Chinese method"), Brazil (the "American method") and Indonesia (the "Hugues" and "Mazek" methods); production is mainly based on five pine species: *Pinus massoniana* Lamb., *Pinus yunanensis* Franch., *Pinus elliottii* Engelm., *Pinus caribaea* Morelet and *Pinus merkussii* Jungh. & de Vriese [7]. The positions of the top resin-producing countries have changed approximately every five decades since the second half of the 19th century [7]. Spain was included in the top resin-producing countries in the mid 1900s, when peak resin production levels were also reached; production in the country then declined at the end of the century until almost disappearing [11]. However, in recent years, changes in world markets have led to reactivation of the resin sector [4,12] placing Spain among the top 10 resin producers in the world [7], although at some distance from the top three producing countries.

In Spain, most resin extraction takes place in the region of Castilla y León, in low density woodland without shrubs and where tapping is the main economic activity. The resin is tapped using the "American method", which began to be used in Spain in the 1950s, replacing the "Hugues method" imported from France in the 19th century [13]. Resin extraction in Spain is seasonal, taking place when weather conditions are favourable; production generally begins between March and June and ends in October or November [14]. Although resin extraction is not a traditional activity in Galicia (NW Spain), the boom in resin production in the mid-1900s led to studies of the potential for production in the region, which were conducted by the former Instituto Forestal de Investigaciones y Experiencias (Institute for Forestry Research and Experimentation) [15]. Reactivation of the resin sector in Spain has led to increasing interest in resin exploitation in Galicia, where pure stands of *Pinus pinaster* currently occupy an area of 217,281 ha [16]. Pine woods differ in Castilla y León and Galicia (where the land is more sloping with presence of shrubs and a higher density of trees), with producers in Galicia having fewer suitable trees available and less surface area for tapping [17]. Timber production is important in Galicia, which supplies 50% of the felled timber produced in Spain. *Pinus pinaster* made up 18% of the 8.5 million cubic metres of timber (with bark) felled in 2017 in Galicia [18], representing the most commonly felled conifer species. Considering the importance of the timber industry in Galicia and the characteristics of Galician woodlands, resin production is envisaged as a complementary activity that does not affect the value of the timber and that enables forest owners to obtain extra income from the trees [19]. Tapping at the end of the cutting rotation is recommended as this does not generally affect the timber quality [19–21]. Long-term resin tapping reduces overall tree growth and can cause damage to the tree that is not compatible with the production of quality timber [20,22,23]. A recent study recommended that resin tapping in Galicia should be carried out in pine stands of age between 30–50 years due to be cut within 2–5 years, depending on site quality and the proposed use for the timber [19].

The factors involved in resin extraction must be determined to enable integration of resin production in a sustainable management model compatible with timber production. Although studies of resin production in the Iberian Peninsula have increased in recent years, less research has focused on regions where resin extraction is not traditionally carried out, and there remains some uncertainty regarding the actual potential for resin production in these regions [24]. In order to enhance production, other possible alternatives to the traditional Spanish model (one face of 12 cm wound [25]) could be tested, i.e., simultaneous opening of two faces as in similar studies conducted in the US [22], and in Brazil and Indonesia [7], as well as increasing the traditional 12 cm wound across the tapping face.

The main aim of the present study was to evaluate whether resin production could be conducted in pine stands in Galicia to complement timber production. We hypothesized that resin production (kg tree^{-1}) will depend on the following factors: (i) the stand location; (ii) the number of faces tapped per tree; (iii) the width of the wound across the tapping face; and (iv) the production year.

2. Material and Methods

2.1. Study Area

The sample plots used to obtain the study data were established by the Centro de Investigación Forestal de Lourizán (Pontevedra, Galicia) in monospecific *Pinus pinaster* stands close to the final felling stage [26,27]. The plot in Caldas de Reis (province of Pontevedra), of surface area 2.9 ha, is situated at an elevation of 250 m above mean sea level (m.s.l.) in an area close to the coast. The area is characterised by an oceanic climate (humid temperate), and the soil is classified as a Humic Cambisol. The plot was established in 2016 (plot "C" coast of Galicia, Figure 1). The plot in Maceda (province of Ourense), of surface area 5.8 ha, is situated at an elevation of 550 m above m.s.l. in the interior of the region. The area is characterised by an oceanic climate (continental), and the soil is classified as a Gleyic Cambisol. The plot was established in 2017 (plot "M" inland Galicia, Figure 1). In the Caldas de Reis plot, shrubs were cleared prior to the study [28], but clearing was not necessary in Maceda.

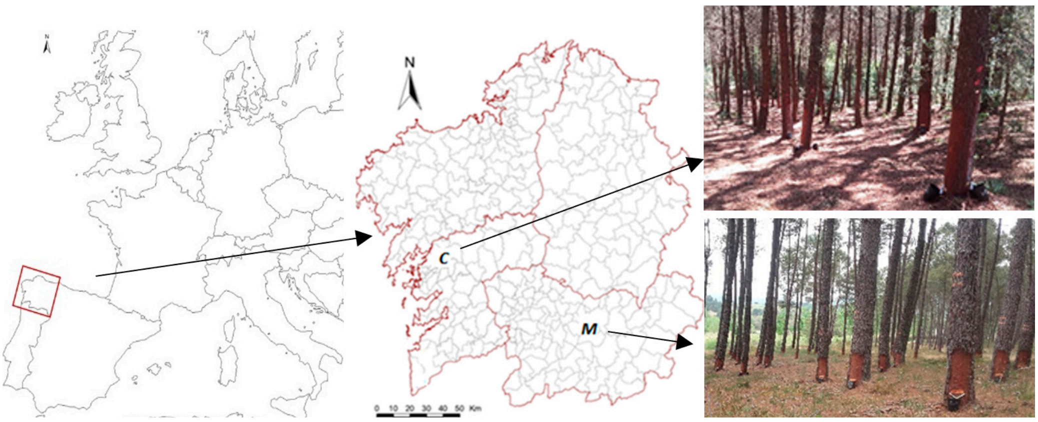

Figure 1. Location of the study plots: Caldas de Reis (C) and Maceda (M).

The trials were carried out during a period of three years in both plots: between 2016 and 2018 in the Caldas de Reis plot and between 2017 and 2019 in the Maceda plot. The American tapping method, which consists of cutting grooves in the stem, removing strips of bark and phloem and applying a stimulant paste, was used. Note that the terms groove and wound are used interchangeably in this paper. The resin flow was collected in a semi-rigid "pot" container of approximate capacity 2 kg. The paste used (Cunningham or Brazilian paste) [12] has a lower concentration of sulphuric acid than the pastes conventionally used in the rest of the Iberian Peninsula [13] and in other parts of the world [29]. The time interval between cutting the grooves and the number of grooves varied depending on the year. In the Caldas de Reis plot, 9 grooves were cut in each tree in 2016. In both plots, 14 grooves were cut in each tree in 2017 and 2018, and in the Maceda plot, 10 grooves were cut in each tree in 2019.

The yearly resin production in each tree was calculated by summing the production from each groove (after subtracting the weight of the pot or pots when two faces were tapped) [27]. The final weight of resin also included the resin adhered to the face, which was scraped into the pot. Each pot was weighed on an electronic scale (Kern HDB 5K5N) of maximum capacity 5 kg and precision 5 g [30].

The experimental design in both locations consisted of establishing three blocks, each including 4 treatments with 50 trees: a groove of width 12 cm on one face, a groove of width 16 cm on one face, a groove of width 12 cm on each of two opposing faces and a groove of width 16 cm on each of two opposing faces. Each tree was identified and the normal diameter, height to the start of the crown and total height were measured at the beginning and end of the experiment (Table 1).

Table 1. Dasometric characteristics of the two study plots: Caldas de Reis and Maceda. D_m is the mean normal diameter (measured at a height of 1.3 m above ground level), H_m is the mean total tree height, H_c is the mean height to the start of crown, H_{cc} is the calculated mean crown height. Measurements were taken the first year of the experience before tapping (initial) and in the autumn-winter just after the last tapping season (final).

Dasometric Variables	Caldas de Reis		Maceda	
	Initial	Final	Initial	Final
Age (years)	27	30	56	59
D_m (cm)	33.2	34.9	41.8	43.4
H_m (m)	19.0	20.7	24.8	26.4
H_c (m)	10.8	13.2	17.6	18.1
H_{cc} (m)	8.3	7.4	7.5	8.3

Meteorological data were also obtained from the 'Monte Medo' weather station, at an elevation of 604 m above m.s.l., 2 km from the Maceda plot, and the 'Caldas de Reis' weather station, at an elevation of 268 m above m.s.l., 3 km from the plot of the same name [31] (Table 2).

Table 2. Meteorological variables in Caldas de Reis and Maceda during the study period. Weather variables were calculated from monthly data (www.meteogalicia.gal, accessed on 3 August 2022) from the observations recorded at the weather stations located in 'Caldas de Reis' for Caldas de Reis plot and 'Monte Medo' for Maceda plot.

Meteorological Variables	2016	2017	2018	2019
Caldas de Reis				
Mean temperature (°C)	13.9	14.3	13.7	
Annual accumulated precipitation (L m^{-2})	2183	1263	1941	
Annual hours of sunshine (h)	2210	2316	1985	
Mean relative humidity (%)	77.3	63.7	81.6	
Maceda				
Mean temperature (°C)		12.8	12.1	12.0
Annual accumulated precipitation (L m^{-2})		778	1266	1261
Annual hours of sunshine (h)		2515	1848	2220
Mean relative humidity (%)		73.4	79.5	77.3

2.2. Statistical Analysis

The data from each location (plot) were initially analysed separately as they were obtained at different times, in 2016, 2017 and 2018 in Caldas de Reis (coastal Galicia) and in 2017, 2018 and 2019 in Maceda (inland Galicia). The effects of the wound width, the number of faces tapped and the production year were analysed for each location using a repeated measures analysis of variance for the three years.

For each location, the model included block 'B' with 3 levels, the wound width 'W' with two levels (12 and 16 cm), and the number of faces 'F' with two levels (one face and two opposing faces), as well as the interactions between these (BxW, BxF, WxF) as fixed factors between subjects and the production season (1st, 2nd, 3rd) as a within-subject factor. The dependent variable was the resin production, expressed as kg per tree. When the data did not comply with the criteria of the test of sphericity, Huynh-Feldt-Lecoutre adjusted probabilities were used [32]. Of the initial 600 observations made in the trial per plot, 594 trees were included from the Caldas de Reis plot and 590 from the Maceda plot. The 3 resin production years correspond to the 1st, 2nd and 3rd year of the trials, as the trees had not been tapped before.

In a second step, the resin production data from the Caldas de Reis and Maceda plots were analysed together for the two years in which trees in both plots were tapped simultaneously (2017 and 2018). The aim of this analysis was to examine the effect of the location and its interaction with production year and to determine whether the production year had the same influence in both locations. As the variable block did not have a significant effect in the separate analysis of each location and the production year was found to have an important effect on resin production, independently of the number of times the trees had been tapped, the "block" factor was removed from the analysis of variance of repeated measures. This applied to the variables location 'L' with two levels (Caldas de Reis and Maceda), wound width 'W' with two levels (12 and 16 cm) and the number of faces 'F' with two levels (one face and two opposing faces), as well as the interactions between these (LxW, LxF, WxF, LxWxF) as fixed factors between subjects and the production year (2017 and 2018) as an within-subject factor. Of the 1200 initial trees, 1186 were included in the joint analysis.

In the analysis of data from each individual location and for both locations together, least square mean (LSM, $p < 0.05$) values were calculated for pre-planned comparisons involving detailed examination of the interactions of interest for interpretation of the results. All of the analyses were conducted with the R statistical package, with Rcmdr (R Commander), specifically with the "WRS2" package [33].

3. Results and Discussion

Annual resin production per tree varied widely depending on factors such as the number of faces opened, the width of the wound, the production year and the plot location. In 2016 and 2018, the mean resin production per tree yielded by the method traditionally used in Spain (tapping one face with a wound of width 12 cm) was lower in Caldas de Reis than values reported for other regions, which range from 3.2–3.5 kg per tree [34,35]; however, in 2017, production reached similar levels as in the cited studies. Production was much lower in Maceda than in the other regions, and yields were also lower than predicted [35]. However, tapping two faces with wounds of width 16 cm produced higher yields.

3.1. Resin Production in Three Consecutive Years

Separate analysis of the data from each location revealed that resin production was homogeneous across blocks (B) in both Caldas de Reis and Maceda. In both locations, the effect of the production season was highly significant ($p < 0.0001$ **), although it did not follow the same trend in both locations. The number of faces (F), the wound width (W) and their interaction (FxW) were also significant factors in both locations ($p = 0.0296$ in Caldas de Reis and $p = 0.0425$ in Maceda). As the significant FxW interaction precludes us from generalizing the results, we therefore compared the production to detect differences in the levels of combinations of these two factors. The details of the interactions and the minimal significant differences in resin production per tree (LSM, $p < 0.05$) in each production year and for each of the locations are shown in Figure 2. Resin production (kg per tree) was significantly higher when two faces were tapped than when only one face was tapped in each of the production years and in each location, at the same level of significance ($p < 0.0001$ **). In both locations, when only one face was tapped, increasing the wound width from 12 to 16 cm did not yield a sustained increase in production over time, although production was significantly higher with the wider wound in the first year in Caldas de Reis. When two faces were tapped, resin production (kg per tree) was significantly higher ($p < 0.0001$ **) and increased by 12–14% when the wider wound was used. Increasing the wound width led to a significant increase in resin production in all years and in both locations, when two faces were opened.

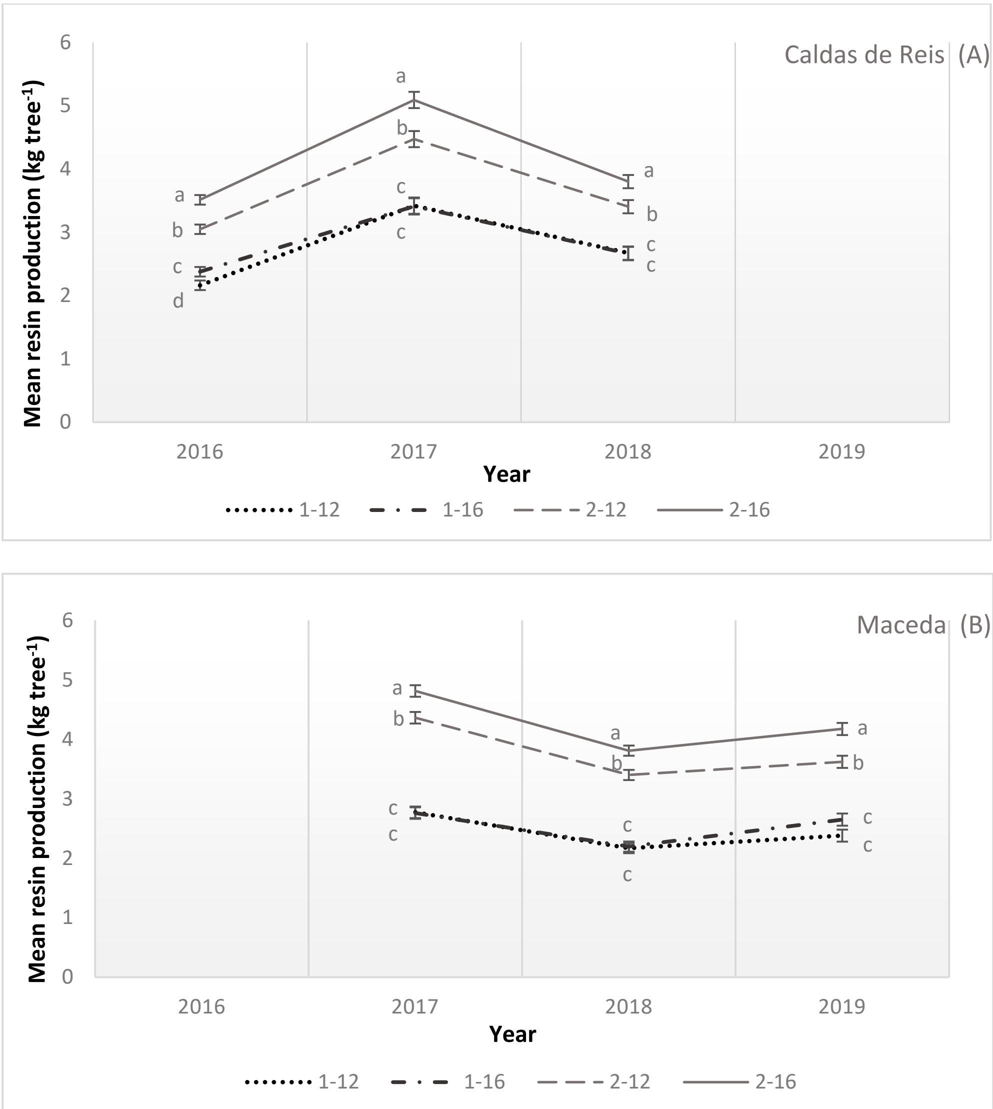

Figure 2. Mean resin production (kg tree^{-1}) from *P. pinaster* in each year in Caldas de Reis (**A**) and Maceda (**B**) for the four combinations of number of faces and wound width. 1–12: one face, 12 cm wound width; 1–16: one face, 16 cm wound width; 2–12: two opposing faces, 12 cm wound width; 2–16: two opposing faces, 16 cm wound width. Bars represent ± standard error. Different letters indicate significant differences between least squares means (LSM $p < 0.05$) for each location in a single season.

For the 12 cm wound width, the process of opening two faces instead of one face yielded a relative mean increase in resin production per tree of 34% in Caldas de Reis and of 54% in Maceda; this increase declined in the 3rd production season in both locations. For the 16 cm wound width, the mean relative increase was 47% in Caldas de Reis and 68% in Maceda. This effect was enhanced in the most productive year (2017), independently of whether it was the 1st (Maceda) or 2nd (Caldas de Reis) production season. Tapping two faces per tree did not double the production levels. This is consistent with the findings of [22], who reported that the simultaneous opening of two faces per tree led to increases in production rarely greater than 40% in *Pinus palustris* Mill. and *Pinus elliottii* Engelm.

Various authors have reported that damage induces a defence reaction in trees, including the formation of new resin canals known as traumatic resin ducts [36–38]. The formation of traumatic resin ducts generates an increase in resin production after the first year of tapping [39–41]. For trees in which the crown height represented 35% of the total tree height, which yielded moderate levels of resin, [22] reported increased production in the second year, but lower production in the third and fourth years. In the present study, in the Maceda plot, resin production was lower in the second year than in the first year, and overall resin production did not increase over time.

3.2. Comparative Analysis of Caldas de Reis and Maceda (Coastal and Inland Galicia) for the Same Production Years (2017 and 2018)

The combined statistical analysis of the data from both locations revealed highly significant differences ($p < 0.0001$ **) in resin production between the two locations and between the two production years (Table 3). The mean resin production, for all treatments in both production years, was significantly higher ($p < 0.0001$ **) in Caldas de Reis than in Maceda (3.6 and 3.3 kg tree^{-1} respectively). Resin production was significantly higher in 2017 than in 2018 ($p < 0.0001$ **). The significant effect of the interaction between production year and location ($p < 0.0001$ **) showed that production was higher in 2017 in both locations. The study findings confirm that the production year and local factors associated with the trial location had a notable influence on resin production, as previously observed in central Spain [42] and in the USA [20,22].

Table 3. Summary of the repeated measures model used to analyse resin production in maritime pine in two years (2017 and 2018) and in two locations (Caldas de Reis and Maceda). Degrees of freedom (df), F-ratios (F), associated probability levels ($p > F$), significant effects (* $p < 0.05$), highly significant effects (** $p < 0.001$).

Source of between-Subjects Variation	**df**	**F**	***p* > F**
Location	1	19.16	<0.0001 **
N° of faces	1	370.37	<0.0001 **
Wound width	1	11.01	0.0009 **
LocationxN° of faces	1	11.22	0.0008 **
LocationxWound width	1	0.02	0.8763
N° of facesxWound width	1	10.63	0.0011 *
LocationxN° of facesx Wound width	1	0.11	0.7350
Error	1178		
Source of within-Subject Variation	**df**	**F**	***p* > F**
Year	1	2334.60	<0.0001 **
YearxLocation	1	17.77	<0.0001 **
YearxN° of faces	1	136.82	<0.0001 **
YearxWound width	1	3.30	0.0696
YearxLocationxN° of faces	1	0.02	0.8813
YearxLocationxWound width	1	1.77	0.1840
YearxN° of facesxWound width	1	4.66	0.0311 *
YearxLocationxN° of facesxWound width	1	1.17	0.2804
Error (year)	1178		

As found in the separate analysis for each location, when considering both production years together, the number of faces and the wound width and their interaction were significant factors (p = 0.0011 *). The interaction between location and number of faces also proved highly significant (p = 0.0008 **). This prevented us from generalizing the results and led us to make specific comparisons to determine where the differences occurred in the combination of both factors.

In the most productive year (2017), in trees in which a single face was tapped, resin production was significantly higher in Caldas de Reis (3.4 kg tree^{-1}) than in Maceda (2.8 kg tree^{-1}), independently of the wound width (Figure 3). The production was more similar in both locations when two opposing faces were tapped (4.8 kg tree^{-1} in Caldas de Reis and 4.6 kg tree^{-1} in Maceda), and it was significantly higher than when a single face was tapped in both locations.

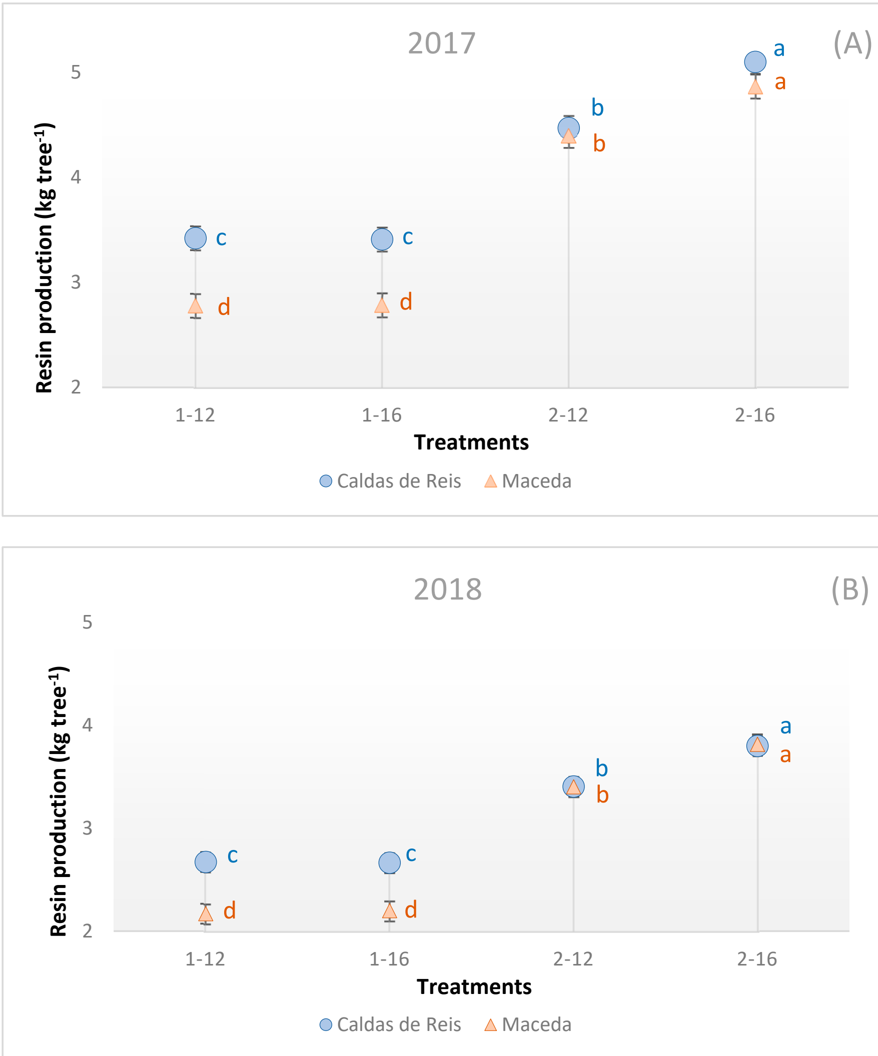

Figure 3. Resin production (kg tree^{-1}) in maritime pine in 2017 (**A**) and 2018 (**B**) in both Caldas de Reis (Pontevedra) and Maceda (Ourense). For each year, different lowercase letters indicate significant differences (LSM, $p < 0.05$) between the combinations of treatments and locations.

Resin production was significantly lower ($p < 0.0001$ **) in 2018 than in 2017, but followed the same trend, with significantly higher production in Caldas de Reis (2.7 kg tree^{-1}) than in Maceda (2.2 kg tree^{-1}) when a single face was tapped, and with the same level of production level in both locations (3.6 kg tree^{-1}) when two faces were tapped. This shows the importance of the number of faces in resin production, as tapping two faces increased the amount of resin secreted relative to tapping one face.

It has been suggested that horizontal grooves could tap more resin canals, particularly axial ducts, than other types of grooves [43]. Increasing the wound width may increase the number of ducts that are tapped and thus increase resin production. Production could also be favoured by application of stimulant paste over a large area, although we did not observe this effect when one face was tapped and the horizontal width of the wound was increased from 12 to 16 cm. However, the increase in the number of ducts tapped would explain the increase in resin production when two faces are tapped, mainly with the 16 cm wound width, which represented the largest tapping area in this trial.

Thus, considering the wound widths used in the present study, an increase in the width of the wound from 12 to 16 cm led to an increase in resin production that varied depending on the number of faces, the location and the production year. In trees in which a single face was tapped, there were no differences in resin production between the two wound widths (Figure 3). Increasing the horizontal width of the grooves does not always imply greater production [35,44]. However, an increase of 4 cm over the traditional 12 cm, in trees with two faces opened, increased production in both locations and in the two consecutive production years by 11 and 14% (Figure 3). The combination of two tapping faces and a wound width of 16 cm maximized resin production. However, the production was influenced by other factors such as the time required and economic investment [17].

The difference in resin production between 2017 and 2018 in both locations may be related to the meteorological conditions, as observed by [14] in trials conducted in the province of Segovia (Spain), characterised by a continental Mediterranean climate, where summer temperature and hydric deficit were positively related to resin production. Other researchers related environmental factors such as light, temperature and moisture content to emissions of volatile substances and resin production [45].

The most productive year (2017) was considered relatively hot and dry in both locations. The annual mean temperature was slightly higher (+0.2 °C) than the mean value in the reference climate period 1986–2015 [46], while the annual accumulated precipitation was lower than the corresponding reference value (21% lower in Caldas de Reis and 32% lower in Maceda). By contrast, 2018 was cooler and wetter, with a lower annual mean temperature (−0.4 °C lower in Caldas de Reis and −0.5 °C lower in Maceda) than the corresponding reference value; precipitation levels were 22% higher in Caldas de Reis and 11% higher in Maceda (Figure 4).

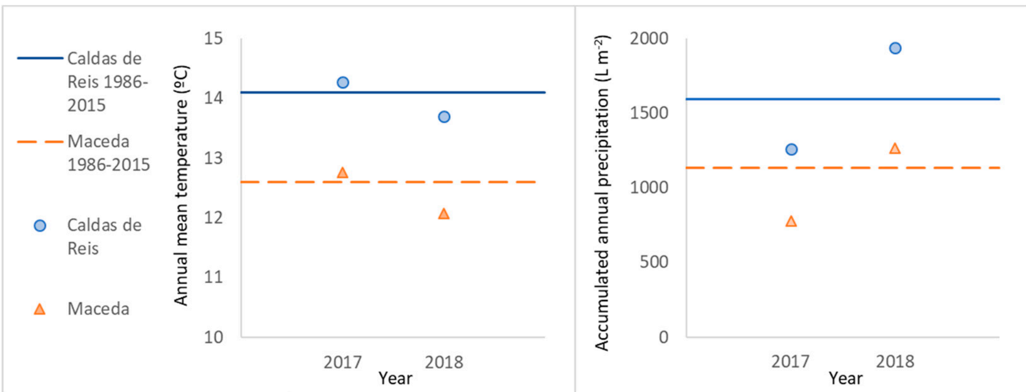

Figure 4. Annual mean temperature °C (**left**) and accumulated annual precipitation L m^{-2} (**right**) in 2017 and 2018 in Caldas de Reis (•) and Maceda (▲) (www.meteogalicia.gal, accessed on 3 August 2022). The horizontal lines indicate the reference climatic values for the period 1986–2015 in Caldas de Reis (–) and Maceda (- -) (www.climatecharts.net, accessed on 3 August 2022).

During the study period, the mean temperature recorded in Caldas de Reis was 1.7 °C higher than that recorded in Maceda, which would favour resin production. The relationship between resin production and maximum and minimum temperatures and possible drought and stress periods, which may reduce resin yields, have been reported for *Pinus pinaster* [14,24,44,47] and also other pine species, such as *Pinus elliottii* Engelm. [48,49] and *Pinus taeda* L. [40].

The location includes various factors that influence resin production: abiotic variables such as topography, soil and climate, and biotic variables such as dendrometric and genetic characteristics. Variables related to the tree size and vigour affect resin production [22,40–42,50]. In *Pinus taeda*, increased resin flow was observed in late summer and 7 days after wounding and was closely related to crown size [40]. In Caldas de Reis, the pine trees are younger and of smaller diameter, height and height to start of the crown than the pine trees in Maceda (Table 1). Nevertheless, calculated crown height was similar in both stands, yielding similar resin production when two faces were opened, according to previous findings. According to some researchers, *Pinus pinaster* displays a large amount of intraspecific genetic variability [51] as well as a high degree of intrapopulational genetic variation [52], giving rise to large differences in resin yields within the same population [24,49,53], with pines of the same genetic material producing up to four times more resin depending on the environmental conditions in the growing area [54]. In a microtapping trial conducted with different populations of *Pinus pinaster*, significant differences among sites and among populations in inland Galician plots were observed [24].

The study findings demonstrate that the variables of location, treatment (combination of number of faces and wound width) and production year affect resin production. The effect of location on resin production can be tested in a representative sample of trees [27] or by using microtapping techniques [55]. The potential resin production can even be evaluated in "microtapping" trials in young stands or plants grown in greenhouses [56].

Resin production provides direct and indirect benefits such as biodiversity conservation and fire prevention [57]. However, in order to make resin production compatible with timber production, management plans must be adapted to the regions and stands involved. The temporal predictions conducted by [58] indicate increases in the area of optimal habitat for *Pinus pinaster* of between 46 and 61% of the current area, by 2050, due to the effects of climate change. It is therefore essential to continue studying the factors that influence production and also alternative, mechanized extraction methods and the use of closed collection bags, to maximize the value of this natural resource [59,60] and thus to be able to establish a sustainable production model for Galician woodlands.

4. Conclusions

The modifications to the resin tapping method tested in the study involved selecting the best combination of wound width and number of faces opened to maximize resin production in pine trees under the particular growing conditions in the NW Iberian Peninsula, which are very different from those in areas where resin extraction is traditionally carried out in other parts of the Iberian Peninsula.

Of the combinations tested, the optimal conditions for maximum resin production were making wounds of width 16 cm on two opposing faces of the trees. The effect of the optimal combination was intensified in the most productive year, in which the meteorological conditions were particularly favourable for resin extraction, being relatively warm and dry.

The location of the pine stands and the particular climatic characteristics must be taken into account before starting resin tapping, as production will depend on the site, particularly when only one face is opened in poor production years. The meteorological conditions in the production year are also important, although to a certain degree unpredictable, as they may affect yields in any location within a limited geographical area, such as the NW Iberian Peninsula.

The importance of these factors in resin production represents a challenge in the current context of climate change and future climate scenarios, and they are being investigated in ongoing trials with a more representative number of locations and production years.

Author Contributions: Conceptualization, A.G.-M., M.J.R.L., E.M.C. and E.G.-G.; methodology, A.G.-M., M.J.R.L. and E.G.-G.; validation, A.G.-M., M.J.R.L. and E.G.-G.; formal analysis, A.G.-M., M.J.R.L. and E.G.-G.; investigation, A.G.-M., M.J.R.L. and E.G.-G.; resources, E.F.B. and E.M.C.; data curation, A.G.-M., M.J.R.L. and E.F.B.; writing—original draft preparation, A.G.-M.; writing—review and editing, A.G.-M., M.J.R.L. and E.G.-G.; visualization, A.G.-M., M.J.R.L. and E.G.-G.; project administration, E.M.C.; funding acquisition, E.M.C. All authors have read and agreed to the published version of the manuscript.

Funding: This study was financed by the supra-autonomic operative group GO RESIMEC (Ministry of the Environment, Government of Spain) and Co-operative action AC-2020-08 (Consellería do Medio Rural, Xunta de Galicia).

Data Availability Statement: Research data is available on demand and can be requested from the authors.

Acknowledgments: The authors are grateful for contributions made by Sergio Frade Castro, Agustín Quintairos Folgoso, Santiago Muñiz García, Alfonso Bara Cerviño, Alfredo Fresco Pereira and Isidro Cruz Souto of the Lourizán Forest Research Centre and by Antonio Fernández García of Resinas Fernández. They are also grateful to the San Clemente (Caldas de Reis) and Foncuberta (Maceda) community forest associations for allowing access to the pine stands used in the trials and to Resinas Naturales for supplying the stimulant paste. They are also grateful to three anonymous expert reviewers for their valuable comments.

Conflicts of Interest: The authors declare no conflict of interest.

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