Dendrochronological Analysis of Three Pine Species Used as Pioneer Species to Stabilize the Coastal Dunes of the Southern Baltic Coast

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Abstract

The objective of the study was to construct the chronologies of three pine species used for coastal dune stabilization on the Polish Baltic coast: native Scots pine *Pinus sylvestris* and two species alien to the European flora – jack pine *Pinus banksiana* and pitch pine *Pinus rigida*. The width of annual growth rings and growth responses to changing environmental conditions was compared in the forest stands of these three species growing in the coastal crowberry pine forest *Empetro nigri-Pinetum*. The prospects of all three species as pioneer tree species on dunes were also discussed.

At the beginning of the growing season in 2008, 61 trees were sampled and consequently 5,077 annual growth rings were measured. The longest chronology of 98 years (1910–2007) was developed for *Pinus sylvestris* and the shortest of 88 years (1920–2007) for *Pinus banksiana*. Dendrochronological curves for samples of *Pinus sylvestris* and *Pinus rigida* are the most coincident (t = 7.9, Gl = 74%), whereas *Pinus sylvestris* and *Pinus banksiana* are least coincident (t = 4.4, Gl = 69%).

The analysis of meteorological conditions in the year preceding the pointer year provided evidence that thermal conditions in the winter season and early spring are the main factor affecting the annual tree-ring width. Higher than the average temperature in January and February, and particularly in March, induces an increased cambial activity in the investigated pine species and the development of wider tree-rings in the following growing season. Low temperatures in winter and early spring reduce the growth.

Growth-climate relationships determined on the basis of pointer years are proved correct by the correlation analysis and response functions. In the case of air temperature, statistically significant values are recorded in winter and spring months. In addition, thermal conditions in July and August appear to be important for *Pinus banksiana*, and August temperature for *Pinus rigida*. Higher rainfall in the preceding summer and high precipitation in late winter and early spring have a positive effect on the tree-ring width for all the examined species.

Key words: tree-ring width, meteorological conditions, Scots pine (*Pinus sylvestris* L.), jack pine (*Pinus banksiana* Lamb.), pitch pine (*Pinus rigida* Mill.), coastal dunes

Introduction

Anthropogenic destruction of the coastal forests on the southern Baltic coast led in the Middle Ages and the following centuries to almost total deforestation of this zone and activation of aeolian processes. In order to prevent negative effects caused by migration of dunes, extensive stabilization of shifting sands by planting pine monocultures has been started in the mid-19th century. Scots pine *Pinus sylvestris* was the primary component of the destroyed forest stands in the alluvial parts of the coast. Reintroduction of the species has helped to reconstruct the coastal crowberry pine forest (*Empetro nigri-Pinetum* Wojt. 1964) on sites where they are the most common type of natural forest vegetation in the Polish zone of the Baltic coast (Piotrowska 1989, 2003) together with the mixed birch-oak forests (*Betulo pendulae-Quercetum roboris* R. Tx. 1930).

Besides *Pinus sylvestris*, other species of trees and shrubs are also used in Poland to stabilize dunes. Other pine species planted in recent decades as a forecrop are mostly mountain pines, *Pinus mugo* and *Pinus uncinata*. In the 19th century and the first half of the 20th century, jack pine *Pinus banksiana* and pitch pine *Pinus rigida* brought to Europe from North America have been introduced. These species, however, proved to be of a little value in forestry and currently they are no longer planted as trees of economic importance. Due to their minimum requirements, the high growth rate of young specimens and resistance to diseases, they have long been used as pioneer species in unstable, nutrient-poor habitats (Bellon et al. 1977, Seneta and Dolatowski 1997).

The Scots pine *Pinus sylvestris* is a species native to Europe and Asia, and is the most widely distributed pine in the world. It grows naturally from Scotland almost to the Pacific Ocean and from above the Arctic Circle in Scandinavia to the Mediterranean. The Scots pine is adapted to a wide variety of climates as indicated by its extremely large natural range. It grows in areas with annual precipitation ranging from 200 to 1,780 mm and survives in Siberia where winter temperatures have been recorded as low as -64° C, and it is found at medium altitudes in the Mediterranean region. In Europe, the Scots pine grows on a wide variety of soil types. It is found on the oldest rocks, on peat lands and also on the most recent glacial deposits, but it is most successful on well-drained sands and gravels (Steven and Carlisle 1959, Steinbeck 1966).

The jack pine *Pinus banksiana* is the most widely distributed pine in North America, with its native range in Canada east of the Rocky Mountains from the Northwest Territories to Nova Scotia, and the northeast of the United States from Minnesota to Maine, with the southernmost part of the range just into northwest Indiana. In the eastern part of its range, jack pine grows in a maritime climate but elsewhere it is found in diverse continental climates characterized by short, warm to cool summers, very cold winters, and low rainfall. The average annual maximum temperatures range from 29° to 38° C, and average annual minimum temperatures are from -21° to -46° C. Average annual precipitation ranges from 250 to 1,400 mm. Jack pine is usually found on sandy soils, but it also grows on loamy soils, on thin soils over the granites and metamorphosed rocks, over limestone, on peats, and on soil over permafrost (Rudolph and Laidly 1990).

The pitch pine *Pinus rigida* also grows over a wide geographical range in North America from central Maine to New York and extreme south-eastern Ontario, south to Virginia and southern Ohio, and in the mountains to eastern Tennessee, northern Georgia, and western South Carolina. Because it grows mostly on the poorer sandy or shallow soils, its distribution is spotty. Pitch pine grows on sites with a wide range of moisture conditions. It is found on excessively drained sands and gravels as well as on muck soils in the swamps. The climate in the range of pitch pine is humid. Average annual precipitation is usually between 940 and 1420 mm and is well distributed throughout the year. The duration of the frost-free season ranges from 112 to 190 days and temperatures range from winter lows of -40° C in the northern part of the range to summer highs above 38° C in most sections (Elias 1980).

In the zone of coastal dunes on the Polish Baltic coast, there are several dozen old forest stands composed of both the native pine species *Pinus sylvestris* and other coniferous tree species introduced to stabilize the sandy substrate (e.g. *Pinus banksiana* and *Pinus rigida*). Therefore, it is possible to compare the responses of native and introduced species, growing in the same habitat conditions, to climatic factors changing over the years.

The objective of the research was to construct the chronologies for one native and two introduced pine species, and to compare the width of their annual growth rings and growth responses to changing weather conditions, as well as to assess the prospects of all three species as pioneer tree species on dunes.

Materials and Methods

Study area

The analysed forest stand covers a narrow zone of the coastal dunes between the town of Kołobrzeg and the village of Dźwirzyno, along a stretch of ca. 3 km long and 200–500 m wide in the central-western part of the southern Baltic coast (Figure 1).

The crowberry pine forest with the dominant *Pinus sylvestris* in the tree layer is a natural forest community of the coastal dunes. Initial stages of the podzol soil (Albic Arenosol) development dominate in the substrate. The habitat is fresh, poor in nutrients, with pH 3.3-3.9 in organic horizons and pH 4.4-5.2 in mineral horizons. The grain size composition of the par-

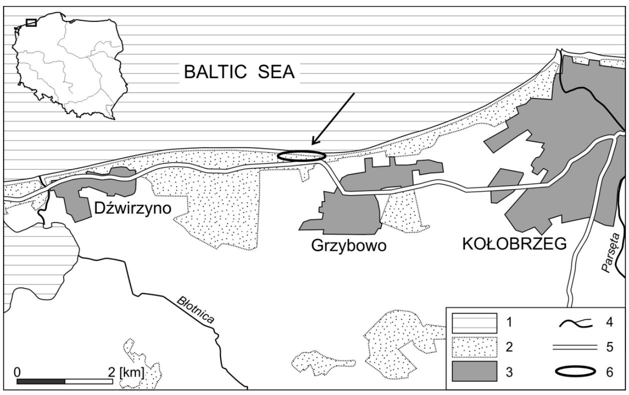

Figure 1. Study area on a regional scale: 1 – sea and lake waters, 2 – forest, 3 – built-up areas, 4 – rivers, 5 – roads, 6 – location of studied pine stands

ent rock consists of sand in 97.5%, silt in 1.5% and the floatable fraction in 1% (Bosiacka 2005).

Apart from dominant *Pinus sylvestris* (20 sampled trees), also a few pine and spruce species of alien origin are present in the tree layer of the described fragment of the crowberry pine forest: *Pinus rigida* (35 specimens with a trunk circumference of 60–140 cm and a height of 14–17 m; 20 sampled trees), *Pinus banksiana* (28 specimens with a trunk circumference of 60–120 cm and a height of 14–18 m; 21 sampled trees), *Pinus strobus* (over 50 specimens up to 180 cm/ 20 m), *Pinus nigra* (over 50 specimens up to 190 cm/ 21 m), *Picea sitchensis* (17 specimens with a trunk circumference of 50–250 cm and a height of 18–20 m), *Picea glauca* (10 specimens with a trunk circumference of 50–130 cm and a height of 7–21 m).

Climate

The average annual temperature for this area is 8.2 ^{0}C (it ranges from 6.4 ^{0}C to 10.9 ^{0}C); July and August are the warmest months (17.1 and 17.0 ^{0}C, respectively), and January is the coldest month with the temperature dropping below 0 ^{0}C (-0.2 ^{0}C). The winter usually begins at the end of the first week of January and lasts till the beginning of February. The last frosts have been recorded between 5 and 15 May (Koźmiński et al. 2012). The total annual precipitation comes to 676 mm (it ranges from nearly 400 mm to over 920 mm per year). July is the wettest month (89 mm) and February is the driest one (35 mm). The average snow cover duration is less than 45 days.

Radial growth analysis

Samples were collected at 1.3 m from the ground surface (at breast height) using Pressler borers. Dry samples were inserted into the stands and their surface was removed by dissecting knives in order to obtain a clear picture of annual growth rings. The width of annual growth rings was measured with an accuracy of 0.01 mm using a binocular with smooth zoom (up to ×45), a movable measuring table connected with a reversible counter and the software Dendrometr (Mindur 2000). Samples were measured starting from the pith end of the core and moving towards the bark; at the same time, all types of anomalies in the anatomic structure of wood tissues were registered. Applying the standard „cross-dating" methods, correlation coefficients, the Student t-test and graphic similarity of individual dendrochronological sequences, the species chronologies were developed (from the 42 most correlated samples) and tested using the software COFECHA from the package DPL (Holmes 1983, 1994). In addition, the following parameters were calculated using the software COFECHA: the average growth ring width, autocorrelation (the correlation between the width of annual growth rings in a given year with the growth rings from the previous year – the first order autocorrelation), standard deviation and average sensitivity (which reflects the average percentage change in the growth width between the measured tree ring and the next one, Fritts 1976). Also the coefficient of similarity Gl (*Gleichläufigkeitswert*) was calculated for chronologies (Huber 1943, Kaennel and Schweingruber 1995, Wilczyński 2010). The Gl- value above 60–65% indicates a high similarity between the compared curves.

Indexing was performed with the software Arstan (Cook and Holmes 1986). Residual chronologies (RES) that result from a double indexing of the series were used for further analysis; autoregressive modelling was applied to eliminate the autocorrelation.

The relationships between climate and tree-ring width were explored using the response function analysis (Fritts 1976, Blasing et al. 1984, Cook and Kairiukstis 1992). The response functions can be calculated with the aid of the DPL computer package (RESPO module, Holmes 1983, 1994). The technique includes multiple regression analysis in which the mean monthly air temperature and monthly sum of precipitation are the independent variables. RESPO calculates coefficients of linear correlation (k) and multiple regression, r, as well as the multiple regression coefficient of determination (r^2). The response function analysis was applied to ascertain the effects of climatic factors on the tree-ring curves in 16-month periods (from June of the year preceding the increment to September of the current growth year) over 61 years (1947–2007) for temperature and over 54 years (1954–2007) for precipitation. The study was made using climatic data obtained from the nearest meteorological station in Kołobrzeg located about 8 km east of the study area. Positive values of the linear correlation coefficient (k) and multiple regression coefficient (r) express a simultaneous increase in the tree-ring width and in the meteorological parameter. The value of r^2 expresses the strength of the relationship between the climatic components analysed and the tree-ring width.

A pointer year is the year in which the tree-ring width in most trees of a population is clearly different (wider or narrower) than the rings developed in earlier and later years (Kaennel and Schweingruber 1995). Pointer years are important in dendrochronological dating as well as in identification and elimination of errors in dating of individual samples. Anomalies in the tree-ring width curves appear in years with favourable or adverse environmental factors including meteorological conditions as the most important and most variable. The pointer year analysis was performed using the TCS software (Walanus 2002); the pointer years were identified from at least 10 trees, the minimum convergence threshold being set at 90%.

Sampling was performed at the beginning of the growing season in 2008, a total of 61 trees were sampled and 5,077 annual growth rings were measured.

Results

Chronologies

The longest chronology of 98 years (abbreviation PS) was developed for *Pinus sylvestris* and represented the period of 1910–2007 (Table 1). The chronology representing *Pinus rigida* is one year shorter – PR: 97 years (1911–2007). These forest stands were planted during the same period estimated at 1901–1903. *Pinus banksiana* trees were planted several years later (ca. 1914/15); therefore the obtained dendrochronological curve (abbreviation PB) is only 88 years long (1920–2007). The annual ring-width of the studied pine species is similar, i.e. ca. 1.3 mm; the highest annual-growth recorded for pitch pine is 1.4 mm (Table 1). Dendrochronological curves for *Pinus sylvestris* and *Pinus rigida* were characterised by the highest similarity (t = 7.9, Gl = 74%) while *Pinus sylvestris* and *Pinus banksiana* – by the lowest (t = 4.4, Gl = 69%) (Table 2). The first 15–20 annual growth rings of each chronology can be classified as juvenile wood with very wide annual growth rings and reduced tree-ring width at the end of this period. The subsequent years in pine chronologies are reflected in the stabilized annual ring-width at the level of 1–2 mm with annual differences determined mainly by changing meteorological conditions. In the 1970s and the 1980s, the annual growth rings were reduced to ca. 1 mm and less, and this trend has prevailed in the chronology of PS and PB to date; only *Pinus rigida* is characterised by higher growth dynamics (wider tree rings) since the late 1980s (Figure 2).

Table 2. Similarity of pine chronologies presented as t-value and Gl-value

t/Gl	PS	PB	PR
PS	X	4.4	7.9
PB	69	X	4.7
PR	74	72	X

Table 1. Statistical characteristics of absolute and indexed pine chronologies

Lab. code	Species	No. of years	Time span	No. of samples	Mean tree-ring width (min.-max.) (mm)
PS	*Pinus sylvestris*	98	1910-2007	16	1.29 (0.83-1.52)
PB	*Pinus banksiana*	88	1920-2007	11	1.35 (0.80-1.52)
PR	*Pinus rigida*	97	1911-2007	15	1.39 (0.63-1.85)

Lab. code	Absolute chronology			Residual chronology		
	Std. deviation	1st order autocorrelation	Mean sensitivity	Std. deviation	1st order autocorrelation	Mean sensitivity
PS	0.652	0.773	0.266	0.185	0.086	0.201
PB	0.754	0.820	0.274	0.193	-0.001	0.227
PR	0.635	0.774	0.256	0.191	0.031	0.224

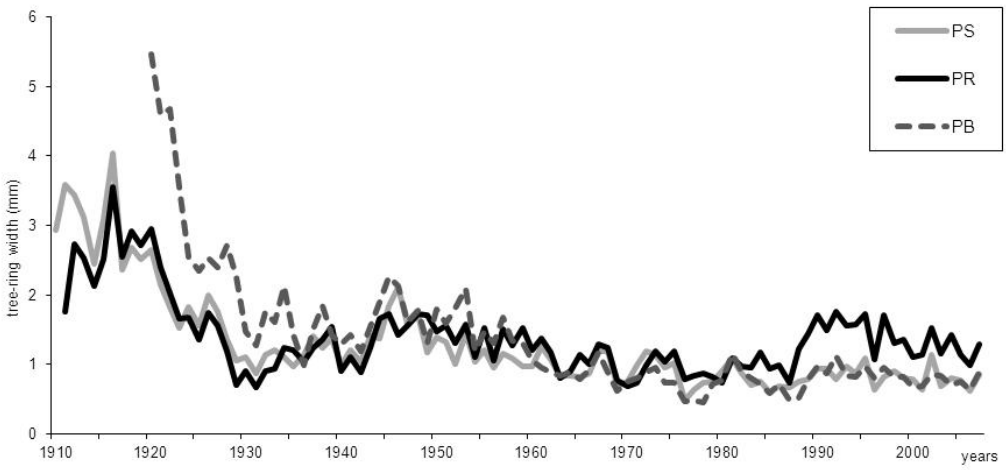

Figure 2. The tree-ring widths of pine chronologies: PS – *Pinus sylvestris*, PR – *Pinus rigida*, PB – *Pinus banksiana*

Dendroclimatology

A total of 61 pointer years were obtained for pine chronologies including 37 negative (-) and 24 positive (+): PS (14-, 6+), PB (8-, 7+) and PR (15-,11+). During the 17 years, pointer years were present in at least two chronologies (1928-, 1929-, 1940-, 1943+, 1952-, 1955+, 1956-, 1957+, 1963-, 1976-, 1981+, 1985-, 1987- and 1998-) or even three chronologies (1954-, 1969- and 2007+). The analysis of meteorological conditions in the year preceding the signature year clearly indicated that the thermal conditions in the winter season and early spring are the main factors affecting the annual ring width. Higher than the average temperature of winter months (January and February), and in particular early spring temperature (March) induces an increased cambial activity in the studied pine species and the development of a wider annual growth ring in the following growing season. The year of 2007 is an example of a positive signature year when the tree-ring width increased in all the analysed pine populations. The year was characterised by a very warm winter: the average air temperature of January was +5.1 ^{0}C, which is the maximum value for the period of post-war observations, and warm February (+1.2 ^{0}C), and by a very warm and early spring (average temperature in March was +6.9 ^{0}C and it was the highest temperature during the observation period). Based on the average annual temperature, the year of 2007 (+9.7 ^{0}C) can be classified as the warmest over a long period. The annual precipitation was higher by ca. 140 mm than the average precipitation; April was relatively dry, although a large amount of rainfall was observed in the summer months. Thus the year can be considered as warm and wet.

Low temperatures in winter and early spring reduce the growth in three pine species. Such conditions and the related growth responses took place i.e. in 1954 and 1969. Hormones and metabolism start to change in pines along with the increasing day length and the increased amount of sunlight reaching the Earth's surface, which result in the increased sensitivity to low temperatures. Exposure of trees to severe frost in late winter and early spring weakens the health condition of trees and reduces the width of annual growth rings developed in the forthcoming growth season. Low precipitation during the spring and summer months (e.g. dry April and May in 1954; dry June and extremely dry July in 1969) might be yet another factor responsible for the growth reduction.

The growth-climate relationships determined on the basis of signature years are confirmed by correlation analysis and response functions (Figure 3). Positive values of correlation and regression dominate in all the analyses for air temperature; statistically significant values are recorded in winter (between December of the year preceding the growth and February of the current year) and in the spring months: March and April. Additionally, thermal conditions in July and August appear to be important for *Pinus banksiana*, and temperatures in August – for *Pinus rigida*.

As a rule, precipitation in the previous season has a positive impact on the annual ring width, and also high precipitation at the end of winter and the beginning of spring (February and March) increases the cambial activity. High coefficients obtained for temperature and precipitation in February and March are associated with the weather conditions preferred by these three pine species: dominant westerly circulation over Central Europe and related inflow of warm and humid air masses from the North Atlantic.

Coefficients of determination indicate a strong impact of meteorological conditions during the development of annual growth rings: the strongest for *Pinus rigida* (integrated 79%, 55% for temperature and 24% for precipitation) and *Pinus sylvestris* (totality 76%, 36% for temperature and 40% for precipitation), slightly lower values were obtained for *Pinus banksiana* (Fig. 3).

Discussion and conclusions

Due to minor economic importance of jack pine *Pinus banksiana* and pitch pine *Pinus rigida* in Europe, and their limited distribution outside their natural range, the available literature deals mainly with dendroclimatological analysis of the studied species from the region of their natural occurrence, i.e. Canada and the United States (Abrams and Orwig 1995, Despland and Houle 1997, Hofgaard et al. 1999, Tardif and Conciatori 2001, Copenheaver et al. 2002, Lloyd and Bunn 2007, Savva et al. 2008, Genries et al. 2012).

As evidenced by the research on *Pinus banksiana* growing in the boreal forest of Quebec (Canada), the species is sensitive to temperature and precipitation at the end of the preceding growing season and, similar to the results obtained in the presented study on the Polish coast, to thermal conditions at the beginning of the current growing season (Hofgaard et al. 1999). According to Despland and Houle (1997), the thermal summer conditions have a significant effect on the radial growth rate and the maturation of seeds in this region. At the border between two Canadian provinces – Quebec and Ontario, the annual growth rings of *Pinus banksiana* were positively correlated with high precipitation in June of the preceding year and high temperature in April, whereas warm September and wet October in the preceding year, as well as high total precipitation in June reduced the annual ring width (Genries et al. 2012). The positive impact of

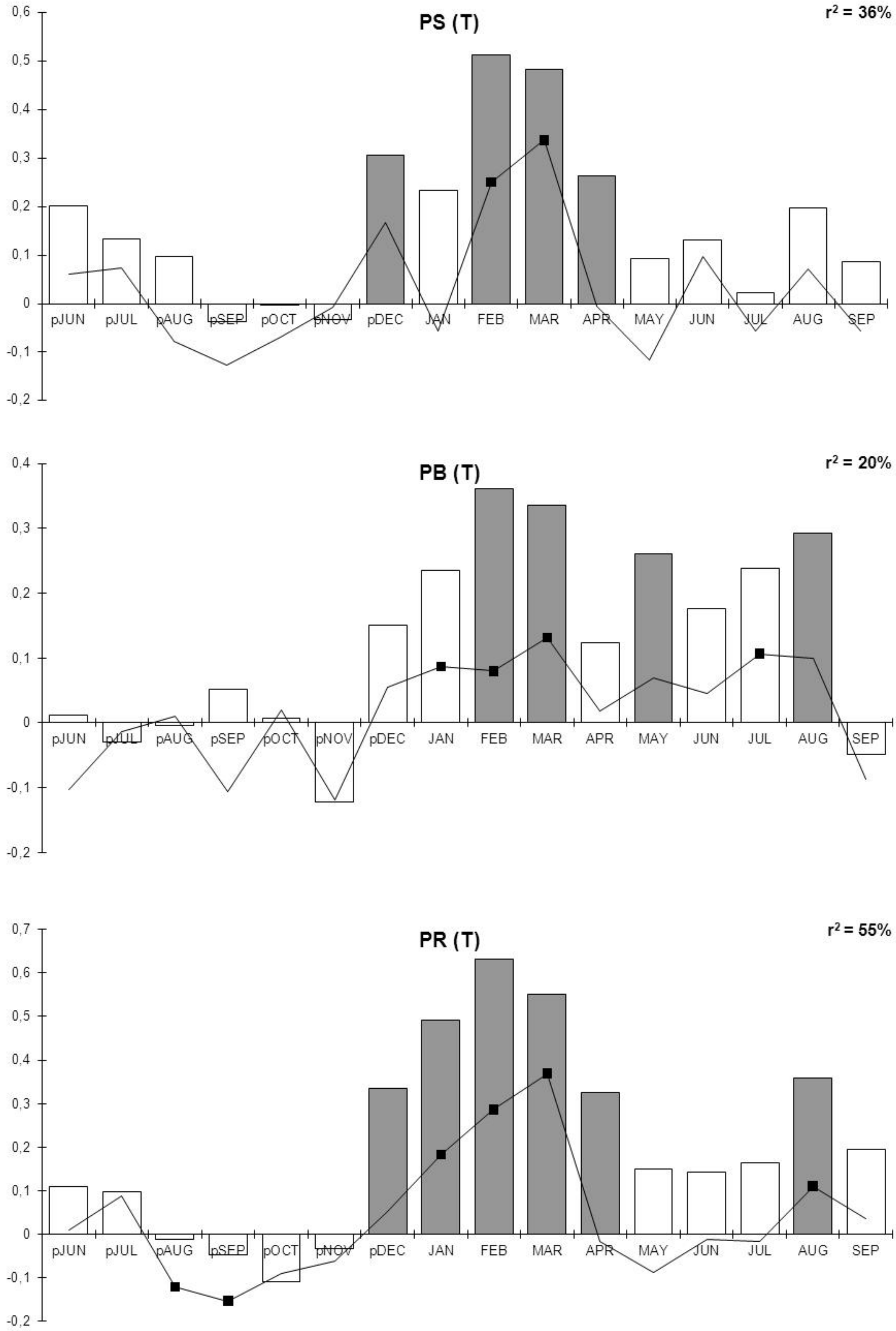

Figure 3. Results of correlation and response function analysis for pine chronologies and air temperature (T) and precipitation (P); bars denote correlation coefficients; line represents response function; significant values (a = 0.05) marked as black squares and gray bars; p – previous year

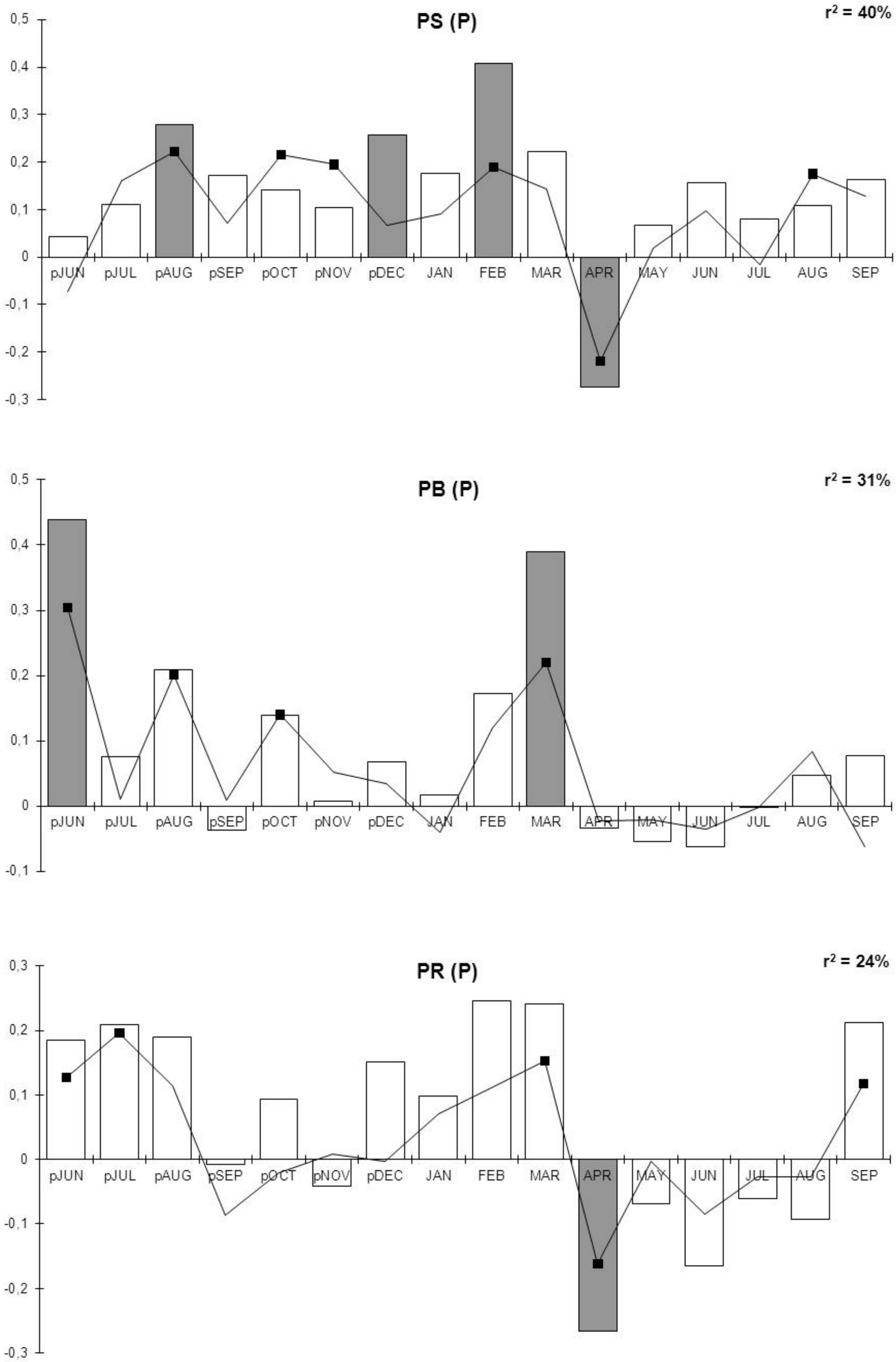

Figure 3. (Continued)

spring thermal conditions on the annual growth rings of this species growing on the borderland between Quebec and Ontario was reported also by Tardif and Conciatori (2001). According to the authors, the amount of rainfall in June was the main factor positively correlated with the radial growth rate, which is basically consistent with the results obtained in the present study, whereas Genries et al. (2012) obtained inverse relationships (the smaller the precipitation the higher the growth).

The research on the growth-climate relationships for *Pinus banksiana* from the regions situated further west of Ontario revealed that the annual ring-width was primarily determined by the amount of precipitation in March, June and December in the year preceding the growth (Savva et al. 2008).

Dendrochronological reports from the USA (the state of Michigan) on the species of *Pinus banksiana* indicate the problem with a false ring (Copenheaver et al. 2006). The authors, however, found no significant correlation between the presence of a false ring in the studied populations and the temperature and precipitation. As evidenced by other studies conducted in the USA (the state of New York), trees of *Pinus banksiana* were sensitive to winter temperatures (November-March) (Pederson et al. 2004) in a similar way as in the presented research on the Polish coast.

Research on the other species – *Pinus rigida* in the USA (the state of New York) revealed that the species is sensitive to prolonged and severe drought (Abrams and Orwig 1995). In the state of Virginia, located south of the state of New York, the width of annual growth rings in trees of this species depends on the thermal and pluvial conditions in the summer and autumn months in the year preceding the growth (Copenheaver et al. 2002).

There are almost no dendrochronological data in the Polish literature related to these studied North American pines, mostly due to their relatively low incidence and decreasing economic importance. Only Oleksyn (1980) analysed the relationship between the width of annual growth rings in *Pinus sylvestris* and *Pinus rigida*, and the Wolf number and the number of sunspots, revealing an increase in the tree-ring width as a result of higher solar activity. Therefore, the results obtained in this study constitute an important contribution to the knowledge about the relationship between the meteorological conditions and the annual growth rings of *Pinus bankasiana* and *Pinus rigida* growing in the area outside the range of their natural distribution.

As evidenced by the comparison between the responses of native *Pinus sylvestris* and introduced *Pinus banksiana* and *Pinus rigida* to changing meteorological conditions on the Polish coast, the width of annual growth rings in all three pine species is similar. *Pinus banksiana* seems to grow faster in the first decades and it would be more useful for dune reforestation, but it is also the least long-lived species (we have noticed the largest number of dead trees of this species in comparison with the other studied pine species in the analysed forest stand on the coastal dunes). The main contraindications to the use of alien species for reforestation of coastal dunes, however, are the conservation requirements of habitats of Community importance (Natura 2000). All coastal dune habitats with characteristic natural vegetation growing on them on the Polish Baltic coast are listed in the European Habitats Directive (Council Directive 92/43/EEC) and all efforts should be made to preserve them in their natural state.

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ДЕНДРОХРОНОЛОГИЧЕСКИЙ АНАЛИЗ ТРЕХ ВИДОВ СОСНЫ, ИСПОЛЬЗУЕМЫХ В КАЧЕСТВЕ ВИДОВ-ПИОНЕРОВ ДЛЯ СТАБИЛИЗАЦИИ ДЮН В ПРИБРЕЖНОЙ ЗОНЕ НА ЮЖНОМ ПОБЕРЕЖЬЕ БАЛТИЙСКОГО МОРЯ

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Резюме

Целью исследования являлось составление хронологии для трех видов сосны, используемых для стабилизации дюн на польском побережье Балтийского моря: местной *Pinus sylvestris* и двух интродуцированных – *Pinus banksiana* и *Pinus rigida*. Популяции данных видов, произрастающих на бедных песчаных почвах прибрежных дюнных массивов в ассоциации вороничных сосняков, сравнивались по ширине годичных колец и реакциям прироста на изменяющиеся условия окружающей среды в разные периоды.

В начале вегетационного сезона 2008 г. были взяты пробы 61 деревьев; получены 5077 колец годового прироста. Самая длинная хронология, насчитывающая, 98 лет, репрезентирующая 1910–2007 гг., составлена для *Pinus sylvestris*, самая короткая – 88 лет (1920–2007) – для *Pinus banksiana*. Сосны обыкновенная и смолистая отличаются наиболее высоким сходством дендрохронологических кривых (t = 7,9; Gl = 74%), тогда как сосны обыкновенная и Банкса – самим низким (t = 4,4; Gl = 69%).

Всего для составленных хронологий выявлено 61 репернх лет, в том числе 37 отрицательных (-) и 24 положительных (+). В 17-ти периодах реперные года выявились одновременно, по крайней мере, в двух хронологиях, а в 3-х – во всех анализируемых дендрохронологических кривых (1954 -, 1969 - и 2007 +). Анализ метеорологических показателей года, предшествующего реперному, позволяет рассматривать термические условия зимнего периода и начала весны в качестве доминирующего фактора, определяющего ширину годичных колец. Повышенная температура, наблюдаемая в январе, феврале и особенно в марте, стимулирует активность камбия у исследуемых видов сосны и способствует появлению более широкого годового прироста в наступающем сезоне. Низкие температуры зимнего периода и начала весны вызывают редукцию прироста.

Зависимость «прирост-климат», определенная на основании реперных годов, подтверждает анализ корреляции и функции отклика. В случае температуры воздуха статистически значимые результаты появляются в зимний период (с декабря предшествующего года до февраля текущего года), а также в весенние месяцы – марте и апреле. Кроме этого, для сосны Банкса существенное значение имеют термические условия июля и августа, а для сосны смолистой – температуры августа. Большое количество осадков в предыдущем летнем сезоне, а также повышенные осадки на переход зимы и весны оказывают положительное влияние на ширину годового прироста.

Ключевые слова: ширина годичных колец, метеорологические условия, сосна обыкновенная (*Pinus sylvestris* L.), сосна Банкса (*Pinus banksiana* Lamb.), сосна смолистая (*Pinus rigida* Mill.), прибрежные дюны