Radial growth response of Pine (*Pinus sylvestris* L.) and Spruce (*Picea abies* L.) Karst. to climate and geohydrological factors

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The longevity of trees usually limits the chronological span for which the climatic informations could be derived from tree ring sequences of living trees. In Lithuania, Pine and Spruce trees are known to live generally for 200-300 years. Tree ring analysis of *Pinus sylvestris* and *Picea abies* from different geohydrological conditions has revealed that the tree ring materials of these species from similar ecological conditions could be taken together to prepare long tree ring chronologies for climatic studies. The study has further brought to light that the archaeological material of these species provide the potential to extend the tree ring chronologies for few more centuries back in time.

Key-words—Growth response, Dendrochronology, *Pinus*, *Picea*, Ecology.

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साराँश

जलवायु एवं भूजलीय कारकों का पाइन (*पाइनस सिल्वेस्ट्रिस एल.*) एवं स्प्रूस (*पाइसिआ एबीज़* एल.) कार्स्ट. की अरीय वृद्धि पर प्रभाव

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जीवित वृक्षों के वृद्धि वलयों के अनुक्रमों से जलवायवी जानकारी एकत्र की जाती है। लिथुआनिया में पाइन और स्प्रूस सामान्यतः 200–300 वर्षों तक जीवित रहते हैं। विभिन्न भूजलीय परिस्थितियों में *पाइनरा सिल्वेस्ट्रिस* एवं *पाइसिआ एबीज़* के वृक्ष वलय विश्लेषण से व्यक्त होता है कि इन जातियों की वृद्धि वलय सामग्री जलवायवी अध्ययन हेतु सर्वथा उपयुक्त है। इस अध्ययन से यह भी पता चला है कि इन जातियों की पुरातात्विक सामग्री कई सदियों तक वृद्धि वलयों की कालानुक्रमिकी के अध्ययन हेतु उपयुक्त रहती है।

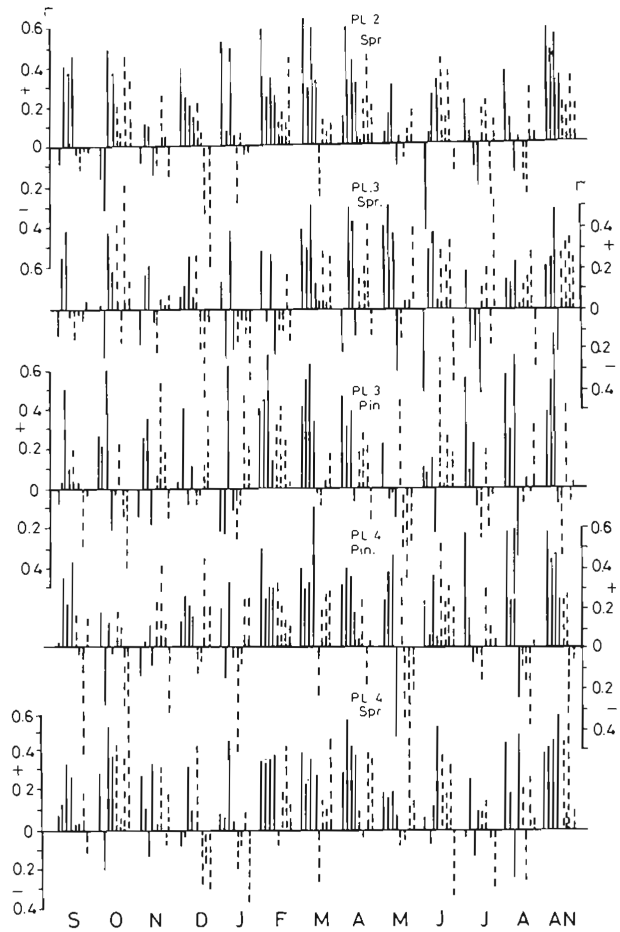
TREE growth is a dynamic process which is continuously influenced by on-going environmental processes of their surroundings. Various tree ring features as ring width, wood density and chemical properties provide proxy information of such changes with the sequential calendar years depending on the length of the series (Bitvinskas, 1974; Fritts, 1976; Lovelius, 1979; Hughes *et al.*, 1982; Jacoby, 1987; Schweingruber, 1988; Cook & Kairiukstis, 1990). In Lithuania, trees used for such studies are usually found to be 200-300 years of age. The samples of living trees may therefore be combined with archaeological and geological timbers to prepare longer chronologies. However, in such cases, the materials of particular species are too limited to develop reliable chronology and even in many cases they could belong to diverse ecological conditions. The materials of different species could be used together for chronology preparation if they possess significantly similar growth behaviour. To work out this possibility, the authors investigated the growth behaviours of *Pinus sylvestris* L. and *Picea abies* (L.) Karst. growing in similar as well as different geohydrological conditions by using the ring width parameter.

MATERIAL AND METHODS

For the present study, three experimental forest plots situated about 30 km from the Kaunas (Lithuania) were selected. These forest plots have quite different ecological conditions. The forest plots 2 and 3, on alluvial sandy soil formed after the last glaciation, are situated in Kazlu-Ruda Forest Division.

The plot 2 is characterized by 70 per cent pine (*Pinus sylvestris*) and 30 per cent spruce (*Picea abies*) population. The type of forest is classified as *Pinetum-oxalidoso-myrtillosum.* The ground has an uneven relief with elevations reaching up to 2.7 m at places. Pine trees are found often growing on elevated places. The soil has good porosity but water drainage is poor. The ground water level is 2.15 m. A distinct alluvial layer with few rootlets is found at 18-31 cm depth and yellow alluvial with hard brown spots at 32-40 cm depth. The third experimental plot, lying about 500 m from the second, grows on a flat terrain. The stand is composed of 50 per cent pine, 40 per cent spruce (30% old and 10% young) and 10 per cent birch. The forest type is known as *Pinetum myrtillosum.* The soil horizons are featured by top 10 cm peat with poorly rotten litter, 21-40 cm brown grey alluvial layer with white spots and 41-51 cm hard, dark brown alluvial layer. The ground water level is at 1.2 m depth. The plot 4 growing on top of the ancient Nemunas Valley located in Chilenu Forest Division has 70 per cent pine and 30 per cent spruce. The type is classified as *Pinetum-oxalidoso-myrtillosum.* The soil is characterised by clay layer at 2 m depth which is non-porous and inhibits the downward water percolation. The soil horizons are similar to that of plot 2 except alluvial and alluvial horizons which are comparatively at higher depth. Grey alluvial layer with brown spots occurs at 68-82 cm depth and grey alluvial with frequent brown spots is present at 83-130 cm depth.

For tree ring analysis 10 increment cores, one from each tree were taken at breast height from each forest plot by using increment corers. Growth rings were dated and measured under the microscope to the accuracy of 0.05 mm. Growth trends from each raw ring width series were removed by 20 year moving average with 5 year step following the procedure of Bitvinskas (1974) and mean chronology of each species from different plots was prepared. The mean ring-width chronologies were then used for climate-growth relationship. For this, the meteorological data has been (annual as well as average monthly temperature and precipitation)



Text-figure 1—Pine and Spruce radial growth correlation with average monthly and annual weather data. From left to right, the coefficients for the first, second, third and fourth periods ______ with temperature ----- with precipitation.

taken from Kaunas meteorological station from 1893-1977. Jablonskis and Janukeniene (1978) classified this meteorological data series on the basis of river flow into four subperiods. The first (1964-1977) and third (1933-1944) periods were found relatively dry, whereas second (1945-1963) and fourth (1922-1936) relatively wet. The correlation studies were done for each period separately as well as with the whole series (Text-figure 1).

RESULTS AND DISCUSSION

The correlation between radial growth of both the taxa (*Pinus sylvestris* and *Picea abies*) and meteorological factors of geohydrological year

Table 1—Mean meteorological data of four climatic periods

Period	Factor	Mean meteorological data												
		IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	AN
1977-	mm	51.7	57.4	59.7	46.9	31.0	32.1	30.9	45.4	56.8	69.7	71.5	58.1	611.3
1964	C°	12.6	6.9	1.9	-2.2	-5.6	-4.0	-0.4	5.7	11.8	16.2	17.5	16.6	6.4
1963-	mm	61.5	41.8	42.2	39.1	29.8	31.2	30.0	39.9	47.9	76.9	84.3	99.6	624.3
1945	C°	12.4	6.9	1.8	-2.0	-4.8	-5.1	-1.5	6.4	12.2	15.8	17.5	16.5	6.3
1944-	mm	54.9	51.6	35.3	27.8	26.2	29.6	31.8	38.4	58.2	60.6	104.0	72.9	591.5
1933	C°	13.1	7.2	2.0	-3.2	-6.8	-3.8	-0.3	5.9	12.0	16.2	18.1	17.6	6.5
1936-	mm	56.3	59.9	47.3	29.2	22.7	21.9	26.5	38.7	72.5	68.3	85.9	110.1	639.3
1922	C°	12.5	7.4	2.0	-3.0	-4.6	-5.0	-0.5	5.5	12.8	14.9	17.7	16.2	6.3

showed positive relationship with the temperature data with only one exception in trial plot 3 for the fourth period (Text-figure 1). It has been seen that the response of the two species growing in similar conditions is more or less similar whereas the same species growing in different conditions respond differently with climatic variables. Annual precipitation of geohydrological year has shown varied response especially in case of pine in trial plot 3. Temperature of September has shown positive correlation with ring widths of spruce and pine of trial plot 4. Similar relationships were also noted in other trial plots as well, with the exception of the first period. The mean of September precipitation during the first period (1964-1977) was low as compared with other periods (Table 1). As July and August were comparatively drier during this period, it could have resulted in deficient soil moisture. Thereafter September rains replenishing the soil with moisture show positive correlation. On the other hand, after rainy July and August in the third period, the water infiltered deeper and precipitation of September had negative influence on pine growth. Similar explanations could be given for the response of pine with the precipitation of October in the third and fourth periods. In trial plot 3 the precipitation of September in the first period had positive influence on pine growth whereas, on spruce negative. It is due to hard alluvial soil layer of plot 3 causing very restricted water infiltration in deeper soil layers. On the other hand September precipitation gives very slight positive influence on spruce growth in plot 4 where alluvial layer is at higher depth. Due to different geohydrological conditions of soils of the plots, the growth responses of pine and spruce vary with precipitation and temperature of November.

Both the species growing in all three experimental plots barring few exceptions have shown positive growth response with the temperature of winter and spring. The identical responses of the two species with thermal regime show that the temperature is the most important factor influencing the tree growth. The reaction of Spruce (trial plot 3) and pine (trial plot 4) with temperature of January in the first and third periods and in the second and fourth periods is of significant interest. January was the coldest in the first and third periods. January temperature of these periods showed positive influence on Spruce and Pine growth. However, growth response of both the species with the temperature of January in the second and fourth periods is negative though January of these two periods were warmer. This increased January temperature accelerates the physiological activities of the trees. The physiologically active trees become prone to damages caused by low temperature. Therefore, high and low temperature fluctuations of January have more negative influence on tree growth than the homogeneously cold January. Winter precipitation also plays important role on tree growth. Thick snow in winter prevents soil from freezing and thus protects from fluctuating atmospheric temperature. On the other hand, quickly melting snow adds to the ground waters and causes negative influence on tree growth. The thick winter snow in the first period prevented the congelation of deeper soil and therefore the high March temperature resulted in quick melting of snow and soaking of the soil. The snow melt water supplemented with March precipitation had negative influence on tree growth. The opposite influence is notable for the third and fourth periods, when the precipitation was poor and was also very cold at the beginning of winter. Due to these conditions in the spring water flowed rapidly without soaking the soil and therefore, precipitation of March showed positive influence. From May, the influence of meteorological factors on the growth behaviour of both the species highly differs. The precipitation of May has positive influence on the growth of spruce almost in all periods whereas negative on pine.

The different growth response of spruce and pine to precipitation of May seems to be due to their different root systems. The roots of spruce are superficial, whereas in pine they penetrate to deeper soil layers. The negative influence on pine seems to be due to water logged condition in deeper soil layers. However, with the increase in temperature of summer, surplus soil water gets evaporated and pine starts showing positive response with summer precipitation. But, in cases of abundant precipitation the negative influence is observed. On the other hand, summer temperature dries up the superficial soil layers and causes moisture deficiency. This is evident from the negative relationship of Spruce with the temperature of July in trial plot 3, barring in the first period.

CONCLUSION

The present investigation has revealed that *Pinus sylvestris* and *Picea abies* growing in similar geohydrological conditions show very similar response to the annual meteorological conditions than of the same species growing in varied conditions. The root system of trees has been found to be very important in determining the growth behaviour of trees in response to climate. The pine, which has deeper root system in comparison to spruce, reacts slowly to changing climatic variables of warm periods.

The study also brings to light that the above two species growing in similar conditions could be used together to develop the chronology for climatic reconstruction especially annual meteorological parameters. The knowledge of tree growth response to climatic factors in different geohydrological conditions would also be helpful in working out the archaeological samples. Tree growth is dependent on the combination of meteorological factors. The preceding months conditions play important role in determining the effect of meteorological factors of the ensuing months. Homogeneous climate periods such as dry or wet phases of the meteorological series show better correlation with tree growth in comparison to the whole series when used together. It shows that climatic reconstructions could be improved by using the homogeneous data series for climate growth modelling.

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