RAM R. YADAV* - TEODORAS T. BITVINSKAS**

(*Birbal Sahni Institute of Palaeobotany, Lucknow, India)
(**Laboratory of Dendroclimatochronology, Institute of Botany, Lithuania)

GROWTH VARIABILITY OF TREES IN KAMCHATKA AS INFLUENCED BY VOLCANIC ERUPTIONS

Key words: Tree rings, growth variability, volcanic eruption, Kamchatka.
Parole chiave: anelli legnosi, variabilità di accrescimento, eruzione vulcanica, Kamchatka.

ABSTRACT

The unique geographical position of Kamchatka and the frequently occurring volcanic eruptions attract the interest of earth scientists, climatologists, foresters, botanists and other disciplines. The volcanic ashes deposited on leaves and the injuries caused by acid gases ejected during an eruption directly affect tree growth. Reduced solar radiation as well as low temperature caused by the huge amount of aerosols thrown into the stratosphere by volcanic eruptions, reduces tree growth indirectly. Tree rings as important source for proxy data offer an unique opportunity in studying the volcanic events of the recent past and the magnitude of their effect on tree growth. A tree-ring study would also provide a sound basis in guiding the judicious forestry schemes in Kamchatka. Investigations with similar objectives have been made in different areas (e.g. YAMAGUCHI 1983; LAMARCHE, HIRSCHBOECK 1984; KAISER, KAISER-BERNHARD 1987).

In the present study, tree-ring sequences of larch (*Larix cajanderi* Mayr), spruce (*Picea cajanensis* Lindl. et Gord.) and pine (*Pinus pumila* Pall.) were used as proxy records.

CLIMATE AND DISTRIBUTION OF LARCH, SPRUCE AND PINE SPECIES IN KAMCHATKA

Kamchatka is located in the far east of the Asian continent (50°57' to 60°50' N and 155°30' to 164°40'). Its climate is largely determined by its extreme geographical position as well as by the frequent occurrence of volcanic eruptions. Detailed information about such volcanic events in Kamchatka are given by Guschenko (1979) and Loginov (1984). The climate in the Kamchatka river valley from where the samples were collected is of the boreal type with moist and severe winters, lasting from October to April. Winds

sometime may be as strong as hurricanes. The summers are short and not very hot. The vegetational period with an average temperature of more than 5°C is usually 125 days long. Growth in the Kamchatka river valley starts in May.

Larch (*Larix cajanderi*) growing on plains, mountains and often in valleys constitutes the main conifer species in the Kamchatka forests. On mountains larch is found to grow on south facing slopes. Old larch forests are restricted to the Kamchatka river valley. Larch is a light-loving tree and does not like frost and wind. It is a pioneer species to colonize the soils of volcanic dusts. It sheds leaves at the end of September and new leaves flush in the middle of May.

Spruce (*Picea cajanensis*) is very much restricted in its distribution and only occurs in the valley of the Kamchatka river. It does not grow north of the junction of the rivers Rossokin and Elovki (56°51'N). To the south it is found up to the river Kirganisk (54°48'N) but sometimes individual spruce trees are found growing somewhat south in the large Kirganisk tundra. Spruce grows usually mixed with larch, pine and white birch and very often it extends into birch forests. Occasionally it ascends to higher elevation on the mountains than larch. It grows on rocks and poor humic soils. Spruce suffers less from frost and snow.

Pine (*Pinus pumilla*), a bushy conifer is widely distributed. In lower forests it meets with larch and birch but principally occupies more open spaces. In sheltered places and under oceanic influences it sometimes reaches 4 to 7 m height. But in open areas where it is continuously affected by wind, remains stunted. Pine grows on sands, rocky as well as volcanic ash deposits.

MATERIALS AND METHODS

Tree core samples of larch, spruce and pine were collected from the Kamchatka river valley and nearby areas in the summer of 1981 by V.P. Balchiunas of the Laboratory of Dendroclimatochronology (Fig. 1). Usually one core was taken from each tree at breast height. In most cases the increment borer reached up to the centre of the tree and so it was easy to determine the age of the trees. A total of 120 samples with 70 larch, 35 spruce and 15 pine were collected. Tree-ring sequences were dated using the standard cross-dating procedure (STOKES, SMILEY 1968). For distinctly characteristic rings, the term 'pointer year' in the sense of SCHWEINGRUBER ET ALII (1990)

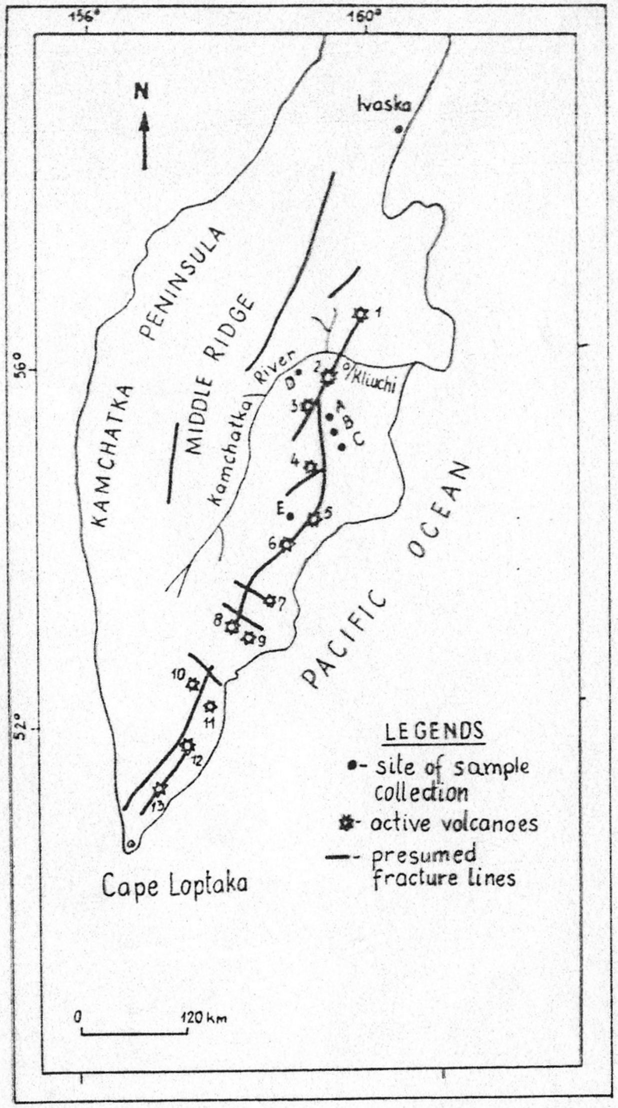

Fig. 1: Map showing the active volcanoes of Kamchatka and sites from where the samples were collected. The volcanoes are: 1. Sheveluch, 2. Kliuchevskaya, 3. Bezimianiy, 4. Plosky Tolbachik, 5. Kizimen, 6. Little Semyachik, 7. Karymskaya, 8. Zhupanovskaya, 9. Koryakskaya, 10. Avacha, 11. Coreliy Chrebet, 12. Mutnovskaya, 13. Ksudach. Sample sites are as A-C, Larch; D, Spruce; E, Pine.

has been used. Precise dating of growth rings is essential to locate missing or false rings in individual specimens and to assign calendar dates to each tree-ring width measured. Missing rings were found to be common in many larch trees whereas in spruce and pine no missing rings occurred. Missing rings were assigned with a zero according to the dendrochronological procedures (e.g. STOKES, SMILEY 1968; BAILLIE, PILCHER 1973). The trees ceased their radial growth most probably just after the year of a very strong volcanic eruption. The tree-rings widths were transformed into dimensionless ring indices following the procedure of BITVINSKAS (1974).

In addition to tree-ring width, basal-area increments were calculated as an important criterion used by foresters to determine the tree productivity. Based on the tree-ring width of the corresponding age and the radius of the previous year, current basal-area increment was estimated for consecutive three to four years after a strong volcanic eruption. Basal-area increment was calculated according to PHIPPS (1983) by using the formula:

$$BSI = \pi (R_n{}^{2} - R_{(n-1)}2),$$

where R_n is the tree radius at the age n (year).

Average basal-area increment was obtained for ten trees of each species. In cases where the cores contained the center of a tree, the radius of the subsequent years was calculated by adding the corresponding ring width. For comparing all three tree species, proportional basal-area increment was taken into consideration. It was obtained by taking the basal area increment of the year prior to the eruption as a reference value (Table 1).

REFLECTION OF VOLCANIC EVENTS IN THE CHRONOLOGIES

The larch chronology extending from 1801 to 1980 AD (Fig. 2) shows that extremely small ring- width indices are strongly associated with severe volcanic eruptions. Low values are also caused due to the combined effect of several weak volcanic events occurring in the same year. During the time span of the larch chronology, strong volcanic eruptions occurred in 1821, 1829, 1904, 1945, 1955 and 1975. After these events the tree growth greatly reduced in the subsequent year. The growth reduction was observed to be maximum when the eruption occurred during the growing season, presumably because a very small amount of photosynthates was produced. Due to a small

Year	Larch	Spruce	Pine
1925	1.00	1.00	1.00
1926*	0.81	0.90	0.92
1927	0.66	0.50	0.66
1928	1.08	0.45	0.57
1929	1.20	0.92	0.93
1944	1.00	1.00	1.00
1945*	0.67	1.02	1.20
1946	0.54	1.26	1.27
1947	1.06	0.79	0.93
1951	1.00	1.00	1.00
1952*	0.57	0.82	0.87
1953	0.75	0.71	0.91
1955	1.00	1.00	1.00
1956*	0.69	0.74	0.77
1957	0.60	0.64	0.92
1958	1.06	1.35	1.39
1967	1.00	1.00	1.00
1968*	0.83	1.11	1.06
1969	0.83	0.76	0.83
1970	1.18	1.27	0.98
1974	1.00	1.00	1.00
1975*	0.78	0.90	1.01
1976	0.44	0.81	0.79
1977	0.90	0.95	1.07

Tab. 1 - Relative basal-area increment larch, spruce and pine as affected by some of the strong volcanic eruptions. The basal-area increment of the year prior to the eruption has been taken as a reference value (* eruption year).

food reserve which is the trigger source of the next year's growth, radial increment abruptly declines in the subsequent year. The extremely narrow earlywood in the next year's tree ring which is largely the product of previous year's food reserve supports this

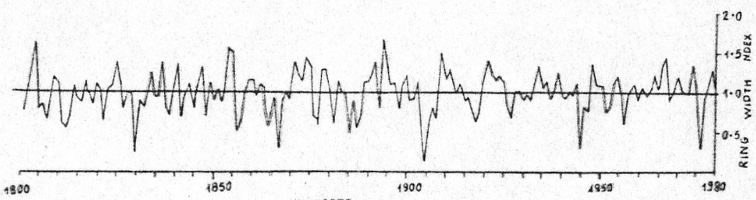

Fig. 2: Larch (*Larix cajenderi* Myr) chronology.

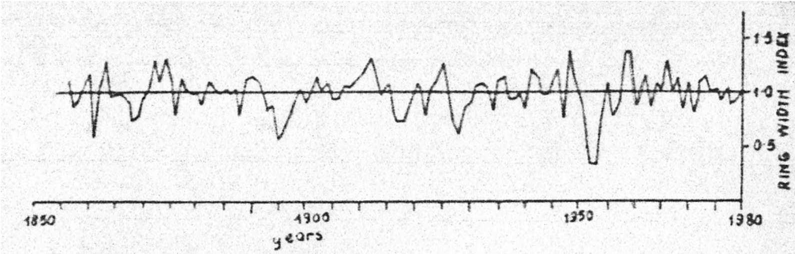

Fig. 3: Spruce (*Picea cajanensis* Lind. et Gord.) chronology.

assumption. This poor food reserve also results in a reduced development of the photosynthetic surface (needles), and new metobolically active roots are further reducing the tree growth in the year after eruption. In many cases no tree rings are formed in the lower trunks as the lower stem has a low priority as compared to buds, shoots and roots. The severe volcanic eruptions occurring far from the area are not very influential in reducing the tree growth. In 1907 the Ksudach volcano, about 500 km south to the larch site experienced a very strong eruption. It was reported that volcanic dusts reached up to 1000 km north (GUSCHENKO 1979). Growth reduction in larch due to this event was detectable but not severe. The growth of larch was found to be small from 1809 to 1811 which could be assigned to reduced solar radiation as the atmosphere was in general laden with volcanic dusts from 1807 up to 1810 (LAMB 1970). Extremely narrow rings were also formed in 1856/57, 1867 and 1918 which cannot be related to any local event. As to the minimum in 1918, the winters from 1912 to 1917 were very severe and could have been one of the responsible factors for the reduced growth.

The spruce chronology extends from 1856 to 1980 AD (Fig. 3).

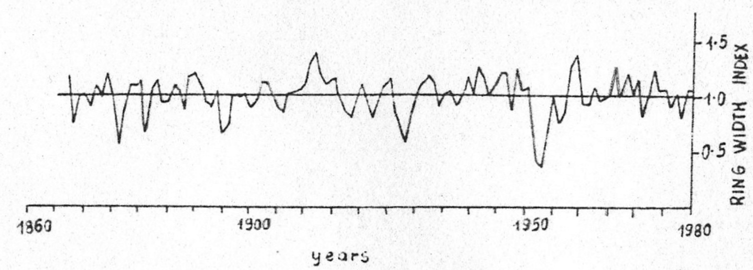

Fig. 4: Pine (*Pinus pumila* Pall.) chronology.

The chronology in general agrees with the larch chronology but the ring-width indices do not fall as abruptly as with larch, and weak volcanic events are even sometimes not reflected at all. During the strong eruptions of 1904, 1945 and 1975 growth did not fall as compared with larch, whereas the 1955 event is clearly reflected.

The pine chronology is exactly identical to that of the spruce chronology indicating that spruce and pine have almost similar growth behaviour in Kamchatka. The chronology extends from 1867 to 1980 AD (Fig. 4). Pine in Kamchatka is bushy and does not reach to higher age and thus limiting its application in chronology building for climatic and other studies.

Basal-area increment study

The relative basal-area increments of the three species were calculated for the period from just after a major volcanic eruption until signs of recovery were noted. The average relative basal-area increment for all three species is based on ten samples each. It is clear from the data that larch suffers a maximum increment loss as compared to the other two species. Spruce and pine show quicker recovery from the injury caused by a volcanic eruption. It is also seen that even in some cases when growth is significantly reduced in larch, no change in the growth pattern of spruce and pine was noticed; for example, in 1945. Due to the volcanic eruptions from 1926 to 1927 when five volcanoes in Kamchatka erupted, maximum loss in the increment of spruce and pine occurred. Exceptionally during this time it is also noted that the recovery in pine and spruce was slow as compared with larch. In larch, basal-area increment shows that growth resumed normality in 1928 whereas in spruce and pine maximum growth reduction occurred in this very year. Basal-area increment during and after various volcanic events shows that growth recovery in all three species studied occurred in most of the cases within two to three years. However, Lovelius (1979) studying the effect of the volcanic eruption of 1945 in Kamchatka on the growth of larch found that normal growth could only be restored after 13 to 14 years. Kaiser and Kaiser-Bernhard (1987), studying the effect of the 1912 Katmai eruption on the growth of sitka spruces on Kodiak Island, found that even the severest damage did not persist longer than three to four years.

Conclusion

On the basis of the present study it can be concluded that the radial increment of all three species is greatly reduced by the consequences of volcanic eruptions. The recovery from the injury usually takes two to three years. The growth reductions in larch are more severe than in spruce and pine. The strong influences of volcanic eruptions on tree growth provide a clear facility to date earlier volcanic eruptions from tree-ring sequences from their vicinity. In the Kamchatka river valley, where there is good hope of finding old larch trees, it should be tried to study the ancient volcanic events of this area.

The growth reductions, as shown by relative basal-area increment changes after strong volcanic eruptions, indicate that spruce and pine suffer less from volcanic eruptions as compared to larch. As spruce is of good timber quality it should be preferred for afforestation in Kamchatka over other conifer species. In the areas where spruce cannot grow, pine should be the favourite alternative for afforestation. Though the pine is not of much timber use because it is bushy, would help in the ecological stabilization and soil binding of degraded areas.

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SUMMARY

Growth variability of trees in Kamchatka as influenced by volcanic eruptions.

Study of tree-ring sequences of *Larix cajanderi* (1801-1980 AD), *Picea cajanensis* (1856-1980 AD) and *Pinus pumila* (1867-1980 AD) from Kamchatka has indicated that the volcanic events occurring in the vicinity of the area cause severe growth reductions in trees which were usually found to continue for two to three years consecutively after the eruption. Such event-response studies could be used as a sensitive measure to study the prehistoric volcanic events. A long record of volcanic events would help in better understanding of their recurrence behaviour.

Basal-area increment study of the above three species shows that the *Larix cajanderi* suffers most due to volcanic events in comparison to other two species.

ZUSAMMENFASSUNG

Durch Vulkanausbrüche verursachte Wachstumsschwankungen der Bäume in Kamchatka.

Die Untersuchung von Jahrringfolgen von *Larix cajanderi* (1801-1980 AD), *Picea cajanensis* (1856-1980 AD) und *Pinus pumila* (1867-1980 AD) in Kamchatka hat gezeigt, daß Ausbrüche von naheliegenden Vulkanen bei den Bäumen erhebliche Zuwachsreduktionen verursachen, die zwei bis drei Jahre andauern. Derartige Ursache-Wirkungsbeziehungen können als empfindliches Merkmal bei der Untersuchung vorgeschichtlicher Vulkanereignisse dienen. Eine lange Zeitreihe für vulkanische Ereignisse würde das Wiederholungsverhalten von Vulkanen verstehen helfen. Die Grundflächenzuwächse der drei Baumarten zeigen, daß *Larix cajanderi* im Vergleich zu den beiden anderen Baumarten am meisten unter Vulkanausbrüchen leidet.

RIASSUNTO

Influenza delle eruzioni vulcaniche sulla variabilità dell'accrescimento di alberi della Kamchatka.

Gli studi sulle sequenze anulari di *Larix cajanderi* (1801-1980 AD), *Picea cajanensis* (1856-1980 AD) e *Pinus pumila* (1867-1980 AD) della Kamchatka hanno evidenziato che i fenomeni vulcanici verificatisi nelle vicinanze della regione hanno causato negli alberi forti

riduzioni di accrescimento, protrattosi per due-tre anni dopo l'eruzione. Queste risposte potrebbero essere utilizzate per lo studio dei fenomeni vulcanici preistorici. Una ricostruzione estesa nel tempo potrebbe inoltre fornire indicazioni sulla ripetitività dei fenomeni vulcanici. Infine gli studi sull'incremento di area basimetrica delle suddette tre specie mostrano che il *Larix cajanderi* risente degli eventi vulcanici in misura maggiore rispetto alle altre due.

Indirizzo degli Autori:
Teodoras T. Bitvinskas
Laboratory of Dendroclimatochronology
Institute of Botany
LITHUANIA

Ram R. Yadav
Birbal Sahni Institute of Palaeobotany
53, University Road
LUCKNOW 226007
India