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INHERENT GROWTH RHYTHM OF SOME LARIX-SPECIES GROWN IN A PLASTIC GREENHOUSE

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SELOSTE:

ERÄIDEN LEHTIKUUSILAJIEN KASVURYTMIN MUUNTUMINEN KASVIHUONEOLOSUHTEISSA

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The daily height growth rate of several larch species grown in a plastic greenhouse and in the open was measured. The growth pattern indoors was completely different compared with the normal outdoor growth pattern. Especially, the phase of maximum growth was unexpectedly long. This fact suggests that there is great potential for using greenhouse cultivation to change the growth pattern of cultivated plants in order to obtain more complete utilization of the potential growing season.

INTRODUCTION

In the boreal zone, the annual growth pattern of vascular plants seems to be mainly determined by temperature, as demonstrated for example by HARI (1972). The basic pattern of growth has proved to be similar irrespective of the plant species, apart from the timing of different growth phases, *i.e.* onset of growth, phase of maximum growth and cessation of growth (cf. VUOKKO *et al.* 1977). The variation in the growth pattern suggests that there are different adaptive mechanisms for utilizing the resources available in the environment. These mechanisms are evidently connected to the frost resistance of different species and may represent a compromise between lethal cold weather and interspecific competition, as argued by NIENSTAEDT (1974) and VUOKKO *et al.* (1977). On the other hand, the annual growth pattern sets limits for plant production even in favourable environmental conditions (cf. KELLOMÄKI 1977).

The aim of the present paper is to study the daily growth pattern of some larch *(Larix* spp.) species grown in a plastic greenhouse in order to determine their inherent growth rhythm and its effect on potential plant production. The dynamic growth model presented by HARI *et al.* (1977) has been applied to the analysis of the data.

Metsänjalostussäätiö (The Foundation for Forest Tree Breeding) is acknowledged for providing the facilities which made this work possible.

MATERIAL

The study material was collected in 1975 at the experimental nursery of Metsänjalostussäätiö (The Foundation for Forest Tree Breeding) near Helsinki (60°36'N, 24°26'E, 120 m a.s.l.), Finland. The larch species under study and some of their characteristics are presented in Table 1. The elongation of the leader or a branch of each larch species was measured once a day at 08.00 a.m. to an accuracy of 0.1 mm. In cases where several shoots were monitored, the results were pooled during data processing. Temperature was monitored using thermographs (model Lambrecht 252), placed in a standard weather chamber at a height of 1.6 meters in the greenhouse and 2,0 meters outdoors. The chart was read once every hour.

The study material representing the greenhouse material was kept uncovered during the winter. The greenhouse was erected on April 14, before the onset of growth. The greenhouse was remoed on August 14. In early spring the greenhouse was heated during night frosts. If the air temperature rose over 20° C during the summer the cover was cooled by two fans. The soil moisture was optimal both outdoors and greenhouse throughout the whole growing period.

Table 1. Description of the study material.

Number	Species	Provenance	Mother tree or seed specification	Additional information
	OUTDOORS			
1	*Larix decidua* Mill.	Switzerland	E 428	Monitoring of elongation of three branches about 2 meters above ground level on south side of the tree
2	*Larix sibirica* Ledeb.	Raivola	E 302	
3	*Larix sibirica* Ledeb.	Novosibirsk	E 388	
4	*Larix sibirica* Ledeb.	Pinega	P 54	
	GREENHOUSE			
3	*Larix laricina* (Dur.) K. Koch x open pollination		E 1148 x Sv. 41 F 71 — USA 6011	Monitoring of crown top and two branches
4	*Larix sibirica* Ledeb. x open pollination		E 1037, 66—501.1 K 308	See outdoor trees
5	*Larix leptolepis* (Sieb. et zucc.) Gord. x *L. decidua* Mill. x open pollination		71 — E 1501 x Hs	
6	*Larix sibirica* Ledeb.		E 403 x open pollination	See outdoor trees

METHODS AND RESULTS

Fig. 1 shows the daily course of height growth both outdoors and in the greenhouse. In order to distinguish between the effect of the inherent growth rhythm and the daily weather factor, the dynamic growth model presented by HARI *et al.* (1977) was applied in the analysis. Let f denote the effect of the inherent growth rhythm on the growth rate. Function f depends on the physiological stage of development. The function f is determined with the parameters a_1, s_1, s_2 and s_c. The relationship between the function f and the parameters is demonstrated in Fig. 2.

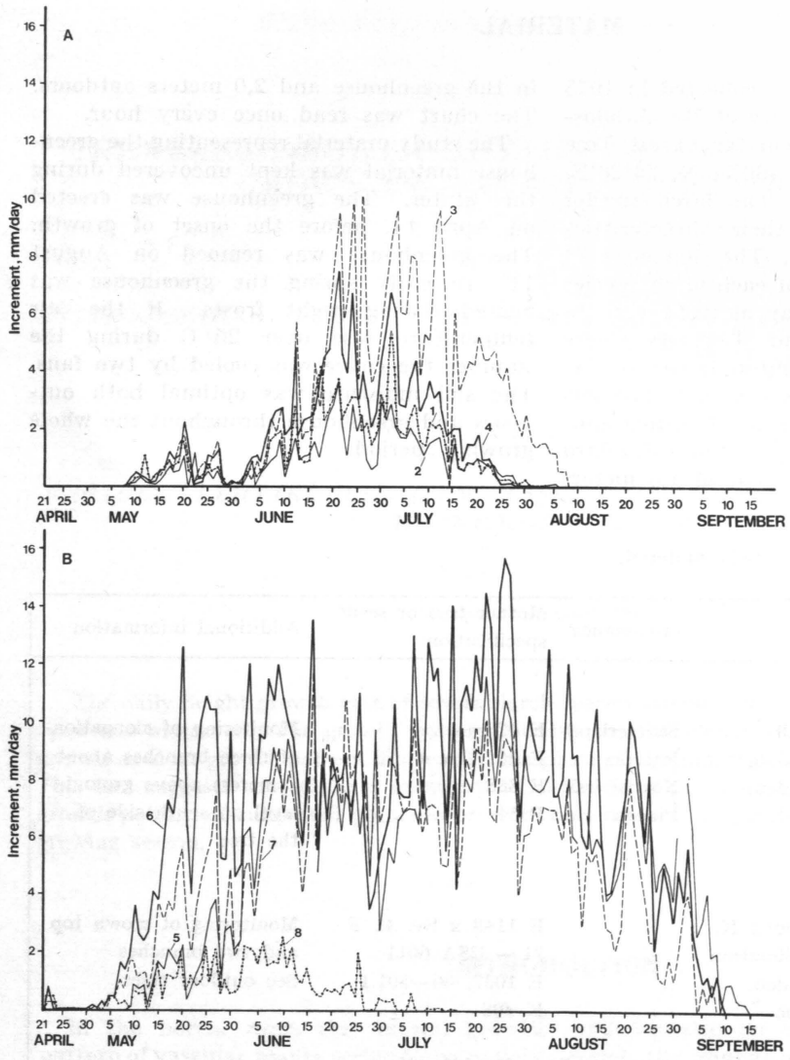

Fig. 1. Daily height growth of the *Larix*-species studied.
A: in outdoor conditions. For species number see Table 1.
B: in a greenhouse. For species number see Table 1.

The effect of the inherent growth rhythm can be considered as constant during period of one day. Let s be the physiological stage of development of the j:th day, and g the height increment of the same day. Assume that the effect of temperature and the inherent growth rhythm is multiplicative. When the growth rate is integrated over a day, the following model for the daily height increment values is arrived at:

$$g_j = f(s_j) \cdot a \cdot kj,$$

where k_j is the daily effect of temperature on the shoot elongation during the j:th day and a is a parameter.

The basic dependence of the growth rate on temperature is shown in Fig. 3. This dependence gave, however, too large daily height increments in the green house during warm days. In order to avoid this systematical discrepancy, the basic dependence of the growth rate was changed in such a way that above a certain threshold temperature the growth rate was assumed to be independent of temperature. The value of the threshold temperature was estimated as being 27° C.

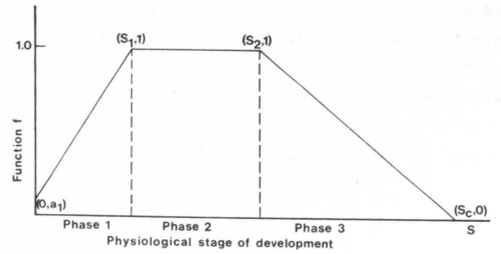

Fig. 2. Basic structure of the inherent growth rhythm applied in analysis.
s_1 is the physiological stage of development in which maximum growth is attained.
s_2 is the physiological stage of development in which growth starts to decrease.
s_c is the physiological stage of development in which growth ceases.
a_1 is the level of growth of the begining of the daily height growth.

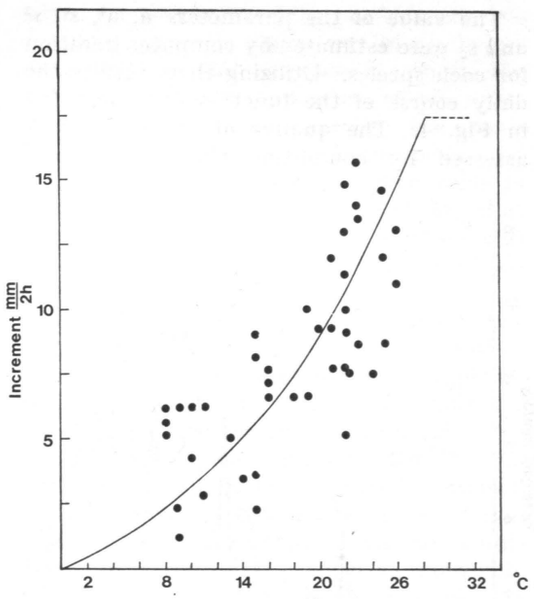

Fig. 3. Dependence of growth rate on temperature and its modification for the analysis (cf. HARI *et al.* 1977).

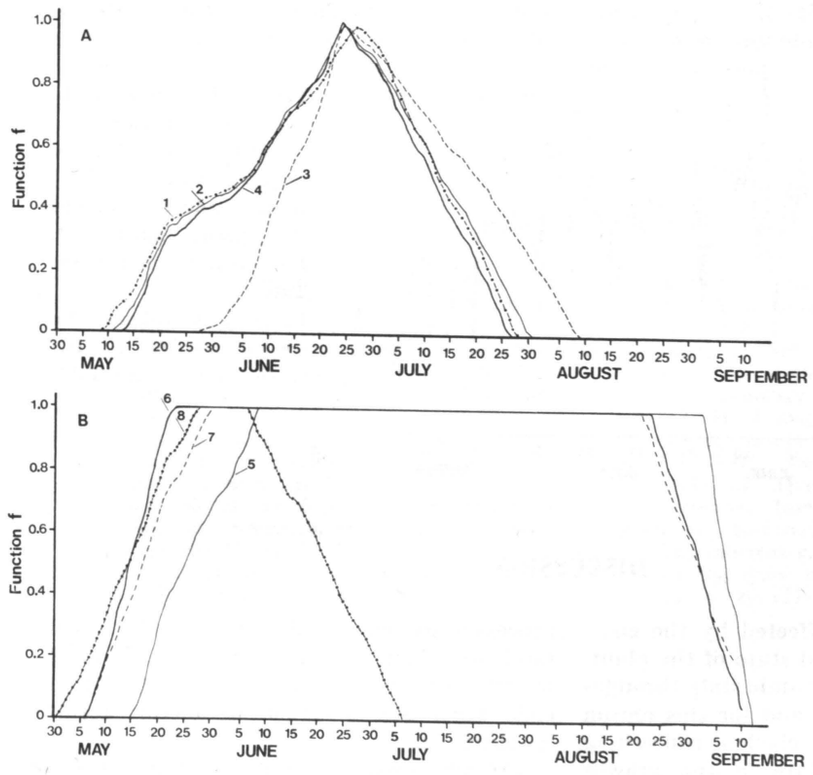

Fig. 4. Inherent growth rhythm of the *Larix*-species studied
A: in outdoor conditions. For species number see Table 1.
B: in a greenhouse. For species number see Table 1.

The value of the parameters a, a^1, s^1, s^2 and s_c were estimated by computer iteration for each species. Utilizing these results the daily course of the function f is presented in Fig. 4. The quality of the model was assessed by computing the daily values of height increment for each species according to the model and then comparing them with the actual measurements. The results are demonstrated in Fig. 5. For further details of the present method see the earlier paper by HARI *et al.* (1977).

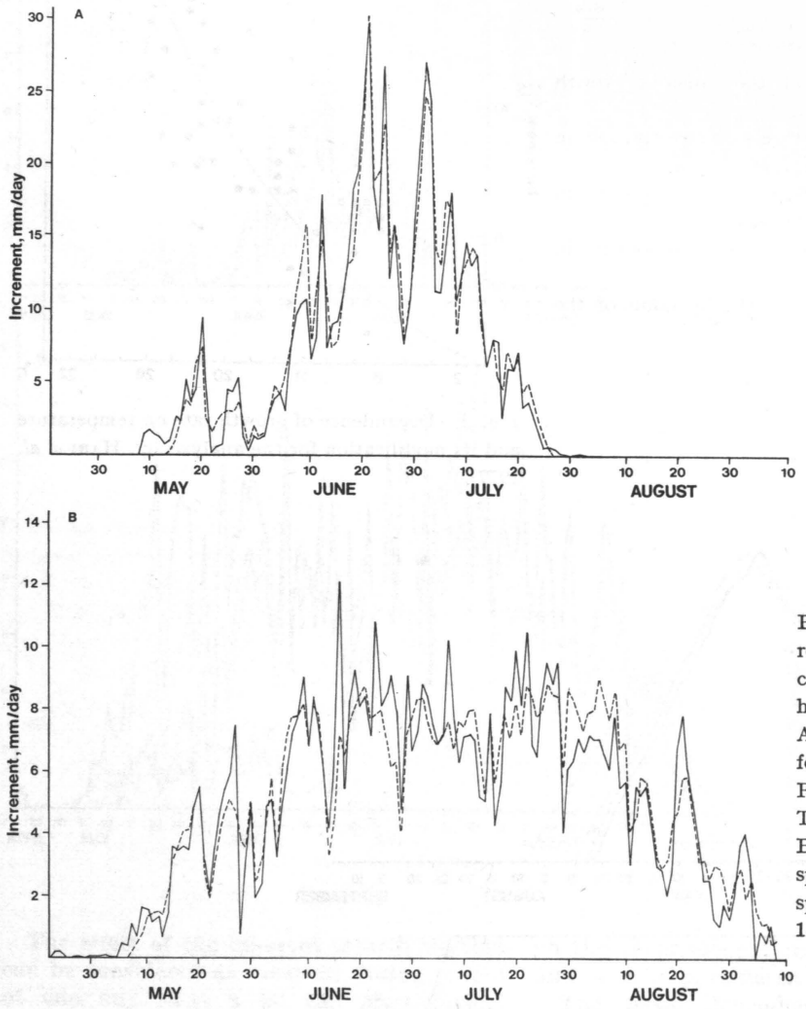

Fig. 5. Examples of the relationship between calculated and observed height growth.
A: in outdoor conditions for species number 4. For species number see Table 1.
B: in a greenhouse for species number 6. For species number see Table 1.

DISCUSSION

The growth rate is affected by the environment and the internal state of the plant. These factors are in a dynamic state throughout the growing period, and for this reason it is difficult to make conclusions concerning the role of internal state in the growth processes by means of standard statistical methods. However, by using the applied model these two factors are separated from each other and a rather satisfactory result is obtained.

The agreement between the observed and computed daily values of height increment was rather satisfactory in both cases, the explained variance was approximately 87 % outdoors and 76 % in the greenhouse. In the greenhouse the degree of determination was, however, systematically lower than outdoors. Difficulties in monitoring the daily height growth decrease the percentage of explained variance. In many cases the difference between observed and computed values is, however, of the same magnitude as the measuring accuracy. This is in a good agreement with the results of HARI *et al.* (1977), VUOKKO *et al.* (1977) and KELLOMÄKI (1977).

As expected, the onset of growth took place in the greenhouse much earlier than outdoors (cf. HARI 1972, SARVAS 1972). In addition, the phase of increasing growth in the greenhouse was much shorter than that outdoors. In the greenhouse the phase of maximum growth was, however, unexpectedly long. Apart from the species number 8 the maximum growth phase lasted for over three months and continued for 7—10 days after removel of the greenhouse. Such a long duration of maximal growth is impossible in outdoor conditions, and thus has to be induced in the greenhouse.

The maximum growth phase outdoors lasted for only a few days. In this case the decreasing growth phase was much longer than that in the greenhouse, where the cessation of growth took place within a few days. Unfortunately, exactly the same species were not grown in both places, and therefore the results are not comparable in every respect. They show, however, that the growth pattern of the study material has changed profoundly in the conditions prevailing in the greenhouse.

Our results are preliminary ones, but they suggest that the normal growth pattern of plant species can be changed by applying suitable technics, as in this case changing the seasonal temperature pattern (cf. KISH *et al.* 1972). Subsequently, the growth period in the greenhouse bas been lengthened, and the period of dry matter accumulation is much longer than that in natural conditions. In greenhouse production especially the altering the natural growth pattern may prove usefull and provide new opportunities for increasing crop production in controlled environments. On the other hand, the special conditions prevailing in greenhouses can have a great effect on the experimental results, and may obscure their interpretation and application.

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KELLOMÄKI, S. 1977. Dynamics of dry matter production in forest ground cover communities with special reference to their successional development. University of Helsinki. Department of Silviculture. Research Notes No. 16.

KISH, A. J., OGLE, W. L. & LOADHOLT, C. B. 1972. A prediction technique for snap bean maturity in corporating soil moisture with heat unit system. Agric. Meteorol. 10: 203—209.

NIENSTAEDT, H. 1974. Genetic variations in some phenological characteristics of forest trees. In: Phenology and seasonality modelling (ed. H. LIETH), pp. 237—254. Springer Verlag. Berlin, Heidelberg, New York.

SARVAS, R. 1972. Investigations on the annual cycle of development of forest trees. Commun. Inst. For. Fenn. 76.3.

VUOKKO, R., KELLOMÄKI, S. & HARI, P. 1977. The inherent growth rhythm and its effect on the daily height increment of plants. Oikos 29: 137—142.

NUORTEVA, MATTI ODC 935.4: 174.7 *Sequoia & Sequoiadendron*

1979. Punapuiden suojeluongelmia Kaliforniassa. Summary: Preservations problems of redwoods in California. — SILVA FENNICA Vol. 13, No. 1, 4 p. Helsinki.

The paper deals with the problems of the preservation of the redwood groves *(Sequoia sempervirens* and *Sequoiadendron gigateum)* in California. The activity to protect these groves from flood and fire may finally lead to the dying of these long-lived trees. A program to use prescribed burning as a tool for the management of natural ecosystem has been started.

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KELLOMÄKI, SEPPO ODC 111.82: 812.31: 174.7
Pinus sylvestris

1979. On geoclimatic variation in basic density of Scots pine wood. Seloste: Ilmastotekijöiden vaikutus männyn puuaineen tiheyteen. — SILVA FENNICA Vol. 13, No. 1, 10 p. Helsinki.

The effect of temperature and water supply on the basic density of Scots pine *(Pinus sylvestris* L.) wood was studied on the basis of material obtained from the literature. On a monthly basis, the basic density increased with increasing mean temperature for June, July and August. The rainfall in these months had no detectable effect on the basic density except through the difference between rainfall and evaporation in July. On a yearly basis, the basic density increased with increasing mean temperature, temperature sum and length of growth period. The effect of water supply on the basic density was evident and a linear relationship between basic density and annual rainfall was detected. The variation in basic density was, however, explained only partially by the chosen factors. Possible reasons for the poor explanatory power have been discussed.

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VASANDER, H., MÄKINEN, A. & PAKARINEN, P. ODC 114.268: 114.35/.36

1979. Kangaskorpimaannosten hivenainejakautumista ja -määristä. Summary: Trace elements in soil profiles of paludified spruce forests. — SILVA FENNICA Vol. 13, No. 1, 9 p. Helsinki.

Gleysol profiles of five southern Finnish sites dominated by Norway spruce *(Picea abies)* were described according to the Canadian system of soil classification, and the total contents of five metals (Pb, Zn, Cu, Mn, Fe) were analyzed in each soil profile. Lead, zinc and manganese showed highest concentrations in the organic surface horizons, while iron had maximum values in the mineral soil: in A-horizon of Rego Gleysols and in B-horizon of Fera Gleysols.

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RAUNEMAA, T., JARTTI, P., HAUTOJÄRVI, A., LINDFORS, V., LAURÉN, J. & RÄISÄNEN, J. ODC 443.3: 160.31: 174.7 *Picea abies*

1979. Trace element analysis of sound and decayed Norway spruce (Picea abies (L.) Karst.) by XRF and NAA methods. Seloste: Terveen ja lahon kuusen hivenaineanalyysejä röntgenfluoresenssi- ja neutroniaktivointimenetelmillä. — SILVA FENNICA Vol. 13, No. 1, 13 p. Helsinki.

Ashed tree samples from sound and decayed Norway spruce were studied by means of fast neutron activation analysis and, for comparison, also by X-ray fluorescence analysis. A. general diminishing was revealed by both methods in most elemental concentrations studied, with the exceptions of K and Rb, when going from a sound tree to a decayed one. The use of the ratio of the amounts of potassium to calcium as an indicator of the degree of decayedness is therefore proposed.

Authors' address: University of Helsinki, Department of Physics, Siltavuorenpenger 20 D, SF-00170 Helsinki 17, Finland.

LAAKSO, PERTTI & SAIKKU, OLLI ODC 832.281: 853: 174.7
Pinus sylvestris

1979. Havaintoja karsituista männyistä sorvatun viilun laadusta. Summary: Observations on the quality of veneer from pruned pine stems. — SILVA FENNICA Vol. 13, No. 1, 7 p. Helsinki.

Observations on the quality of veneer from pruned pine stems are presented. The material was obtained from stems which were pruned 27 years earlier up to the height of 5—6 m. The rotary cutting was made from 16 pruned stems and 3 unpruned stems. The proportion of good quality veneer was 46 per cent in pruned stems and 14 in the others. The veneer with excellent quality was obtained from pruned stems up to the height of three meters, that is to say a little under the pruning line.

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HARI, PERTTI, KANNINEN, MARKKU, KELLOMÄKI, SEPPO, LUUKKANEN, OLAVI, PELKONEN, PAAVO, SALMINEN, RAIMO & SMOLANDER, HEIKKI ODC 161——015.7

1979. An automatic system for measurements of gas exchange and environmental factors in a forest stand, with special reference to measuring principles. — SILVA FENNICA Vol. 13, No. 1, 8 p. Helsinki.

A system for measuring the net photosynthesis, transpiration and environmental factors within the canopy and ground cover vegetation is described. The system operates continuously throughout the growing season in a young Scots pine *(Pinus sylvestris* L.) stand. A data-logging unit controls the system and carries out the measurements of the readings of the sensors of photosynthesis, transpiration, light intensity outside the canopy, light climate inside the assimilation chambers, and dry and wet temperatures from selected points. These measurements are shown digitally and automatically punched onto paper tape.

Authors' address: University of Helsinki, Department of Silviculture, Unioninkatu 40 B, SF-00170 Helsinki 17, Finland.

SAASTAMOINEN, OLLI ODC 907.2

1979. Valaistun hiihtoreitin käytön ajallinen vaihtelu. Summary: Time patterns in the use of an urban skiing route. — SILVA FENNICA Vol. 13, No. 1, 6 p. Helsinki.

Temporal variations in use of an illuminated skiing route located near a town were examined. Three time patterns (monthly, daily, hourly) were determined on the basis of empirical data. Preliminary data about the the participation rates on Sundays of population living near the route were given.

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KOSKIMÄKI, ANTTI, HARI, PERTTI, KELLOMÄKI, SEPPO & KANNINEN, MARKKU ODC 161.4: 174.7 *Larix*

1979. Inherent growth rhythm of some *Larix*-species grown in a plastic greenhouse. Seloste: Eräiden lehtikuusilajien kasvurytmin muuntuminen kasvihuoneolosuhteissa. — SILVA FENNICA Vol. 13, No. 1, 7 p. Helsinki.

The daily height growth rate of several larch species grown in a plastic greenhouse and in the open was measured. The growth pattern indoors was completely different compared with that under outdoor conditions. Especially, the phase of maximum growth was unexpectedly long. This fact suggests that there is great potential for using greenhouse cultivating to change the growth pattern of cultivated plants in order to obtain more complete utilization of the potential growing season.

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Silva Fennica-sarjassa julkaistaan lyhyitä metsätieteellisiä tutkimuksia ja kirjoituksia kotimaisilla kielillä tai jollakin suurella tieteellisellä kielellä. Julkaistavaksi tarkoitettu käsikirjoitus on jätettävä Seuran sihteerille painatuskelpoisessa asussa. Seuran hallitus ratkaisee asiantuntijoita kuultuaan, hyväksytäänko kirjoitus painettavaksi.

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ILVESSALO, Y. 1952. Metsikön kasvun ja poistuman välisestä suhteesta. Summary: On the relation between growth and removal in forest stands. — Commun. Inst. For. Fenn. 40.1.

WILCOX, W. W., PONG, W. Y. & PARMETER, J. R. 1973. Effects of mistletoe and other defects on lumber guality in white fir. Wood & Fiber 4 (4): 272—277.

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Hämeenlinna 1979, Arvi A. Karisto Osakeyhtiön kirjapaino