LODGEPOLE PINE FROM FAR NORTHERN CANADA PERFORMS WELL IN A MILDER SWEDISH ENVIRONMENT

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Abstract. Results of a height assessment made in a 12-year-old experimental plantation at latitude 62° N, altitude 550 m in Sweden indicate that the productivity of lodgepole pine *(Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) from the very far north of its distribution range in western Canada was generally good. Only small differences in average performance could be ascribed to variation in the geographical origin of 801 open-pollinated, single-tree progenies collected at latitudes ranging from 51 to 64° N and altitudes from 400 to 1700 m in British Columbia and the Yukon Territory. Performance, predicted based on parent breeding values for tree height, decreased by an average of 8 % when moving from the lowest to the highest altitudes of origin, whereas when moving from the southernmost to the northernmost site of origin it increased slightly. An analysis in which latitude and altitude were simultaneously taken into account confirmed the greater importance of altitudinal origin, although this conclusion should be interpreted with care since the latitudes and altitudes were strongly correlated *($r = -0.73$).* The experimental site was situated in the southern part of the north-Swedish lodgepole pine utilization area. Thus the findings suggest that the use of lodgepole pine from the northernmost seed importation locations may be profitable even in comparatively southern Swedish reforestation zones. Furthermore, such provenances should have the added advantage of being less susceptible to environmental stress. Where there is concern about the ability of lodgepole pine to tolerate harsh conditions in southern zones, these results suggest that it would be better to use more northern provenances rather than provenances from higher elevations.

Keywords: Altitude, breeding value, half-sib, hardiness, height, latitude, open pollination, *Pinus contorta* Dougl. ex Loud. var. latifolia Engelm., provenance, survival, Sweden.

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INTRODUCTION

During the early introduction of lodgepole pine *(Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) to Sweden, more northern provenances were sometimes suspected to have equally high production potential on sites where more southerly provenances had so far been assumed to be `optimal' as discussed by Lindgren et al. (1988). Since then, a shift towards more northern provenances has often been suggested (e.g. Lindgren et al. 1993) though without much further experimental basis. In order to bring to light details which might support or refute such hypotheses, some test sites within the southern part of the geographical utilization range in Sweden were planted with both very northern and more southern provenances in the spring of 1984.

MATERIAL AND METHODS

This report examines one of the 1984 test sites[2], where roughly 850 open-pollinated single-tree progenies (assumed half-sibs), representing around 70 stands, were tested. Their origin was the interior distribution region of lodgepole pine in Canada between 50°51' and 63°52' N. As shown in Fig. 1 (further described by Ericsson 1993), they represented most families collected in the 1970s

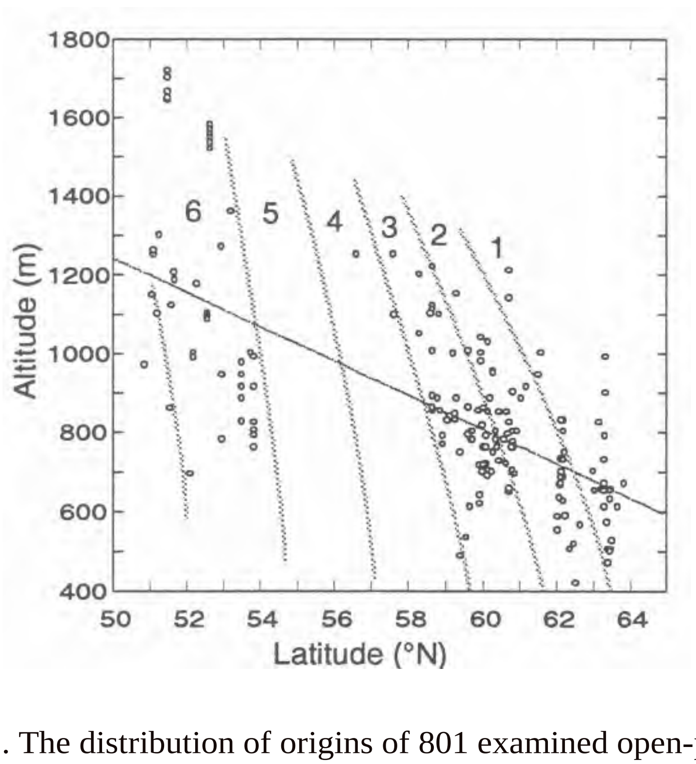

Fig. 1. The distribution of origins of 801 examined open-pollinated families. Seed collection zones 1-6 and the regression line of altitude on latitude *(r* = –0.73) are indicated. Points are frequently overlaid.

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[2]Identification at SkogForsk: S23F846383 Dalsvallen

from the lodgepole pine selection zones 1, 2, 3, and 6. Zone 1 to 6 correspond to the span from the northern Yukon south to central British Columbia. The test site, situated on 62°11' N, 13°35' E at 550 m elevation in Sweden, is actually located around where the zone 4 or 5 material was intended to be used, but those zones were not represented. (Among provenances, interpolation was to be preferred before extrapolation. Other test site results presented later will complement the information on material from all zones.) Despite the exclusion of zones 4 and 5, the huge number of progenies was considered technically impossible to handle within one single experimental area. Therefore, the material was subdivided into six sets, each of which was designed to hold, as far as possible, equal representation of mother trees selected within a stand or neighbouring stands.

Thus six independent experiments were installed close to each other, each containing equivalent provenance samples. An individual family was usually represented by ten seedlings distributed randomly within a 'single-tree plot' experiment, arranged with 1x2.2 m spacing. Survival data and heights from an average of about nine living trees per family were collected in September 1995 (Table 1). With respect to the provenance investigation, the equivalent composition of the six experiments did legitimate that data and results were merged.

Table 1. Mean tree survival and height in six equivalent 12-year-old provenance experiments on one test site.

Experiment no.	Number of half-sib families	Number of living trees	Survival (%)	Mean height (cm)
1	133	1238	91.8	260.7
2	134	1301	92.8	238.9
3	133	1348	94.2	238.1
4	137	1338	93.7	227.7
5	133	1230	92.1	215.0
6	131	1269	93.8	226.4
Sum / mean	801 [a]	7724	93.1	234.5

[a] Totally 53 families with less than five trees were discarded

Breeding values for tree height were separately computed within each experiment, where the fixed effects of the mixed-model equations corresponded to a ten-block area subdivision, designed to eliminate disturbing environmental influence (cf. Ericsson 1997). The mother tree breeding values from all six sets were subsequently merged and chosen to represent the general production potential to be compared by provenance. The mean of heritability estimates for tree height was $h^2 = 0.209$.

Survivals were compared using actual occurrences.

RESULTS AND DISCUSSION

The association between productivity and origin was examined by linear regressions of tree height, (*h* cm) on latitude and altitude of origin (*l* ° and *a* m) respectively (Fig. 2). The average influence of the latitudinal origin was quite small and in favour of northern seed source origins ($h = 198.5 + 0.61711$; Fig. 2a). However, the influence of seed source altitude was stronger ($h = 247.8 - 1.511a/100$; Fig 2b), favouring milder climates. The height increased by an average of 8 % when moving from the highest (1700 m) to the lowest altitude of origin (400 m), while the corresponding height difference between extreme latitudes was 3 %.

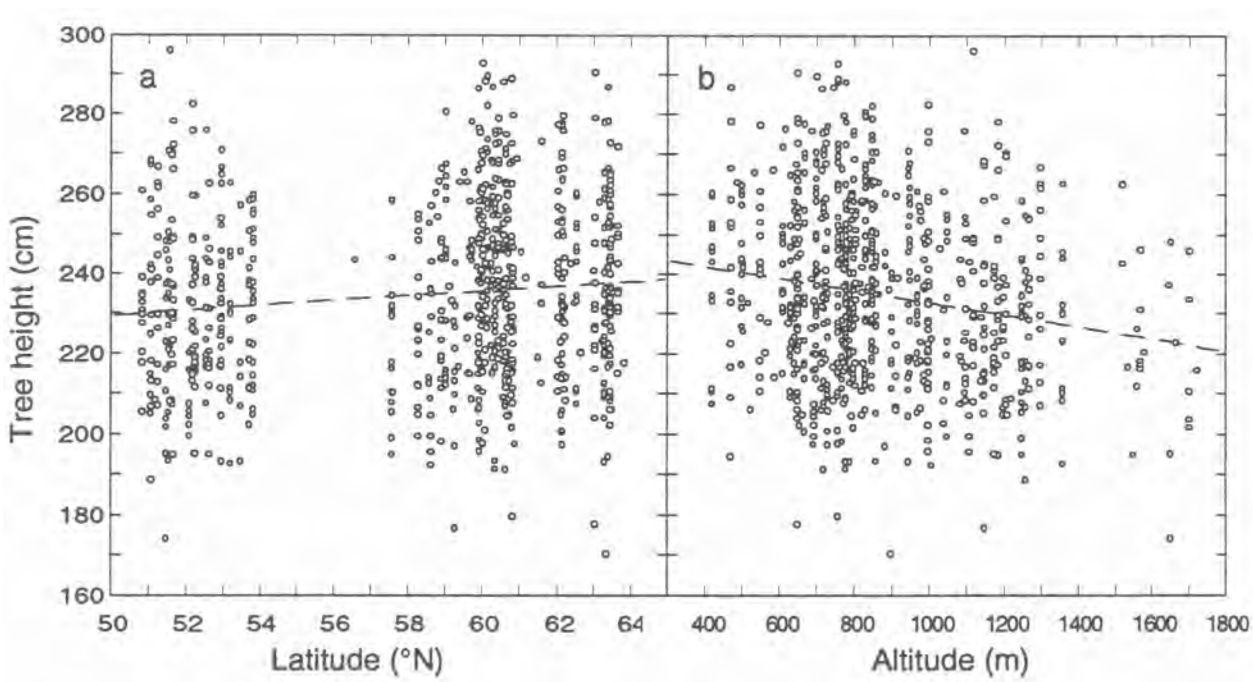

Fig. 2a–b. Mother tree breeding values for height plotted against mother tree latitude and altitude, respectively. The broken lines indicate regression association.

A multiple regression on both latitude and altitude removed most influence from latitude and added a little more influence to altitude ($h = 253.8 - 0.08575/ - 1.617a/100$; not shown). Thus, the regression analysis appears to indicate that the latitude of origin is relatively unimportant compared to altitude. One must however recognize the strong correlation between them (Fig. 1), which makes such a conclusion somewhat uncertain.

The tree mortality rate had been very low up to the time of assessment, and in many families all trees had survived. Therefore, survival plotted in the same way as is height in Fig. 2, will be difficult to interpret because of the aggregation at 100 %. Instead survival class means are displayed jointly with mean heights in Fig. 3, using classes corresponding to seed collection zone, latitudinal, and altitudinal subdivisions respectively (cf. Fig. 1). Although the differences were small, the northern and/or low-elevation progenies showed less mortality. The height bars are class means from the data of Figs. 1 and 2. The visible positive correlation between survival and height in Fig. 3 is a consequence of the class subdivision. It turns out quite small when computed from family data (0.02).

Lindgren & Nilsson (1992) found a clear population-mean differentiation by latitude in the development of frost tolerance of needles from five-year-old trees originating from roughly the same provenance range considered for Sweden, from 55° N in central British Columbia to 63° N in the Yukon Territory. The results of this investigation support the use of furthest northern origins to obtain increased hardiness on north Swedish sites without loss of productivity. The lower productivity of high-altitude provenances, mentioned by Rehfeldt (1980, 1983) and coinciding with Fig. 3c, is thus avoided. The results likewise support the suggestion by Fries & Lindgren (1986), among others, that higher latitude origins rather than higher elevations will increase hardiness with a minimum loss of productivity.

These findings indicate that a few northern, outstanding provenances may be sufficient for use all over northern Sweden, in accordance with the conclusion by Lindgren (1993) that single provenances have been noted to perform surprisingly well over a wide geographical range. A natural question is whether this would also be a possible outcome in Canada. Southward transfer there is normally associated with notable slower growth, naturally accompanied by better survival. Ying et al. (1985) show repeatedly negative correlations between height and latitudinal as well as elevational origin. On the other hand, they note that suitable provenances from interior sources may grow quickly and appear to be broadly adapted to diverse site conditions. The elevational influence on population differentiation seems to decrease with increase in latitude (Ying 1991). Nothing indicates, however, that the latitudinal differentiation would be relatively lower on higher latitudes in Canada.

It is unclear whether or not such flexibility of northern lodgepole pine would occur in Canada if, for example, Yukon provenances were utilized in central interior British Columbia. If there are

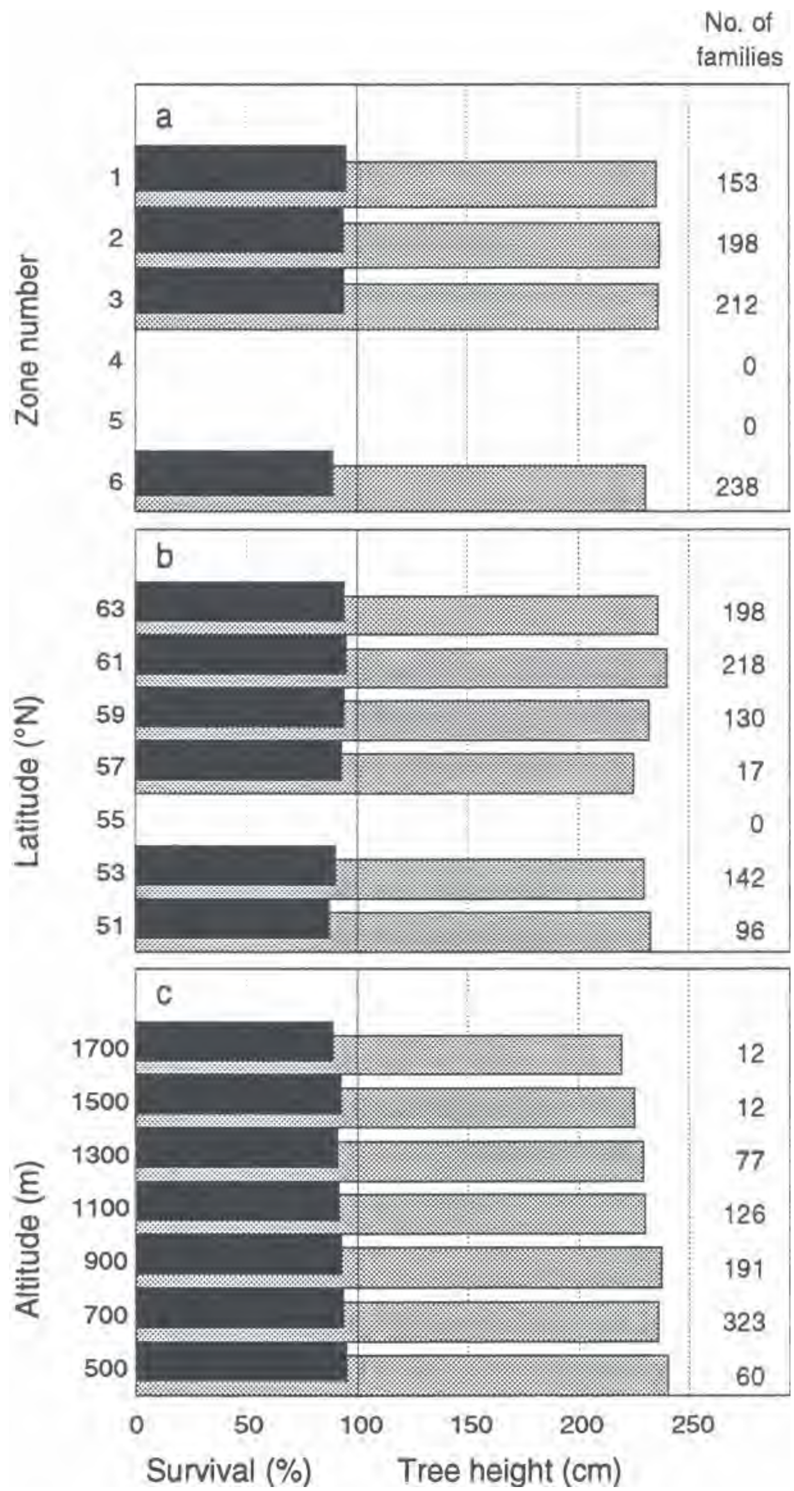

Fig. 3a—c. Mean survival and mean tree height from mother tree breeding values classified by seed collection zone and by latitude and altitude class of the mother trees (middle class values indicated).

differences compared to Sweden they may be due to differences in light, which is latitude-dependent and little modified by weather fluctuations. The typical transfer of lodgepole pine from Canada to Sweden implies a five-degree-move northward in order to obtain a roughly equivalent temperature climate. Thus the light environment is different between Canada and Sweden on otherwise similar sites.

CONCLUSIONS

The results indicate that the recommendations regarding lodgepole pine provenance choice for north Swedish reforestation sites may be revised. More northern provenances than previously suggested (Lindgren et al. 1988) should be considered, if available. Such a choice seems to combine equal production potential with better robustness with respect to climatic stress, leading to lower mortality rates.

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LITERATURE CITED

Ericsson, T. 1993. Provenance qualities of the *Pinus contorta* breeding base in Sweden (Report no. 4 1993, Forestry Research Institute of Sweden), 33 pp. Uppsala.

Ericsson, T. 1997. Enhanced heritabilities and BLUPs through appropriate blocking of progeny trials. Manuscript.

Fries, & Lindgren, D. 1986. Performance of plus tzee progenies of Pinus contorta originating north of latitude 55° N in a Swedish trial at 64° N. Can. J. For. Res. 16: 427-437.

Lindgren, D., Lindgren, K. & Krutzsch, P. 1993. Use of lodgepole pine and its provenances in Sweden. In: Lindgren, D. (ed.), *Pinus contorta* from untamed forests to domesticated crop, Proceedings of the IUFRO meeting and Frans Kempe Symposium 1992 on *P. c.* provenances and breeding (Report 11, Dept. of Forest Genetics and Plant Physiology, Swedish Univ. of Agr. Sci.), 238-263. Umeå.

Lindgren, K. 1993. Where to use which *Pinus contorta* provenances? In: Lindgren, D. (ed.), *Pinus contorta* from untamed forests to domesticated crop, Proceedings of the IUFRO meeting and Frans Kempe Symposium 1992 on *P. c.* provenances and breeding (Report 11, Dept. of Forest Genetics and Plant Physiology, Swedish Univ. of Agr. Sci.), 162-180. Umeå.

Lindgren, K. & Nilsson, J.-E. 1992. Cold acclimation of *Pinus sylvestris* and *Pinus contorta* provenances as measured by freezing tolerance of detached needles. Scand. J. For. Res. 7: 309-315.

Lindgren, K., Lindgren, D. & Rosvall, 0. 1988. Forflyttningsrekommendationer for provenienser av contortatall i Sverige [Lodgepole pine provenance transfer recommendations for Sweden] (Arbetsrapport nr 27, Inst. för skoglig genetik och vaxtfysiologi, SLU), 43 pp. Umeå . (In Swedish)

Rehfeldt, G. E. 1980. Cold acclimation in populations of *Pinus contorta* from the northern Rocky Mountains. Botan. Gaz. 141: 458-463.

Rehfeldt, G. E. 1983. Adaptation of *Pinus contorta* populations to heterogeneous environments in northern Idaho. Can. J. For. Res. 13: 405-411.

Ying, C. C. 1991. Performance of lodgepole pine provenances at sites in southwestern British Columbia. Silvae Genet. 40: 215-223.

Ying, C. C., Illingworth, K. & Carlson, M. 1985. Geographic variation in lodgepole pine and its implications for tree improvement in British Columbia. In: Baumgartner, D. M., Krebill, R. G., Arnott, J. T. & Weetman, G. F. (eds.), Lodgepole pine, the species and its management (Symposium proceedings), 45-53. Pullman: Cooperative extension service, Washington State University.