Provenance Differences in Conifer Seedling Variable Chlorophyll Fluorescence Responses Detected Using the Integrating Fluorometer[1]

W. Vidaver,[2] P. Toivonen,[3] R. Brooke,[4] G. Lister,[5] and W. Binder[6]

Vidaver, W.; Toivonen, P.; Brooke, R.; Lister, G.; Binder, W. 1989. Provenance Differences in Conifer Seedling Variable Chlorophyll Fluorescence Responses Detected Using the Integrating Fluorometer. In: Landis, T.D., technical coordinator. Proceedings, Intermountain Forest Nursery Association; 1989 August 14-18; Bismarck, ND. General Technical Report RM-184. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 103-107. Available at: http:www.fcnanet.org/proceedings/1989/vidaver.pdf

Abstract.-- Differing from white spruce, Douglas-fir seedlings showed no day length-dependent inactivation of photosynthetic photochemistry. Seedlings of both species show reversible inactivation in response to temperature or drought stress. Provenance differences were observed in the responses of coastal Douglas-fir: high elevation seedlings appeared to be more sensitive to declining temperatures than low elevation seedlings.

INTRODUCTION

In common with other kinds of stress-resistant plants, temperate conifer species regulate photosynthetic activity in response to environmental variations (Pharis *et al*, 1970; Hawkins and Lister, 1985; Strand and Lundmark, 1987; Toivonen and Vidaver, 1988; Vidaver *et al*, 1988; 1989). Several temperate conifers, so far examined in our laboratory, are able to inactivate photochemistry in response to low temperatures or water stress and seedlings of at least one species, white spruce, demonstrate a progressive, daylength-dependent inactivation with the approach of fall (Vidaver *et al*, 1988; 1989). This ability to regulate photochemistry is believed to protect needle chloroplasts from stress-induced photodamage (Bolhar-Nordenkampf and Lechner, 1988; Vidaver *et al*, 1988; 1989). In contrast, daylength-dependent regulation of photochemistry was not detected in seedlings of two coastal Douglas-fir provenance types. However, provenance differences were observed in these Douglas-fir seedlings in the induction of inactivation by low temperatures: seedlings from a high elevation provenance began to inactivate at a higher temperature than seedlings from a low elevation provenance.

MATERIALS AND METHODS

2-0 white spruce (*Picea glauca* (Moench) Voss) and 1-0 coastal Douglas-fir (*Pseudotsuga menziesii*) (Mirb) Franco) container-grown (PSB-313) seedlings were obtained from the B.C. Ministry of Forests nursery in Surrey, B.C. (approx. 49° 08' N, 122° 48' W). They were

[1]Presented at the Intermountain Forest Nursery Association meeting; 1989 August 14-17; Bismarck, North Dakota.

[2]William Vidaver, Professor, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C.

[3]Peter Toivonen, Research Associate, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C. Current address: Agriculture Canada, Research Station, Agassiz, B.C.

[4]Robert Brooke, Associate Professor, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C.

[5]Geoffrey Lister, Assistant Professor, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C.

[6]Wolfgang Binder, Adjunct Professor, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., and Conifer Seedling Physiologist, Research Branch, British Columbia Ministry of Forests, Victoria, B.C.

then maintained in a growing compound at Simon Fraser University (365 m asl), Burnaby, B.C., until tested. The white spruce seedlot was 8981 (origin 58° N, 120° W, 750 m asl) and coastal Douglas-fir seedlots used were 1273 (origin 49° N 122° W, 152 m asl), 6399 (origin 49° N 122° W, 760+ m asl) and 2968 (origin 49° N 125° W, 670 m asl).

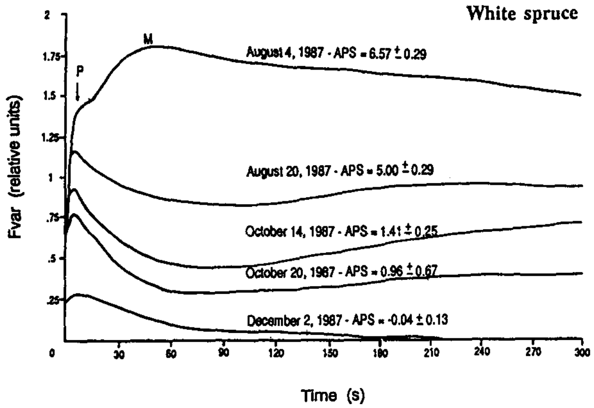

Figure 1:--F_{VAR}, curves for seedlot 8981 white spruce seedlings during progression toward photosynthetic inactivation in 1987. Apparent photosynthesis (APS) shown as mg CO_2/g dry wt./hr. (Redrawn from Fig. 5 in Vidaver *et al,* 1988).

For the fluorescence measurements, shoots of dark-adapted, well watered seedlings were placed in the spherical cuvette of an integrating fluorometer and fluorescence emission (F_{VAR}) data were collected according to the methods of Vidaver *et al,* (1989).

RESULTS AND DISCUSSION

In white spruce, daylength-dependent inactivation begins around mid-August and usually nears completion by the end of October (Fig. 1). The timing of this progression toward inactivation is somewhat more advanced in higher latitude provenance types than for those more southerly (Vidaver *et al* 1989). Transient, stress-dependent inactivation can be superimposed on this progression towards winter dormancy (Vidaver *et al,* 1989).

Although photochemical activity in Douglas-fir seedlings fluctuated markedly over the period of July to early December, there was no indication of progression toward fall inactivation (Fig. 2). Presumably, these fluctuations reflect levels of temperature and/or water stress (Vidaver *et al,* 1988) prior to and at the time of measurement.

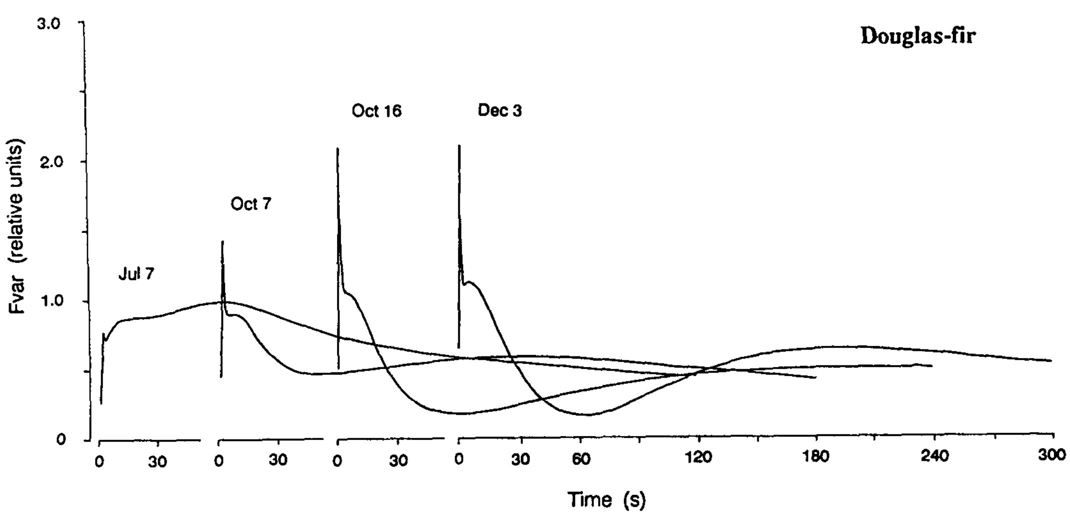

Figure 2:--F_{VAR} curves for seedlot 2968 Douglas-fir seedlings measured at intervals from early July until early December 1987. Note that except for July 7, the initial F_{VAR} spike is much more pronounced in these Douglas-fir seedlings compared to white spruce. The July 7 response is indicative of rather severe water stress (see Vidaver *et al,* 1988).

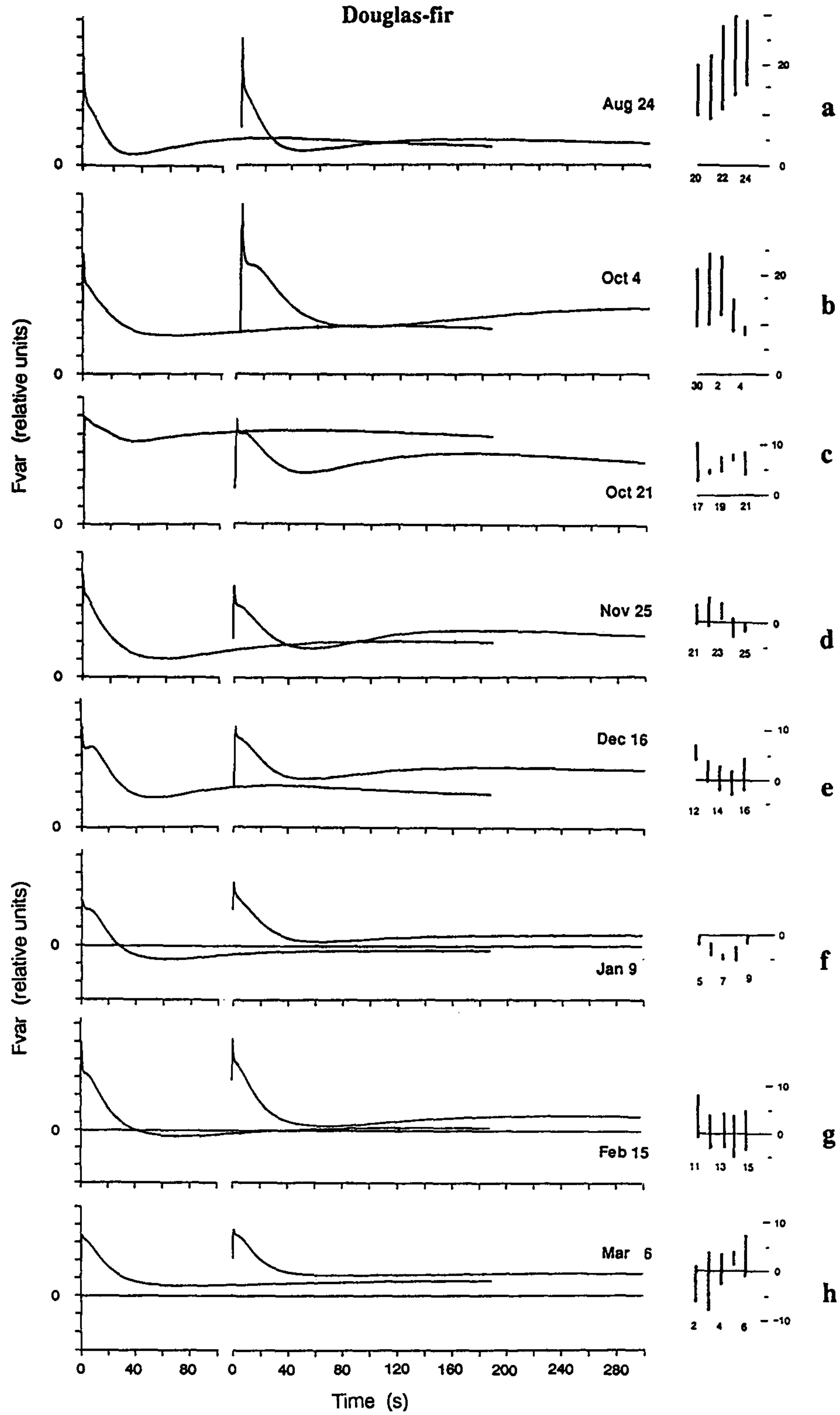

Figure 3(a-h).-- F_{VAR} curves for high elevation (seedlot 6399) and low elevation (seedlot 1273) Douglas-fir seedlings measured over the period from late August 1987 until early March 1988. Responses of 1273 seedlings are shown on the left side of graphs, 6399 on the right. Bar graphs at right display temperature data for four days prior to and on the day of measurement.

Both high (seedlot 6399, 760m) and low elevation (seedlot 1273, 152m) coastal Douglas-fir seedlings displayed indications of water stress in late August when daytime temperatures were approaching 30° C (Fig. 3a). By early October, when temperatures were dropping, seedlings of both provenances showed some recovery in activity but the high elevation seedlings were more active (Fig. 3b). By the third week in October, with further temperature decline, activity decreased in both seedlots but more so in the high elevation seedlings (Fig. 3c). In late November when sub-freezing temperatures were experienced, activity in both seedlots was low but remained somewhat higher in the low elevation seedlings (Fig. 3d). Activities in both seedlots remained low on Dec. 16 following a period of nighttime frost. The greatest extent of inactivation of both seedlots was observed on Jan. 9 (Fig. 3e), at a time when daily temperatures did not exceed 0° C. Considerable recovery was seen in both seedlots measured on Feb. 15 (Fig. 3g), coinciding with an increase in daytime temperatures. In early March following a period of low temperatures, activities had declined again in both seedlots. These results indicate that photochemical activity in both high and low elevation coastal Douglas-fir seedlings can decline during periods of high or low temperatures. Photochemical activity reached its lowest level during a period when daytime temperatures were below 0° C (Fig. 3f), but higher activity levels were sustained during periods when daytime temperatures were relatively high even though subfreezing temperatures were experienced at night (Fig. 3e, g). These results indicate that inactivation is largely a response to light during low temperature exposure and is in agreement with reports of Strand and Lundmark (1988) and Strand and Oquist (1985). Since activities were relatively high in October when white spruce seedlings would show substantial inactivation (Fig. 1), it appears unlikely that activity in the coastal Douglas-fir seedlings we measured was appreciably affected by daylength. A greater decline in high elevation seedlings during a period of decreasing temperatures (Fig. 3b-c) may indicate that they are more sensitive to chilling than the low elevation seedlings.

Presumably, these response differences relate to ways the species are adapted to their environments (Rehfeldt, 1986). White spruce ranges over a habitat characterized by rigorous winters and the possibility of drought anytime during the growing season. The more severe climate of northern provenances probably accounts for the earlier inactivation of seedlings from such regions. White spruce tends to be a slow growing species but is remarkably resistant to low winter temperatures and summer drought. In part, its slow growth may be attributable to the early fall inactivation of photosynthesis which persists until dormancy is broken in the spring. On the other hand, coastal Douglas-fir is highly opportunistic: it appears to undergo transient inactivation in response to drought or low temperatures but photosynthesis resumes rapidly upon stress alleviation at any time during the year.

It is not yet known whether conifers other than Engelmann (unpublished data) and white spruce possess the daylength-dependent inactivation mechanism. The data presented here suggest it may not be present in coastal Douglas-fir.

OPERATIONAL USES OF F_{VAR} ASSESSMENT IN THE NURSERY

Variable chlorophyll fluorescence (F_{VAR}) assessment with an integrating fluorometer is a useful and reliable indicator of photosynthetic activity of intact conifer seedlings. For white spruce, because of the coincidence of photochemical inactivation and the progression toward dormancy, F_{VAR} data can be used by nursery growers to determine the optimum lifting window dates for this species.

F_{VAR} assessment also provides information about reactivation of photochemistry. This can be used to monitor seedling recovery from cold dark storage or from the effects of environmental stress. Knowledge of the differences in F_{VAR} responses can help to optimize nursery operations for the various conifer species and provenance types. Seedling genotypes could be identified using F_{VAR}, lessening the uncertainty of matching stock types with outplanting site selection.

A commercial version of the integrating fluorometer (Fluoroscan, Intec Inoventures Inc., Victoria, B.C.) is designed to be used operationally by nursery growers. Initial deployment of this system is expected to begin in September 1989.

ACKNOWLEDGEMENTS

This research was supported by Canada - British Columbia Forest Resource Development Agreement (FRDA) contract 2.19 and by Science Council of B.C. AGAR grant R.C.(67). Contributions of Sylvain Dube in developing the computer data acquisition/analysis software and Jyoti Vithlani for technical assistance are gratefully acknowledged.

LITERATURE CITED

Bolhar-Nordenkampf, H.R. and E.G. Lechner. 1988. Temperature and light dependent modifications of chlorophyll fluorescence kinetics in spruce needles during winter. Photosyn. Res. 18:287-298.

Hawkins, C.D.B. and G.R. Lister. 1985. In vivo chlorophyll fluorescence as an indicator of the dormancy stage in Douglas-fir seedlings. Can. J. For. Res. 15:607-612.

Pharis, R.P., H. Hellmers and E. Schuurmans. 1970. Effects of subfreezing temperatures on photosynthesis of evergreen conifers under controlled conditions. Photosyn. Res. 4:273-279.

Rehfeldt, G.E. 1986. Adaptive variation in *Pinus ponderosa* from Intermountain regions. I. Snake and Salmon River basins. Forest Sci. 32:79-92.

Strand, M. and T. Lundmark. 1987. Effects of low night temperature and light on chlorophyll fluorescence of field-grown seedlings of Scots pine (*Pinus sylvestris* L.). Tree Physiology 3:211-244.

Strand, M. and G. Oquist. 1985. Inhibition of photosynthesis by freezing temperatures and high light levels in cold-acclimated seedlings of Scots pine (*Pinus sylvestris*). II. Effects on chlorophyll fluorescence at room temperature and 77K. Physiol. Plant. 65:117-123.

Toivonen, P. and W. Vidaver. 1988. Variable chlorophyll$_a$ fluorescence and CO_2 uptake in water-stressed white spruce seedlings. Plant Physiol. 86:744-748.

Vidaver, W., P. Toivonen, G. Lister, R. Brooke and W. Binder. 1988. Variable chlorophyll$_a$ fluorescence and its potential use in tree seedling production and forest regeneration. In: Proceedings, Combined Meeting of the Western Forest Nursery Associations, Vernon, B.C., August 8-11. USDA Forest Service General Technical Report RM-167, pp.127-132.

Vidaver, W., W. Binder, R.C. Brooke, G.R. Lister and P.M.A. Toivonen. 1989. Assessment of photosynthetic activity of nursery grown *Picea glauca* (Moench) Voss seedlings using an integrating fluorometer to monitor variable chlorophyll fluorescence. Can. J. For. Res. (in press).