forest management note

Note No. 33 Northern Forestry Centre Edmonton, Alberta

FIELD PERFORMANCE OF CONTAINERIZED CONIFER SEEDLINGS SOUTH OF GRANDE PRAIRIE, ALBERTA

INTRODUCTION

Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss), the primary species in stands of the Wapiti map area south of Grande Prairie, Alberta, are much in demand for pulpwood and sawtimber. Extensive cutting during the past decade in the Lower Foothills (B.19a) Section of the Boreal Forest Region (Rowe 1972) has placed a demand on container stock production for reforestation. Some nurseries have produced smaller multiple-crop seedlings to meet this demand. This Note examines the effects of site, method of conditioning, and year of planting on growth, leadering, mortality, height growth, and rehabilitation of small lodgepole pine and white spruce containerized seedlings.

STUDY AREA

The study area overlooks the Cutbank valley near the confluence of the Cutbank and Smoky rivers and is at the northeastern extremity of the Alberta Plateau-Benchlands (Twardy and Corns 1980). The Continental till on the test site is a relatively stable clay to clay loam, and the dominant soil is a Luvisol that grades into poorly drained Gleysols and Brunisols of Torrens 1 and Edson 4/t Soil Units. Even-aged lodgepole pine is the dominant tree in residual stands, and there are understories of white spruce, pockets of black spruce (*Picea mariana* (Mill.) B.S.P.) on seepage sites and in poorly drained depressions, and the occasional subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and aspen (*Populus tremuloides* Michz.). Twardy and Corns (1980) have rated the forest productivity of the prevalent vegetation types of the study area as moderate for pine, with a mean annual increment of 3.1-3.7 $m^3\ ha^{-1}\ yr^{-1}$ and a site index height of 16.3 $\pm$ 5.6 m at 70 years. Boyacioglu and Van Waas (1971) have rated the potential forest productivity of the land as Canada Land Inventory Class 4 with moderately severe limitations and a mean annual increment of 3.56–4.89 $m^3\ ha^{-1}\ yr^{-1}$ for white spruce.

In 1976, two test sites were located along a Procter and Gamble forestry road on adjacent cut blocks 36 and 38 in sections 29 and 30 of Township 65, Range 6, west of the 6th Meridian. The clay soils averaged 35% silt and had good fertility and good to moderately good physical structure (Zalasky 1980). On Cut Block 36, ponding due to rainfall and snowmelt drained slowly because of fine soil texture and level ground. Summer diurnal air drainage was moderate because of turbulent air affected by higher ground and an opening to the north and south in the residual timber stands that bordered the cut blocks. Site 1 on Cut Block 36 was lightly scarified without unduly disturbing the shallow duff layer. Site 2 on Cut Block 38 had moderately well-drained soil and was located on a landing that would be expected to have a more compacted soil than Site 1. Elevation of the plots was 960 m.

The climate of the study area and its limitations were defined by Carder (1965) and McKenzie and McLean (1980). The temperature of the cut blocks varies due to

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invasions of warm Pacific air and Continental cold air and diurnal cold-air drainage from higher slopes. October temperatures may drop to −17.5°C. Winter temperatures are unstable and can drop to −47°C for short periods in January. Rising temperatures and melting snow alternating with cold outbreaks of −17.5°C or colder result in freeze-thaw cycles of surface soils by mid-February (Thorn 1979). Warm temperatures bare the ground and cause sap to flow in woody ground vegetation, promoting winter injury, mortality, and frost heave of transplants and woody species (Carder 1965; Heidman 1976; Twardy and Corns 1980).

METHODS

Rainfall data and air temperatures at heights of 5 cm and 1 m were taken on the two sites during May to October of 1976 to 1980 using rain gauges and thermograph recorders. Table 1 shows the air temperature distribution of the sites grouped into temperature ranges and expressed as percentages of total monthly hours. Soil temperatures were taken with thermistors in 1976. Winter data were obtained from published reports (Carder 1965; Breadon and Schultz 1973) and from Procter and Gamble Limited. Ground-frost heave and frost damage to native shrubs and trees were also noted.

Two sites, two planting dates, four methods of conditioning, and two planting years were used to test the performance of minimum size lodgepole pine and white spruce seedlings. Seeds of both species were obtained from seed trees close to the planting site. Using six different seeding dates and six lots of two trays per lot, the 1977 and 1978 seedlings were reared in 40-cm^3 Spencer-Lemaire containers in the greenhouse for 10 weeks at temperatures of 20–25°C and a 20-h photoperiod. Beginning the fourth week after seeding, seedlings were given complete fertilizer regimes once a week (Carlson 1983). To protect the young seedlings from spring frost damage, they were conditioned for 10 weeks in growth chambers by decreasing fertilization, irrigation, photoperiod, and thermoperiod. In 1977, one-half of the seedlings were conditioned with a 10-h photoperiod, the other half were conditioned with a 20-h photoperiod, and all seedlings received a 15°C day and a 10°C night thermoperiod. In 1978, all seedlings received a 15-h photoperiod, one-half of the seedlings received a 10°C night and 15°C day thermoperiod, and the other half received a 15°C constant temperature. Prior to outplanting, seedlings ranged in height from 5 to 10 cm, representing an average height of 7.5 cm (Fig. 1).

All seedlings were outplanted with a Pottiputki planting tool into the mineral soil at weekly intervals between May 17 and June 21 of 1977 and 1978. In total, 4 800 seedlings were outplanted in a randomized split-block design. Each block contained two species arranged in 12 plots according to conditioning treatments for the site and planting year.

The causes of seedling failures after first-year growth were determined in the early spring by examining randomly selected seedlings for dead buds, needles, and shoots. Adjacent spare seedlings were sampled and analyzed in the laboratory for evidence of frost damage to the cambium, the external indicators of which are cankers, dieback, and abnormal shoot formation (Zalasky 1980). Frost heave was determined each autumn and spring by checking for separation of soil layers at the interface of the shallow root system and for root extrusion, which causes a seedling to lose its anchorage. Frost damage other than mortality had to be assessed subjectively because there was no accurate method of quantification.

Data on mortality, growth, leadering, and height of seedlings were tallied annually, and remeasurements were taken in 1983. The data were used to determine the extent to which frost injury and frost heave retarded seedling performance. The data were also used to determine the interval of rehabilitation needed after an average of 92% of the seedlings in both species suffered leadering losses. Seedling performance was also assessed on Site 2, where there were areas both with and without forbs. Leadering habits of 10 randomly selected seedlings were rated from 1 to 4 using the rehabilitation criteria shown in Table 2. Figures 2–5 illustrate characteristics of each leadering habit.

The preliminary analysis method of Jeffers (1959) was used to analyze the 1980 and 1983 seedling height measurements to determine if the differences between two means were more than three times the standard error in each performance category. The data were combined if no differences were found between the two photoperiods, the two thermoperiods, and the two sites. The photoperiod- and thermoperiod-treated seedlings were designated as 1977 and 1978 lodgepole pine or white spruce.

RESULTS AND DISCUSSION

First-year Shoot Sensitivity to Site Radiation

During the June–July 1977 and 1978 growing periods, the soil in the study area was cold. At a depth of 5 cm the soil temperatures ranged from 8 to 10°C on Site 1 and from 9 to 12°C on Site 2. The summers were

Table 1. Monthly air temperature distribution on two sites of the Wapiti map area south of Grande Prairie, Alberta

Temperature ranges (°C)	Percentage of total monthly hours											
	Site 1						Site 2					
	May	June	July	August	September	Seasonal average	May	June	July	August	September	Seasonal average
1977												
−7 to 0	10	3	0	1	4	4	4	1	0	0	1	1
1 to 7	47	20	20	20	61	34	53	18	19	19	63	34
8 to 14	30	45	52	45	32	40	34	55	58	54	33	47
15 to 29	13	32	28	34	3	22	9	26	23	27	3	18
1978												
−7 to 0	30	3	0	1	0	7	19	0	0	4	4	5
1 to 7	46	17	8	20	39	26	53	17	7	30	64	34
8 to 14	18	43	48	48	57	43	22	41	51	44	31	38
15 to 29	6	37	44	31	4	24	6	42	42	22	1	23

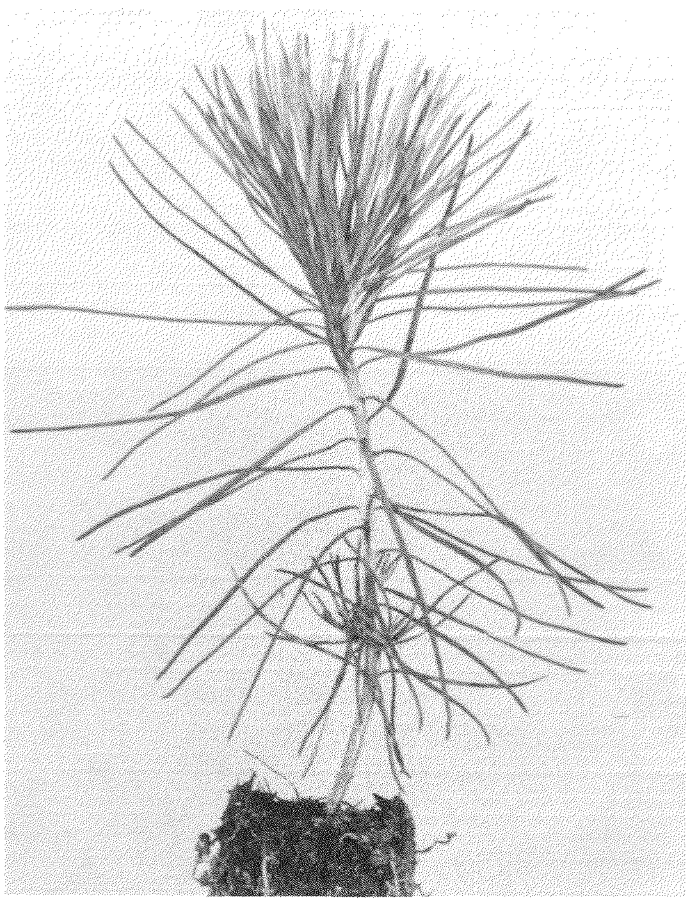

Figure 1. Lodgepole pine seedling with plug prior to outplanting and representing an average height of 7.5 cm.

Table 2. **Leadering habits and rehabilitation patterns in lodgepole pine and white spruce following winter damage**

Leadering habit	Winter damage	Rehabilitation pattern			Seedling form
		Growth potential	Foliation	New shoots	
1	Leader dieback; root dieback; frost heaved	Marginal lateral and terminal growth; mid-summer flushing	Sparse; leaves chlorotic; defoliation common	Epicormic; sparse; spindly	Severely stunted; stem crooks
2	Bud dieback; frost heaved	Good lateral growth; poor lateral growth; second flushes	Good; dense	Epicormic and normal lateral; interfoliaceous in lodgepole pine	Moderately stunted; bushy, flat-topped, or ball-shaped; multistemmed; stem crooks
3	Terminal bud failure	Good lateral growth; good terminal but forked; occasional second flushes	Good; normal to dense	Epicormic and normal	Slightly stunted because of temporary forking; stem crooks
4	Nil	Excellent; vigorous	Good; normal	Normal	Normal with single leading shoot

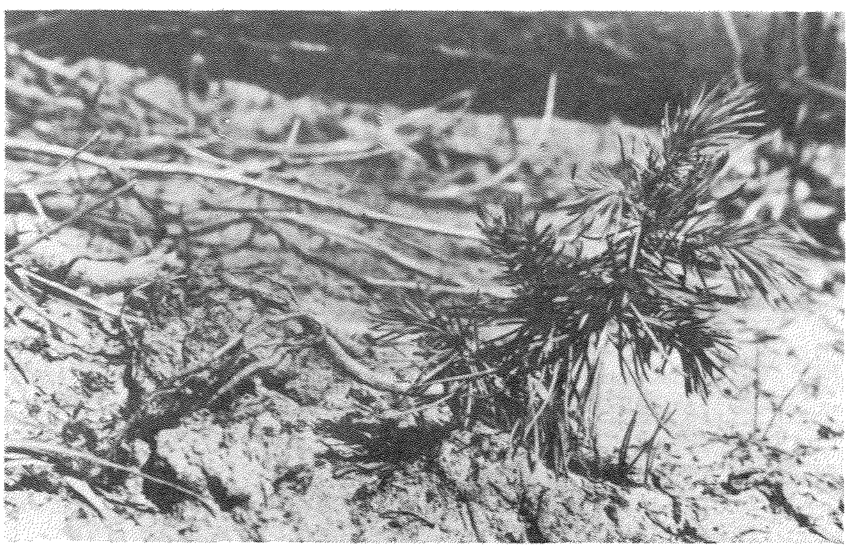

Figure 2. **Winter-damaged and frost-heaved white spruce seedling showing late flushing, loss of foliage and terminal bud, and poor rejuvenation of adventitious foliage characteristic of Habit 1.**

Figure 3. Bushy, multistemmed lodgepole pine seedling showing considerable loss in crown and stem form characteristic of Habit 2.

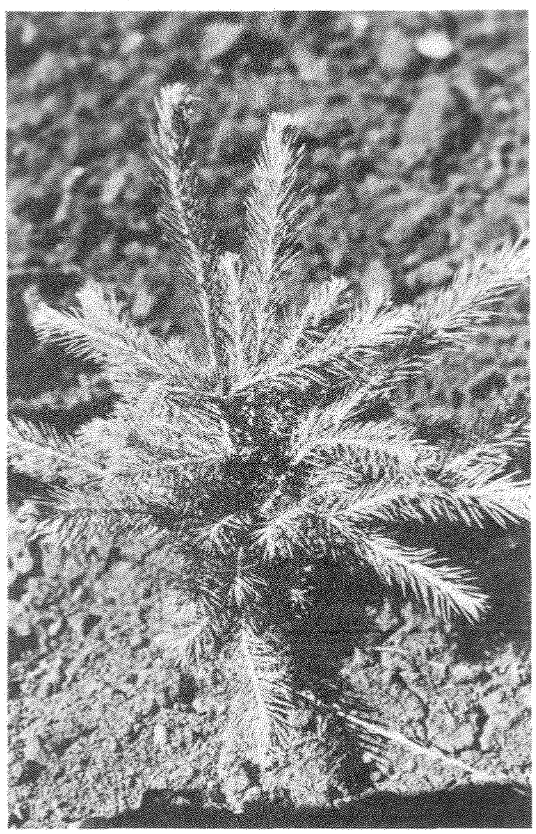

Figure 4. Rejuvenated Habit 3 white spruce seedling showing minor loss in crown and stem form. The forked leaders show normal and abnormal needle development.

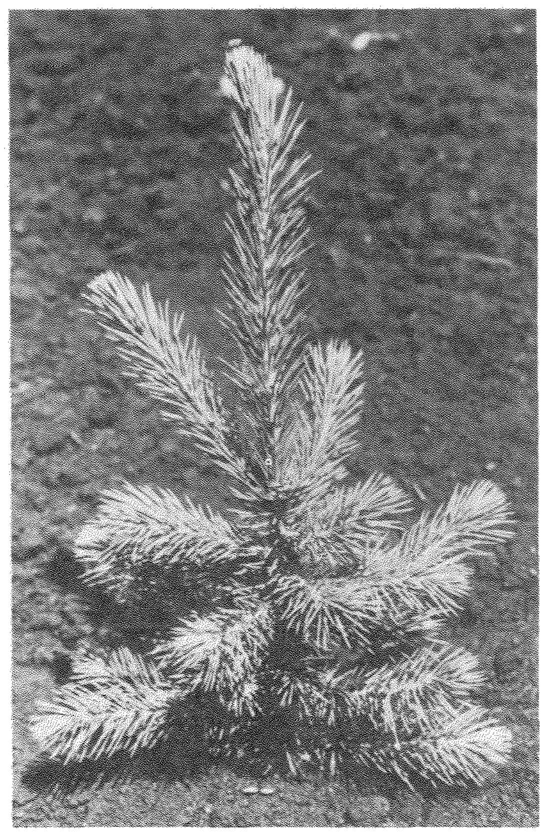

Figure 5. White spruce seedling showing good form characteristic of Habit 4.

interrupted by cooler air temperatures (Table 1) that retarded growth for one or more days. The occurrence of frost in May and June did not pose any danger to dormant white spruce, but the occurrence of warm day temperatures during this period frequently stimulated early flushing in lodgepole pine, exposing them to the danger of frost damage. Lodgepole pine had up to 48% leader crooks as a result of frost damage to the cambium in the first year. Growth of new shoots was rapid during the summer rise in temperatures. White spruce flushed later than pine, usually during July under more stable warm air temperatures. New shoots developed during July and August, when the soil temperature was 12–14°C. Current shoots of white spruce were susceptible to late August frost. Leader development was normal in both species.

Winter Damage and Growth Defects

In the first 2 years, the lethal effects of winter damage were more severe in white spruce than in lodgepole pine (Tables 3 and 4). Mortality of white spruce on both sites was not serious enough to lower the average survival rate below 80%. The nonlethal effects of winter damage had a major impact on both species by retarding leader development and stimulating growth defects. Following the first winter, lodgepole pine had 91% defective seedlings, and white spruce had 94%.

In 1980, white spruce had 8–14% winter-killed seedlings, compared to 1% or less for lodgepole pine. Winter damage resulting in stunted, bushy, and forked (habits 1–3) seedlings accounted for 7–15% of the defective seedlings in lodgepole pine and 24–49% of the defective seedlings in white spruce. The number of stunted, bushy, and forked seedlings of both species was the same on both sites. Stunted and bushy seedlings grew slowly, with most of the growth channeled into lateral shoots.

Initial deep dormancy in white spruce may have contributed to a delayed growth rhythm, subsequent winter damage, and slower rehabilitation of leaders. As growth rhythm improved, growth defects declined faster in lodgepole pine than in white spruce (Table 3). Survival was not critically affected by slow rehabilitation of stunted and bushy seedlings (Table 4).

Rehabilitation of Leadering

On both sites, lodgepole pine and white spruce with leadering habits 1–3 (Figs. 2–4) rehabilitated by 1983, as shown in Table 4. After rehabilitation of lodgepole pine, the average percentage of seedlings with Habit 4 leaders increased from 88% in 1980 to 95% in 1983. After rehabilitation of white spruce, the average percentage of seedlings with Habit 4 leaders increased from 54% in 1980 to 90% in 1983. Normal leadering in white spruce was restored in 5 years to the same level as that achieved by lodgepole pine in 3 years (Fig. 5).

Rehabilitation of seedlings with leadering habits 1–3 depends largely on the amount of reserve vigor and photosynthetic capacity available within the seedlings. The weakest Habit 1 seedlings usually remain in that category for 2 years. The few seedlings that retained habits 2 and 3 were those with partially rehabilitated Habit 1. Subsequent rehabilitation of Habit 1 is accelerated into transitional multileadered and forked stages of branch and foliage development that enable the Habit 1 seedling to rehabilitate to a Habit 4 seedling with normal foliation and leadering.

Height Growth

The average 1983 height growth of 1977 lodgepole pine was 22 cm on Site 1 and 16 cm on Site 2. The average 1983 height growth of 1978 lodgepole pine was 19 cm on both sites. Height growth of 1977 and 1978 white spruce was similar on both sites. As Habit 4 leadering climaxed, the annual height growths achieved in 1983 were 7 and 6.4 cm on sites 1 and 2 for 1977 seedlings and 7 cm on both sites for 1978 seedlings.

Winter injury impedes the rehabilitation and establishment of seedlings for 3-5 years and affects any system for regeneration of cut blocks. Freezing conditions and loss of leadering strongly hinder the rehabilitation and height growth of juvenile survivors; therefore, local interpretations of climate and growing conditions are necessary to predict the success of restocking and the cost per established seedling (Breadon and Schultz 1973). The site conditions in the study area are acceptable for growth and establishment of small lodgepole pine and white spruce seedlings.

The Influence of Forbs on Field Performance of Seedlings

Because of their initial development and small size prior to 1980, forbs were not a strong influencing factor on microclimate and the growth of seedlings, and thus there were a large number of slow-growing lodgepole pine and white spruce seedlings. Site 2 was ideal for studying the influence of forbs because one-third of the seedlings developed under the protection of forbs and two-thirds of the seedlings developed in the absence of forbs. The prevalent forbs consisted of showy aster, bunchberry, pink corydalis, Bicknell's geranium, palmate-leaved coltsfoot, and white clover.

Table 3. Mortality and leadering habit in 1980 of containerized seedlings planted at Grande Prairie, Alberta

Species	Site	No. of seedlings planted	No. of dead seedlings to 1980	Leadering habit (no. of seedlings) 1	2	3	4
1977 seedlings							
Lodgepole pine	1	600	9	3	11	28	549
	2	600	6	5	12	44	533
White spruce	1	600	85	24	51	88	352
	2	600	54	33	41	123	349
1978 seedlings							
Lodgepole pine	1	600	3	1	7	64	526
	2	600	6	0	87	3	503
White spruce	1	600	68	14	65	218	249
	2	600	47	17	37	173	360

Table 4. Winter damage, leadering habit, and mean height in 1983 in lodgepole pine and white spruce containerized seedlings at Grande Prairie, Alberta

Species	Site	Frost damage: Avg % killed	Frost damage: Avg % frost heaved	Leadering habit (avg % of seedlings) 1	2	3	4	Mean height (cm)
1977 seedlings								
Lodgepole pine	1	2	1	0	0	9	91	131.7
	2	3	1	0	1	2	97	95.6
White spruce	1	15	2	0	3	6	91	42.8
	2	10	17	1	2	6	91	38.5
1978 seedlings								
Lodgepole pine	1 & 2	1	0	0	0	2	98	94.4
White spruce	1 & 2	10	4	0	1	11	88	35.1

Table 5. The influence of Site 2 forbs on field performance of 1977 and 1978 preconditioned seedlings

Performance criteria	Lodgepole pine: With forbs	Lodgepole pine: Without forbs	White spruce: With forbs	White spruce: Without forbs
1977 crop				
Average height (cm)	75.28	133.81	32.91	51.51
% Habit 4 leadering	91	97	81	85
% mortality	5	1	10	11
1978 crop				
Average height (cm)	77.74	85.65	31.09	41.15
% Habit 4 leadering	97	96	80	92
% mortality	2	1	9	6

In the absence of forbs on Site 2, 1977 and 1978 lodgepole pine and white spruce had similar height growth (Table 5). In the presence of forbs, the 1977 lodgepole pine and white spruce had significantly better height growth than did 1978 lodgepole pine and white spruce. On Site 2, the height growths of the two conifers in the presence of forbs compared favorably to those of seedlings on Site 1, which grew among a uniform distribution of forbs. When seedlings of both species were compared in the absence and presence of forbs, differences in height growth were considerably wider; both species performed much better in the presence of forbs. This difference was more noticeable in the 1977 seedlings, and the relationship was noticeably stronger in lodgepole pine.

Percentages of leadering and survival were appreciably higher in lodgepole pine than in white spruce in both the absence and presence of forbs (Table 5). The only appreciable differences in leadering and survival of seedlings between the 1977 and 1978 crops were caused by the presence of forbs; both species had higher percentages of leadering and survival in the presence of forbs. In lodgepole pine, the higher mortality rate in 1977 was a result of late frost damage to early immature shoots. In white spruce, the higher rate was a result of early frost damage to late immature shoots in 1977.

CONCLUSIONS

Height growth of 1977 and 1978 outplanted lodgepole pine containerized seedlings occurred in June under colder foothills site conditions, and height growth of white spruce occurred in July and August under warmer conditions. Both lodgepole pine and white spruce were winter-damaged; the white spruce was affected most by mortality and loss of leadering and height growth. Winter damage stimulated growth defects in both species. Lodgepole pine rejuvenated single leadering to a satisfactory level in 3 years, and white spruce required 5 years. Winter damage impedes rehabilitation and establishment of seedlings and affects the regeneration of cut blocks, but the recuperative capabilities of pine and spruce following winter damage are noteworthy. Both sites favored lodgepole pine but not enough to eliminate white spruce as an alternative species. Seedlings of both species had consistently greater height growth in the presence of forbs and reached a maximum height growth on Site 1, which had a uniform distribution of forbs.

RECOMMENDATIONS

To improve seedling performance on Torrens 1 and Edson 4 Soil Units, small seedlings of lodgepole pine and white spruce should be acclimated with an 8-h photoperiod and 20°C for 10 weeks followed by 4 weeks in storage at −2 to 0°C. Seedlings may then be planted safely in May and June on sites with or without initially established forbs. The method of acclimation should reduce mortality and the occurrence of defective seedlings after planting to an insignificant value.

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August 1986

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