SEED SOURCE LIFTING WINDOWS FOR DOUGLAS-FIR IN THE HUMBOLDT NURSERY

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ABSTRACT

Field survivals of seedlings grown in California's Humboldt Nursery continue to range from excellent to disastrous. Since most complaints about Humboldt seedlings originate from interior regions east and southeast of the nursery's north-coastal site, survival would seem to depend largely on the seed source and the planting location. For selected sources, we determined the relation of first-year survival in the area of seed origin to the time that seedlings were lifted in the nursery. The findings are a skeletal guide to the proper times to lift planting stock for each region served by Humboldt Nursery.

INTRODUCTION

Reforestation of Douglas-fir in southwestern Oregon and northern California depends heavily on the U. S. Forest Service Humboldt Nursery. located only a mile from the ocean, near McKinleyville in northwestern California, this nursery grows seedlings for 12 to 14 National Forests and the Bureau of Land Management. Together, these units manage forests)f Douglas-fir that span eight climatic regions and 30 or more tree seed :ones (Buck and others 1970, USDA Forest Serv. 1966).

Because Humboldt's maritime climate always triggers new growth in March, all Humboldt seedlings are lifted sometime during the winter season. Seedlings destined for the coastal forests, where climate is not restrictive, are often outplanted immediately. Seedlings destined for the inland forests are held in cold storage to secure their dormancy, stored reserves, and root growth capacity until spring opens the planting sites. Seedling mortality is especially common on the inland forests, with their colder winters, later springs, and hot, dry summers, and local foresters have often wondered whether any coastal nursery can properly condition seedlings for inland sites. Not surprisingly, every plantation failure renews doubts about the survival potentials of Humboldt seedlings.

California studies on the western yellow pines and true firs have shown that field survival of bare-root seedlings varies with the seed source, lifting date, time in cold storage, and planting season (Jenkinson 1975, and unpublished data). For spring planting, the calendar period during which seedlings of any particular source can be lifted with high survival potentials--the "lifting window"--is fixed by the seedlings' response to nursery climate and cold storage.

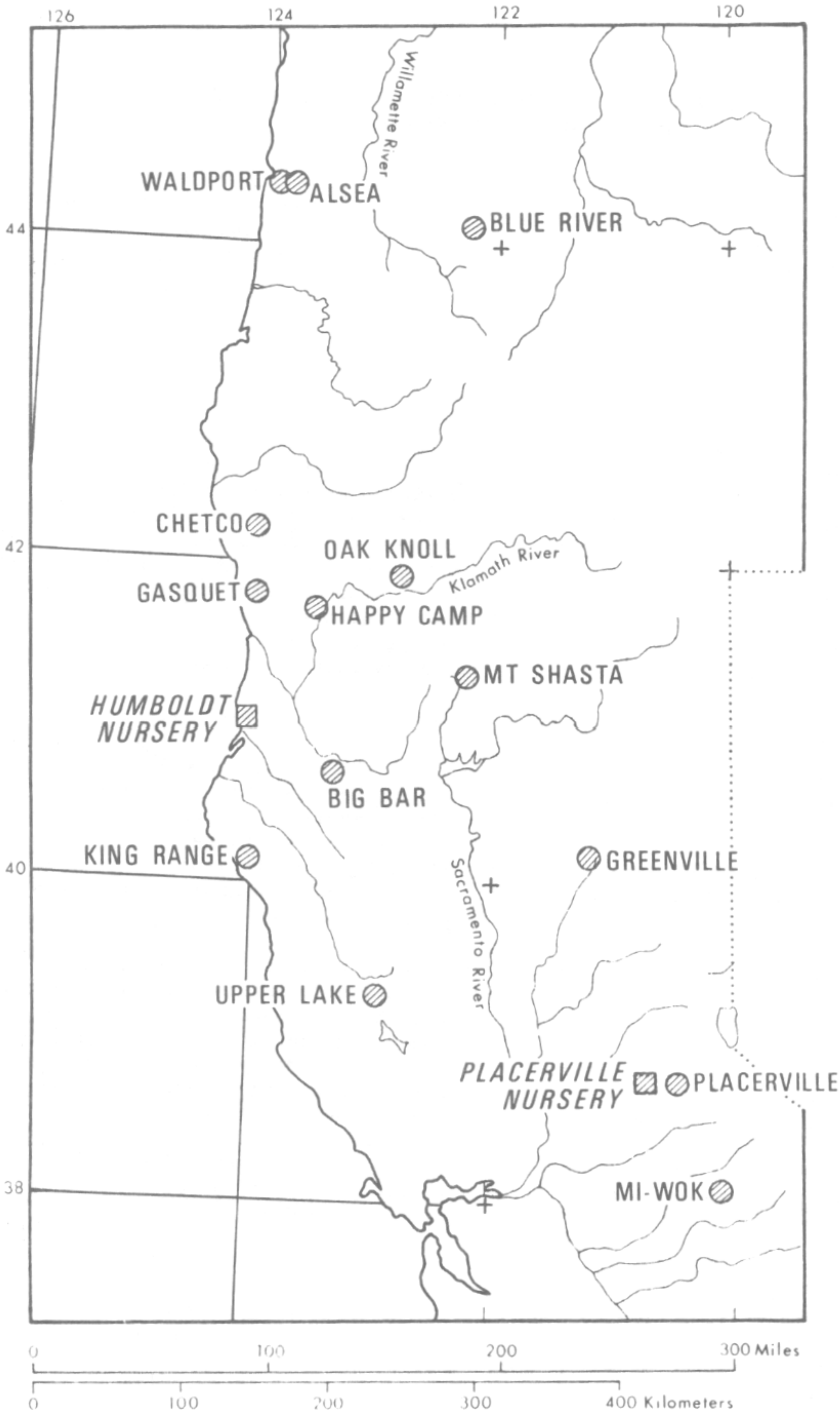

Figure 1--Geographic locations of Douglas-fir seed sources and of the Humboldt and Placerville Nurseries.

This paper describes lifting windows that are based on field survivals of selected sources of Douglas-fir grown in the Humboldt Nursery. The relation of field survival to nursery lifting date and to root growth capacity of stored seedlings at planting time was determined for one or more sources in each climatic region.

PROCEDURES

Fourteen sources that typify the areas served by the Humboldt and Placerville Nurseries were selected from among the sources represented in the production beds at Humboldt. The sources chosen lie along two coastto-interior transects in central Oregon and extreme northern California, and along two latitudinal transects through the Pacific Coast Ranges and Cascade-Sierra Nevada (fig. 1).

During the winter season of 1976-77, 2-year-old seedlings of each source were lifted from the beds at monthly intervals. These seedlings had grown at a density of 30 to 35 per 0.1 m^2 (1 ft^2) and had been undercut once at a depth of 20 cm (8 in) in late summer of their second year. After culling, the seedlings were root-pruned 25 cm (10 in) below the cotyledon node and were stored at 1°C (33-35°F) in the nursery's standard polyethylene lined packing bags.

Stored seedlings of every source were planted in spring on the Ranger District of origin. At about the same time, samples of the stored seedlings were tested for root growth capacity in a standard greenhouse environment.

Field Survival Tests

For 13 sources, the first-year survival of Humboldt seedlings was evaluated for each of five or six lifting dates. The design of each field planting was 10 replications of a randomized block of 10-seedling rows oriented down the prevailing slope. For most sources, each block consisted of five rows, one for each lifting date. Remote canyon slopes prohibited our test of the Mi-Wok source, so first-year survival for a single lifting was obtained by scoring the local reforestation planting.

To compare fresh and stored seedlings in a coastal forest site, each of six liftings for the Gasquet source was divided into two groups, one for immediate and the other for spring planting. The block was a splitplot type with the major plots representing lifting dates, each plot containing single rows of fresh and stored seedlings.

To compare nurseries, seedlings of the Greenville and Placerville sources were sampled both at Humboldt and in the Placerville Nursery, at 2800 ft in the western Sierra Nevada. For the Greenville source, the block was a split-plot type with the major plots representing nurseries, each plot containing a single row of seedlings for each lifting date. For the Placerville source, however, seedlings from each nursery were planted independently and on dissimilar sites.

Planting typically was done on a well-prepared site when the soil was warming to 5-7°C (40-45°F) at a depth of 8 cm (3 in). Planting dates ranged from early March to early May, and on every site the seedlings were planted before the last spring rain. On most sites, the planting holes were made with a soil auger, spacing was 0.6 X 0.6 m, and the seedlings were kept free of competing vegetation through the summer. Seedling mortality, its cause, and the condition of every live seedling were recorded monthly until heavy rains ended the local summer drought.

Root Growth Capacity Tests

The root growth capacities (RGC) of stored seedlings were tested in the standard environment during April or May. For each source and lifting date, 10 seedlings were planted in each of three stainless-steel containers measuring 7.5 X 37.5 X 30 cm deep. The planting mix consisted of equal volumes of moist nursery soil, perlite, sand, and shredded redwood conditioner. After planting, each container was irrigated, drained overnight, weighed to 0.1 kg, and plugged with a rubber stopper to make it watertight.

The design of the RGC test was three replications of a randomized block of 10-seedling containers. For most sources, each block consisted of 5 containers, one for each lifting date. One block of containers was suspended in each of three stainless-steel, controlled-temperature baths, and the soil and root temperatures were held near 20°C (68°F). Air temperatures were held between 17°C (63°F) at night and 25°C (78°F) during the day. A 53-percent-shade screen over the greenhouse reduced the incident sunlight and heat load. For tests of fresh-lifted seedlings of the Gasquet source, the natural photoperiod was extended to 16 hours by mercury-phosphor lights operated from 6 to 8 a.m. and from 4 to 10 p.m.

Air circulation was continuous, and water lost from the containers by evapotranspiration was replaced weekly. Each container was unstoppered to insure uniform penetration of added water, placed on a scale, watered to its initial weight, restoppered, and returned to the bath. After four weeks, the seedlings were washed free of the planting mix. New elongation was recorded for each root that grew 1.5 cm (0.6 in) or more, and totaled for each seedling.

Data Analyses

The field survival data were subjected to analysis of variance, and the correlation of seedling survival and root growth capacity at planting time was determined by regression analysis.

RESULTS

Large differences in first-year seedling survival between sources were no surprise in view of the wide variation in site environment and planting time (table 1). Collectively, our planting sites sampled the full spectrum of climatic and edaphic conditions found in clearcuts and after wildfires.

The relation between field survival and the date seedlings were lifted and stored at the nursery defined a lifting window that was specific for each source (table 1). Large increases and decreases in survival between adjacent lifting dates clearly indicated the limits of each window, regardless of whether the best survivals were excellent (Alsea, over 95 percent), just acceptable (Big Bar, over 70 percent), or relatively poor (Upper Lake,

Table 1--Field survivals and lifting windows for selected sources of Douglas-fir grown in the Humboldt Nursery. Two-year-old seedlings were lifted at monthly intervals through the winter season, stored at 1°C, and planted in spring on the District of seed origin. [1]

Seed source: Tree seed zone and Ranger District		Planting site: Elevation (feet)	Planting site: Slope and aspect	Planting date	Field survival by lifting date at nursery, 1976-77: Nov 1-8	Dec 6-13	Jan 3-10	Feb 1-7	Mar 1-7
					Percent				
Central Oregon									
061.10	Waldport	900	5%,NW	Apr 15	35	[89	94	86	96]
252.10	Alsea	750	20-75%,SW-SE	Apr 21	60	[97	97	98	100]
472.30	Blue River	2300	35%,SW	Apr 8	64	[90	80	88]	76
Klamath Mountains									
082.25	Chetco	2700	30%,S-SW	Mar 15	13	55	69	[82	76]
301.30	Gasquet	1700	15%,S	Apr 25	[88	98	98	97	98]
301.30	Happy Camp	2100	20E	Mar 10	38	[85	95	94	93]
321.40	Oak Knoll	4000	10%,S	May 4	1	39	55	[71]	52
312.40	Big Bar	3250	10%,NW	Mar 17	45	[78	78	70	78]
Coast Ranges									
390.25	King Range	2000	50%,NE/SW	Mar 18	5	45	[67	66	81]
372.30	Upper Lake	3400	ridgetop	Mar 10	6	[45	56	48	51]
Cascade-Sierra Nevada									
516.30	Mt. Shasta	5200	3%,SW	May 6	7	41	[72	71	71]
523.45	Greenville	4300	10%,E	Apr 25	1	39	66	[84]	73
526.40	Placerville	4600	30%,NE	Apr 1	0	77	[92	90]	74
531.40	Mi-Wok	5000	25-40%,W	Apr 15	nd	nd	nd	93	nd

[1] Brackets show the lifting window indicated by field survival. For every test, the variation associated with lifting date is significant ($p = 0.01$). Mi-Wok survival was determined in the local reforestation planting; nd = not determined.

near 50 percent). The best survivals showed that the width of the lifting window varied from 4 months in the Gasquet source to 6 weeks and less in the Chetco, Oak Knoll, and Greenville sources.

Of the 13 sources tested, only the Gasquet source could be lifted and safely stored at any time during the 4 months between early November and early March. Results of the Gasquet planting, in extreme northwestern California, also suggested that outplanting could start in October and continue through April on slopes subject to maritime influence (table 2). Field survival averaged 97 percent for seedlings transplanted from the nursery during the 5-month period of early October to early March, and an equally high 96 percent for seedlings lifted within the window and held in cold storage until planted in late April.

Five sources apparently could be lifted and stored at any time during the 3 months between early December and early March: Waldport, Alsea, Happy Camp, Big Bar, and Upper Lake (table 1). Within this 3-month window, survivals ranged from 97 to 100 percent for Alsea and from 45 to 56 percent for Upper Lake, reflecting extraordinary differences between planting-site environments but good uniformity of survival potential within the window.

Four sources had lifting windows spanning no more than 2 months. The King Range and Mt. Shasta sources showed a survival plateau in January-February, while the Blue River and Placerville sources showed a plateau between mid-December and late February.

In contrast to the plateaus of other sources, the survival potentials of the Chetco, Oak Knoll, and Greenville sources appeared to peak. The relation of survival to date lifted and stored clearly indicated early February as the optimum time to lift these sources for spring planting. The Mi-Wok window remains unknown, but the 93 percent survival of the reforestation planting showed that the first of February was a good time to lift this source, too (table 1).

In the Greenville planting, survivals for both August and November indicated that seedlings could be lifted and stored 6 weeks earlier at the Placerville Nursery than at Humboldt (table 3A). Final survivals of 93 and 84 percent showed that mid-December and mid-January lifts were equally good for Placerville, but survivals of 84 and 73 percent marked late January and February lifts as the best for Humboldt.

Nurseries could not be compared in the Placerville planting, because the Humboldt seedlings were planted in deep soil on a 30-percent northeast slope and those from Placerville were planted in shallow soil on a ridgetop (table 3B). Prickly sow thistle invaded both sites in July, but produced particularly intense summer competition for available soil water on the ridgetop site. Final survival percentages were acceptable only for Humboldt seedlings, a result attributable to the greater amount of soil water and lower potential for evapotranspiration in the Humboldt plots.

For every source, root growth capacity (RGC) varied with the date that seedlings were lifted and stored at the nursery. With few exceptions, field survival was strongly associated with seedling RGC (tables 2, 3). On the more favorable sites, the best estimate of survival was the percentage of seedlings that produced at least 0.1 or 0.2 m of new root elongation in the standard greenhouse environment. On harsher sites, this relation between survival and RGC was demonstrated only when the minimum acceptable length of new root elongation of individual seedlings--the apparent critical value of RGC--was raised from 0.2 to 0.5 and even 1 m. For survival and the apparent critical RGC, the coefficients of determination (r^2) ranged from 0.79 to 0.99 (table 3).

Table 2--Root growth capacity (RGC) and field survival of Douglas-fir (301.30) planted on the Gasquet Ranger District. For each lifting date, one group of seedlings was planted within 2 days (fresh) and another was stored at 1°C and planted April 25.

[1] Determined on seedlings tested four weeks in a standard environment; expressed as mean new root elongation per seedling, and as percent of seedlings showing new root elongation over specified amounts. Fresh seedlings were tested immediately and stored seedlings were tested Apr 25-May 23.

Date lifted at Humboldt Nursery	Root growth capacity[1]: Root elongation		Stored seedlings with elongation over			Field survival on Aug 10	
	Fresh	Stored	0.1 m	0.2 m	0.3 m	Fresh	Stored[2]
	--m/seedling--		-------Percent-------			----Percent----	
Oct 4	0.90	0.00	0	0	0	95	22
Nov 8	1.13	.57	55	50	45	97	88
Dec 13	.76	.92	100	97	93	97	98
Jan 10	.86	.80	97	83	80	97	98
Feb 7	1.22	.68	100	97	93	99	97
Mar 7	.78	.91	100	100	93	99	98

2 r^2 = 0.90 for survival and the percent of stored seedlings with an RGC of 0.1 m or more.

Table 3--Root growth capacity (RGC) and field survival of Douglas-fir planted on the District of seed origin.

A. Greenville (523.45) Planting date: Apr 25 RGC test: Apr 13-May 10

Nursery, and date lifted and stored	Root growth capacity [1]				Field survival	
	Root elongation	Seedlings with elongation over				
		0.2 m	0.5 m	0.7 m	Aug 2	Nov 8 [2]
	m/seedling	--------Percent--------			----Percent---	
Humboldt						
Nov 1	0.21	40	17	7	1	1
Dec 6	.93	100	63	57	63	39
Jan 3	1.31	100	100	83	91	66
Jan 31	1.20	100	90	73	93	84
Feb 28	.91	87	73	60	97	73
Placerville						
Nov 16	.52	83	43	23	87	45
Dec 13	1.09	100	90	87	98	93
Jan 17	1.00	100	83	70	99	84

[1] Determined on seedlings tested four weeks in a standard environment; expressed as mean new root elongation per seedling, and as percent of seedlings showing new root elongation over specified amounts.

[2] r^2 = 0.84 (Humboldt), and 0.98 (Placerville), for survival and the percent of seedlings with an RGC over 0.5 m.

B. Placerville (526.40) Planting date: Apr 1 RGC test: Apr 13-May 10

Nursery, planting site, and date lifted and stored	Root growth capacity			Field survival	
	Root elongation	Seedlings with elongation over			
		0.2 m	0.9 m	Jul 1	Oct 7 [1]
	m/seedling	----Percent----		----Percent---	
Humboldt, NE slope					
Nov 1	0.00	0	0	4	0
Dec 6	.56	77	13	96	77
Jan 3	.44	73	13	100	92
Jan 31	.89	90	40	99	90
Feb 28	.48	77	13	96	74
Placerville, ridgetop					
Nov 16	.67	73	30	75	21
Dec 13	.77	93	37	97	27
Jan 17	1.28	97	63	96	47
Feb 15	.51	87	20	99	20
Mar 16	nd [2]	nd	nd	98	22

[1] r^2 = 0.95 and 0.96 for survival and the percent of seedlings with an RGC over 0.2 m (NE slope) and 0.9 m (ridgetop).

[2] nd = not determined.

Table 3--Root growth capacity (RGC) and field survival of Douglas-fir planted on the District of seed origin--Continued.

C. Mi-Wok (531.40) Planting date: Apr 4-15 [1] RGC test: Apr 13-May 10

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Seedlings with elongation over 0.2 m	Seedlings with elongation over 0.9 m	Field survival on Oct 5 [1]
	m/seedling	----Percent----		----Percent----
Nov 1	0.47	70	13	nd
Dec 6	.63	87	30	nd
Jan 3	.58	90	23	nd
Jan 31	1.23	93	60	93
Feb 28	.47	73	17	nd

[1] Reforestation planting only.

D. Chetco (082.25) Planting date: Apr 23, 1976 RGC test: Apr 20-May 18
Mar 17, 1977 Mar 28-Apr 25

Planting year, and date lifted and stored at Humboldt	Root growth capacity: Root elongation	Seedlings with elongation over 0.1 m	Seedlings with elongation over 0.2 m	Seedlings with elongation over 0.4 m	Field survival	
	m/seedling	--------Percent--------			----Percent---	
1976					Jul 26	Oct 25 [1]
Nov 6	0.00	0	0	0	0	0
Dec 10	.41	40	40	27	22	28
Jan 6	1.51	77	70	70	73	73
Feb 10	1.93	100	100	100	97	96
Mar 16	.49	73	63	40	90	84
1977					Jul 11	Sept 30 [2]
Nov 8	.05	7	3	3	37	13
Dec 13	1.16	100	100	100	90	55
Jan 10	.88	97	93	87	94	69
Feb 7	.77	100	97	77	99	82
Mar 7	.62	100	90	70	100	76

[1] r^2 = 0.96 and 0.91 for survival and the percent of seedlings with an RGC over 0.1 m and 0.2 m.

[2] r^2 = 0.87 and 0.83 for survival and the percent of seedlings with an RGC over 0.1 m and 0.2 m.

Table 3--Root growth capacity (RGC) and field survival of Douglas-fir planted on the District of seed origin--Continued.

E. Waldport (061.10) Planting date: Apr 15 RGC test: May 2-30

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Seedlings with elongation over 0.1 m	0.2 m	0.3 m	Field survival: Jul 12	Aug 18 [1]
	m/seedling	Percent			Percent	
Nov 8	0.14	23	20	17	38	35
Dec 13	.69	97	97	90	95	89
Jan 10	.90	100	100	93	97	94
Feb 7	.94	100	100	100	96	86
Mar 7	.65	100	93	83	99	96

[1] r^2 = 0.98 for survival and the percent of seedlings with an RGC over 0.1 m

F. Alsea (252.10) Planting date: Apr 21 RGC test: Apr 11-May 9

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Seedlings with elongation over 0.1 m	0.2 m	Field survival: Jul 5	Oct 10 [1]
	m/seedling	Percent		Percent	
Nov 8	0.36	37	30	65	60
Dec 13	.64	93	93	99	97
Jan 10	.86	100	100	99	97
Feb 7	.89	100	100	99	98
Mar 7	.52	100	93	100	100

[1] r^2 = 0.99 for survival and the percent of seedlings with an RGC over 0.1 m.

G. Blue River (472.30) Planting date: Apr 8 RGC test: May 2-30

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Seedlings with elongation over 0.1 m	0.2 m	Field survival: Jul 8	Sept 12
	m/seedling	Percent		Percent	
Nov 8	0.46	73	63	92	64
Dec 13	.45	80	57	97	90
Jan 10	.57	83	77	100	80
Feb 7	.62	97	93	100	88
Mar 7	.64	87	77	99	76

Table 3--Root growth capacity (RGC) and field survival of Douglas-fir planted on the District of seed origin--Continued.

H. Upper Lake (372.30) Planting date: Mar 8 RGC test: Apr 4-May 2

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Root growth capacity: Seedlings with elongation over 0.2 m	Root growth capacity: Seedlings with elongation over 1.0 m	Field survival: Jul 8	Field survival: Oct 11[1]
	m/seedling	Percent	Percent	Percent	Percent
Nov 8	0.03	0	0	4	4
Dec 13	.77	70	50	56	45
Jan 10	1.29	83	47	76	56
Feb 7	1.54	90	66	71	48
Mar 7	1.02	87	47	72	51

[1] r^2 = 0.82 for survival and the percent of seedlings with an RGC over 1.0 m.

I. King Range (390.25) Planting date: Mar 18 RGC test: Apr 4-May 2

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Root growth capacity: Seedlings with elongation over 0.2 m	Root growth capacity: Seedlings with elongation over 0.7 m	Field survival: Jun 15	Field survival: Sept 22[1]
	m/seedling	Percent	Percent	Percent	Percent
Nov 1	0.00	0	0	10	5
Dec 6	.73	70	50	91	45
Jan 3	1.15	80	63	95	67
Jan 31	.95	87	70	98	66
Feb 28	nd	nd	nd	98	81

[1] r^2 = 0.98 for survival and the percent of seedlings with an RGC over 0.7 m.

J. Happy Camp (301.30) Planting date: Mar 10 RGC test: Mar 28-Apr 24

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Root growth capacity: Seedlings with elongation over 0.1 m	Root growth capacity: Seedlings with elongation over 0.2 m	Field survival: Jun 28	Field survival: Aug 26[1]	Leader growth[2]
	m/seedling	Percent	Percent	Percent	Percent	Cm/seedling
Nov 8	0.24	40	27	41	38	4.2
Dec 13	.57	87	70	92	85	5.1
Jan 10	.52	95	90	97	95	6.3
Feb 7	.67	100	93	99	94	5.8
Mar 7	.33	80	55	97	93	4.9

[1] r^2 = 0.91 for survival and the percent of seedlings with an RGC over 0.1 m.

[2] r^2 = 0.96 for leader growth and the percent of seedlings with an RGC over 0.2 m.

Table 3--Root growth capacity (RGC) and field survival of Douglas-fir planted on the District of seed origin--Continued.

K. Oak Knoll (321.40) Planting date: May 4 RGC test: May 23-Jun 20

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Root growth capacity: Seedlings with elongation over 0.2 m	Root growth capacity: Seedlings with elongation over 0.4 m	Field survival: Jul 25	Field survival: Sept 27 [1]
	m/seedling	Percent	Percent	Percent	Percent
Nov 1	0.06	7	3	6	1
Dec 6	.36	73	40	70	39
Jan 3	.42	77	53	87	55
Jan 31	.74	90	83	94	71
Feb 28	.53	87	57	82	52

[1] $r^2 = 0.97$ for survival and the percent of seedlings with an RGC over 0.4 m.

L. Big Bar (312.40) Planting date: Mar 17 RGC test: May 9-Jun 6

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Root growth capacity: Seedlings with elongation over 0.1 m	Root growth capacity: Seedlings with elongation over 0.2 m	Root growth capacity: Seedlings with elongation over 0.3 m	Field survival: Jul 8	Field survival: Sept 23 [1]
	m/seedling	Percent	Percent	Percent	Percent	Percent
Nov 1	0.15	40	27	20	58	45
Dec 6	.58	93	90	67	89	78
Jan 3	.29	83	60	47	94	78
Jan 31	.50	90	83	60	93	70
Feb 28	.33	75	60	50	94	78

[1] $r^2 = 0.79$ for survival and the percent of seedlings with an RGC over 0.1 m.

M. Mt. Shasta (516.30) Planting date: May 6 RGC test: May 9-Jun 6

Date lifted and stored at Humboldt	Root growth capacity: Root elongation	Root growth capacity: Seedlings with elongation over 0.1 m	Root growth capacity: Seedlings with elongation over 0.2 m	Root growth capacity: Seedlings with elongation over 0.3 m	Field survival: Jul 13	Field survival: Sept 9 [1]
	m/seedling	Percent	Percent	Percent	Percent	Percent
Nov 1	0.05	13	10	10	10	7
Dec 6	.71	83	77	73	62	41
Jan 3	.55	100	77	67	83	72
Jan 31	.80	100	97	93	92	71
Feb 28	.42	87	73	63	81	71

[1] $r^2 = 0.79$ for survival and the percent of seedlings with an RGC over 0.2 m.

DISCUSSION AND CONCLUSIONS

Although final survival in the field largely depends on the level of environmental stress at the planting site, the survival potential of a particular source is locked in the day those seedlings are lifted and stored at the nursery. Lifting windows, because they relate field survival to the date seedlings are lifted and stored, ire the western nurseryman's best guide to proper lifting times for spring planting.
They are also the forester's principal guide to seedling quality. Sources with wide windows allow exceptional flexibility in the lifting schedule, and without sacrifice of survival potential. Sources with narrow windows demand special attention from both the nurseryman and the forester. In either event, any request for seedlings outside their demonstrated window will be foolish at best, because the post-planting climate is always uncertain.

Is the lifting window for a particular source consistent from one nursery year to the next? The initial indication is yes. Survivals of seedlings from a single Chetco seed lot, sown in consecutive years at Humboldt and planted in consecutive years on the Chetco District in the Klamath Mountains of southwestern Oregon (fig. 1), defined the same 6-week window in 1976 and 1977 (fig. 2A). The window clearly centered on February, even though the test sites and planting times were substantially different. The 1977 test was planted in mid-March in a brushfield conversion unit located 17 miles inland at 2700 ft, while the 1976 test was planted in late April in a recent Douglas-fir clearcut located 12 miles inland at
1600 ft. The apparent critical value of root growth capacity for individual seedlings was about 0.2 m on each site (table 3D). In the clearcut, seedling survival after two summers was just 1 to 4 percent below that recorded after the first summer, and confirmed our first-year estimate of the Chetco window.

Although spring is the rational and generally accepted season to plant in areas away from the Pacific Coast, high-survival planting--with a combination of fresh and stored seedlings--may extend from October to May in areas subject to maritime influence. In California's north coast region, mild winter soil temperatures combined with well-distributed spring rains can guarantee survival of Humboldt seedlings when site preparation has eliminated competing vegetation for the first summer (table 2). The high survivals of recent winter plantings on the Gasquet District (pers. commun., District Silviculturist) indicate that maritime influence may extend eastward along the drainages to a longitude near the crest of the western Siskivou Mountains.

For spring planting, the minimum root growth capacity (RGC) that a root-pruned seedling must have to insure its survival depends on the severity of the site at planting time and during the subsequent growing season. The survival rate on a specific site reflects the percent of planted seedlings that have an RGC greater than some critical value. The apparent critical values found in our survival tests ranged from 0.1 m and less in a variety of coastal and northern sites--Waldport. Alsea. Blue

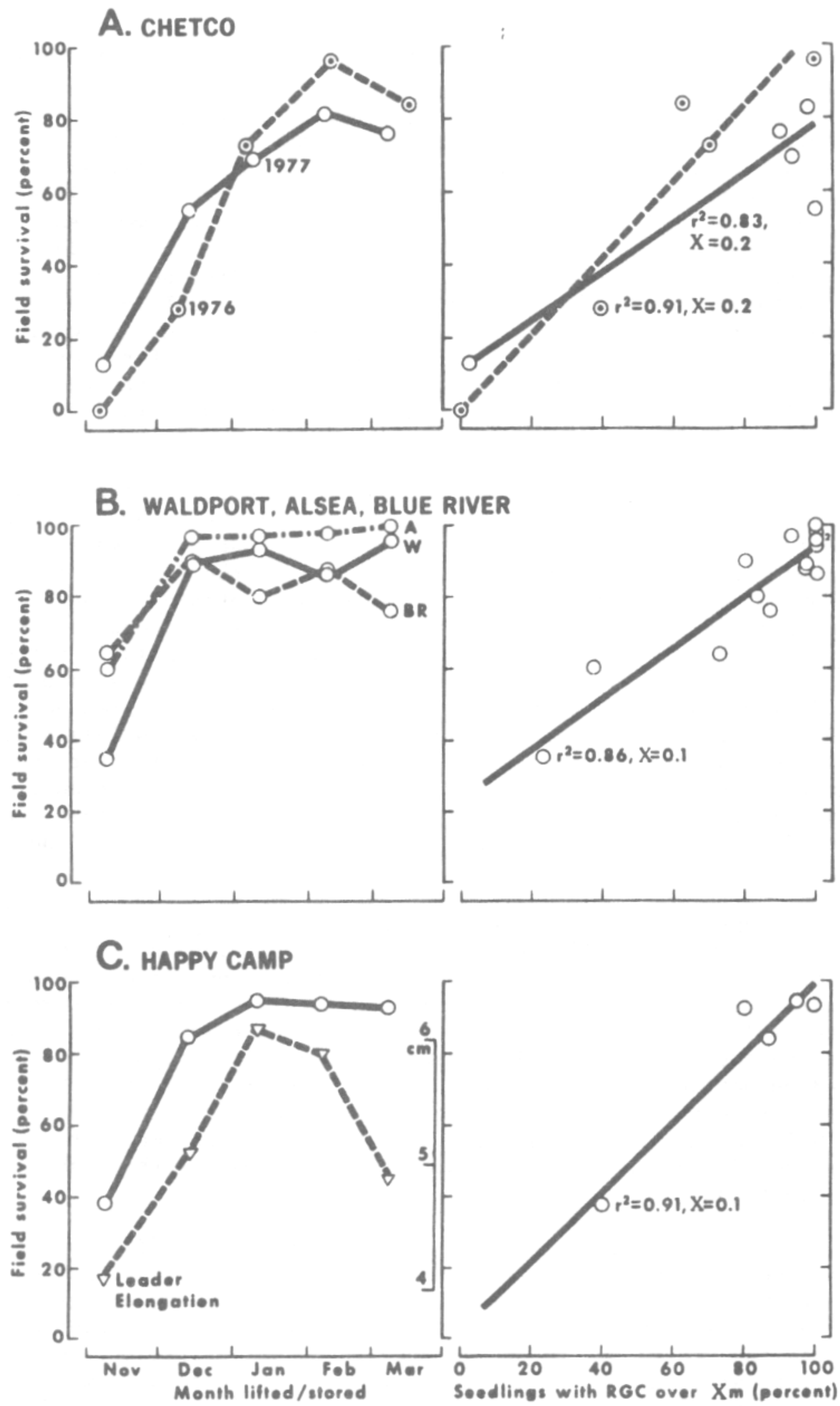

Figure 2--Field survival of Douglas-fir varies with nursery lifting date and the corresponding fraction of seedlings that exceed a critical root growth capacity (RGC). Examples are sources in the Klamath Mountains (A,C,D), central Oregon (B), and the Sierra Nevada (E,F).

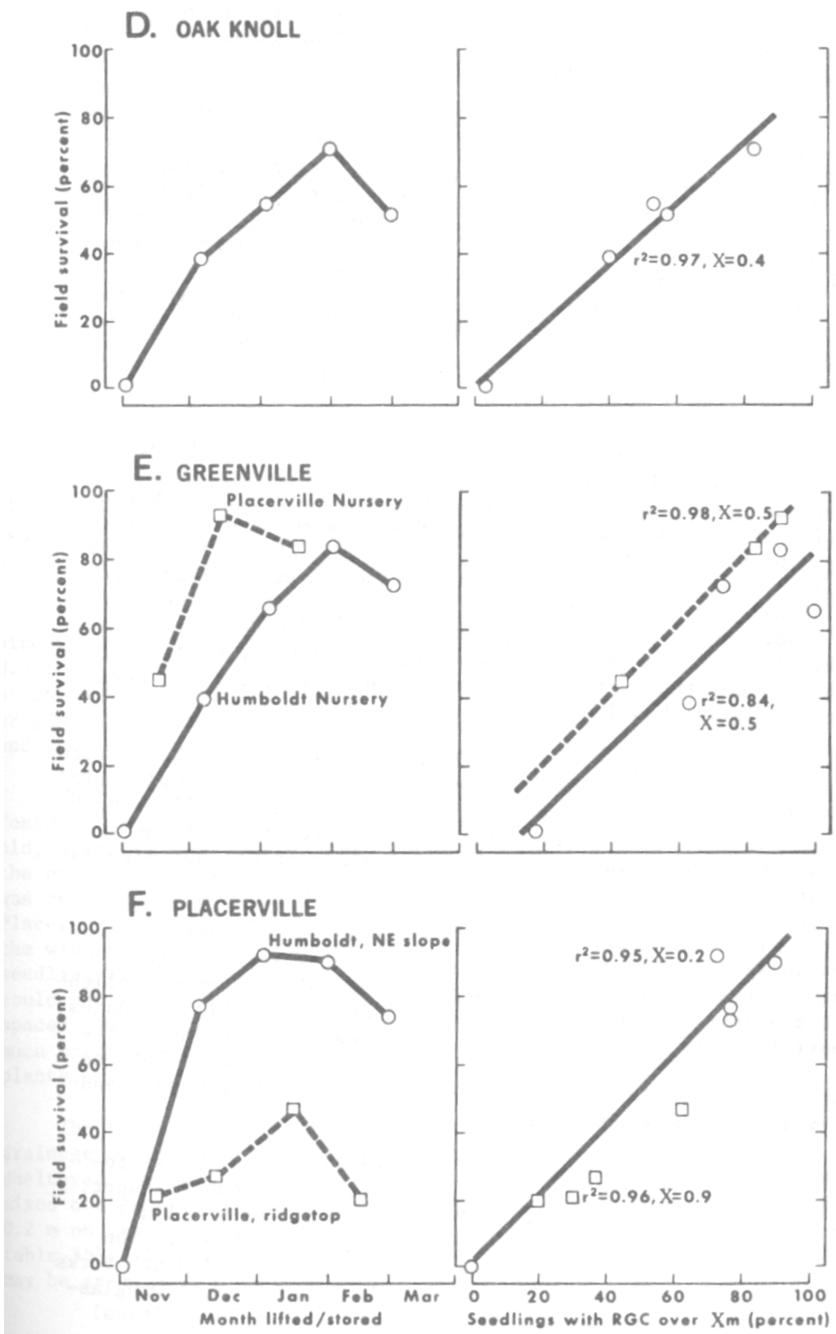

Figure 2- Field survival of Douglas-fir varies with nursery lifting date and corresponding fraction of seedlings that exceed a critical root growth capacity (RGC)--Continued.

River, Gasquet, and Happy Camp, to 0.4 and 1.0 m in a diversity of California's more harsh interior sites--Upper Lake, King Range, Oak Knoll, Greenville, and Placerville (fig. 1).

On our central Oregon transect, the Waldport, Alsea, and Blue River sources shared wide lifting windows and were planted in climatically mild test sites. The Waldport and Alsea plantings are in the Alsea River drainage about 8 and 16 miles from the coast. Both sites are clearcuts within Douglas-fir/western hemlock forest. The Blue River planting is in a Douglas-fir clearcut in the South Fork McKenzie River drainage of the western Cascades. All three plantings had frequent rains through May (5 to 7 in) and 11 weeks of summer drought terminated by heavy rains in late August (2 to 3.5 in). The best estimate of critical RGC for these plantings was 0.1 m, as 86 percent of the variation in survival was associated with variation in the percent of seedlings having an RGC of at least 0.1 m (fig. 2B, table 3E-G).

California's Coast Range sources also shared relatively wide windows, but were evidently planted in severe local climates. The Upper Lake planting is between Clear Lake and Lake Pillsbury in the southern North Coast Range. The site is a ridgetop in a region of mixed conifer forest that was denuded by wildfire in 1966. The planted seedlings were damaged by hard freezes in March and were exposed to frequent summer winds. For lifting dates within the Upper Lake window, field survival averaged 50 percent, and 52 percent of the seedlings tested for RGC had new root elongations totaling 1.0 m or more (table 3H). The implication is clear: On the Upper Lake site, the critical RGC was at least 1 m, and any seedling with an RGC of less than 1 m died.

The King Range planting, in the Mattole River drainage on the eastern side of California's north coast King Range, is in an area of Douglas-fir/ mixed evergreen forest that burned in 1973 and was logged in 1976. Survivals within the source window averaged 64 and 79 percent on southwest and northeast slopes, but variance associated with aspect was not significant. The apparent critical value of RGC was 0.7 m (table 31).

For sources like Upper Lake and King Range, the RGCs--hence the survival potentials--of individual seedlings are so variable and the planting sites so severe that the only way to assure plantation establishment may be to double the number of seedlings planted. For lifting dates within the Upper Lake and King Range windows, at least 15 percent of the seedlings had an RGC near zero. In the other extreme, RGCs were between 1 and 4.4 m in 50 percent of the Upper Lake seedlings, and between 1 and 3.6 m in 40 percent of the King Range seedlings.

The Gasquet, Happy Camp and Oak Knoll sources lie on our coast-to-interior transect of the central Klamath Mountains. Along the transect, the lifting window decreased from Gasquet's 4 months to Oak Knoll's 1 month, and the critical value of RGC increased from 0.1 to 0.4 m. The Gasquet planting, 9 miles inland on a ridge between Middle and South Forks of Smith River, is in a reforestation backlog unit in an area of Douglasfir/sugar pine forest that was destroyed by fire in 1918. The critical RGC for seedlings planted in April approached 0.1 m (table 2).

The Happy Camp planting is in the Klamath River drainage of the western Siskiyous. The site is in a clearcut unit of Douglas-fir, tan oak, and madrone. The critical RGC was close to 0,1 m (fig, 2C, table 3J). Like survival, leader growth of the surviving Happy Camp trees also varied with the month seedlings were lifted and stored. The differences were small, with leader elongation ranging from 4 cm on November trees to 6 cm on January trees, yet 96 percent of this variation in height growth was associated with variation in the percent of seedlings with an RGC over 0.2 m. Barring animal damage, leader elongation in the second field season should tell us whether the relation has any practical significance.

The Oak Knoll planting, at the east end of the Klamath transect, is on serpentinite soil in the West Fork Beaver Creek drainage of the eastern Siskiyous. The site is in a recently logged area of typically open, mixed conifer forest that is heavy to Jeffrey pine. The critical RGC was 0.4 m (fig. 2D, table 3K).

Big Bar, the most southerly of the Klamath Mountains plantings, lies within the Hayfork Creek headwaters of the South Fork Trinity River. The site is in a cleared unit of mixed evergreen forest. The lifting window of 3 months matched that for Happy Camp, but any meaningful estimation of the critical RGC was precluded by our 2-month delay of the RGC test (table 3L). The critical value was probably higher than 0.1 m.

For sources along the Cascade-Sierra Nevada transect, the lifting window was 2 months or less, and the critical value of RGC ranged from 0.2 to 0.9 m. The Mt. Shasta planting is on the south slope of Mt. Shasta at an elevation of 5200 ft, of necessity some 2000 ft higher than the seed origin. The site is in a clearcut block in white fir/ponderosa pine forest, and the critical RGC was at least 0.2 m (table 3M).

The Greenville planting is south of Lake Almanor in the North Fork Feather River drainage of the northern Sierra Nevada. This site is in an old, sparsely regenerated burn in an area of mixed conifer forest, and the critical RGC for planted seedlings, whether Humboldt or Placerville, was very close to 0.5 m (fig. 2E, table 3A). The better peak survival of Placerville seedlings was not associated with a higher RGC, as RGCs within the windows were the same for both nurseries. Visual comparisons of seedling tops suggested that foliar differences in morphology and physiology could be responsible. Needles of Placerville seedlings were more closely spaced, stouter, and more glaucous than needles of Humboldt seedlings, and such morphologic modifications might reduce early water losses from outplants.

The Placerville plantings are in the South Fork American River rainage of the western Sierra Nevada. The contrasting sites are a heltered northeast-facing slope and an exposed ridgetop in the same ixed conifer clearcut. The critical values for planted seedlings were .2 m on the slope and at least 0.9 m on the adjacent ridgetop (fig. 2F, able 3B). Evidently, the difference in severity between adjacent sites

Collectively, field survivals on the 14 Districts suggest no reason to change the present allocation of Douglas-fir sources between the Humboldt and Placerville Nurseries. Placerville normally grows all of the seedlings for reforestation in the Sierra Nevada and California's Cascade Range, but Humboldt obviously can grow seedlings with high survival potentials for these interior forests too, should the need arise. Along our Cascade-Sierra Nevada transect, first-year survival of Humboldt seedlings varied from good to excellent in four widely separated localities. For dates within the source lifting windows, survival was 72 and 71 percent on the Mt. Shasta District, 84 and 73 on the Greenville, 92 and 90 on the Placerville, and 93 percent on the Mi-Wok (table 1).

The source lifting windows described are quite variable, and are as yet too few to provide a solid basis for generalizations to non-study areas. We need to know additional windows. But can we ascertain the window for a particular source (area) without the actual field survival test? We think so: A single RGC test of stored seedlings can define a window that is close to the window described by field survival (fig. 2, table 3). The width of the window, of course, might or might not depend on the severity of the site. It would for sources like Placerville and Mi-Wok (table 3B,C), but would not for sources like Upper Lake and King Range (table 3H,I). The gaps in our knowledge of how the source lifting window varies between and within climatic regions--and especially throughout the Klamath Mountains--may be narrowed when we evaluate the results of current tests of Douglas-fir grown at Humboldt Nursery.

For the present study, our seed sources represented only those elevational bands in which extensive planting is now being done. We cannot say whether sources from north and south aspects or from other elevations in the same seed zone will behave similarly. Studies of ponderosa pine from the Sierra Nevada (Jenkinson 1976) and from southern California (unpublished data) indicate that elevation of the parent stand does influence seedling response. Hence, the effect of source elevation--and probably aspect of the parent stand--should also be evaluated for Douglas-fir.

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