Field Performance of Mini-Plug Transplants'

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Abstract.--A new stock type, mini-plug ™ transplant (MPT), has been developed at Weyerhaeuser Company. MPT's are started in the greenhouse and transplanted into the nursery where they are grown for one season. Advantages of using MPT's are (1) short production time to improve flexibility of regeneration planning, (2) ease of planting due to compact mop-like root system and (3) relatively low production costs. A total of 68 trials to evaluate Douglas-fir MPT's were installed at six regions in Washington and Oregon in 1985, 1986 and 1987. Survival, vigor, damage and height growth were measured annually. The results showed that probably owing to favorable root to shoot ratio and fibrous roots, MPT's performed as well as or better than other bareroot stock types including 2+0's, low density 2+0's, 1+1's, plug+l's and 2+1's at a majority of sites. MPT's put on the same amount of height growth or greater than the other stock types. Furthermore, MPT's appreciably exceeded the other stock types on a relative growth rate based on the original height. However, MPT's had less total height than other stock types due to its smaller initial height. There appeared to be no preference of MPT's over other stock types in terms of frequency of big-game browsing and rabbit clipping. But, because of their smaller size, MPT's were unable to withstand heavy animal damage as well as larger stock types.

INTRODUCTION

A new method of producing planting stock called "mini-plug ™ transplant (MPT)" has been adapted from the agricultural transplant industry for forestry by Steve Hee and his nursery staff, Weyerhaeuser Timberland Division (Hee, et al., 1988). Mini-plug[tm] starter crops are sown in December into trays with cavities about one cubic inch in volume. They are grown for 5-6 months in the greenhouse under an extended daylength. Actively growing starter plants, 4-5 inches in height, are then transplanted into the nursery beds by machine around May and grown for one season before outplanting.

There are a number of advantages to using MPT's. First, they take only one year to grow and thus increase flexibility of regeneration planning. Second, they are potentially inexpensive as compared with other types of transplants including 1+1's, 2+1's and plug+l's because of short production time, greater growing density and a high degree of mechanization. Third, they have a compact fibrous root system and are easy to plant in the field.

To determine the field performance potential of Douglas-fir MPT's, we installed a total of 68 field trials at six geographic regions in Washington and Oregon and have been monitoring their performance in comparison with other stock types in these trials annually. The present paper reports our observations to date.

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MATERIALS AND METHODS

Field performance of MPT's was compared with that of 2+0's, low density 2+0's, plug+l's, 1+1's and 2+1's of Douglas-fir at the following six Weyerhaeuser western regions: Cascade, Chehalis, Twin Harbors, Longview regions in Washington and Springfield and Coos Bay regions in Oregon. At each region, three types of trials were installed: (1) stock comparison tests (SCT), (2) field performance trials (FPT) and (3) region block plantings (RBP).

All the stock used in this study were produced at one of three Weyerhaeuser barreoot nurseries: Aurora located near Portland, Oregon; Mima near Olympia, Washington; and Turner near Salem, Oregon. MPT starter plants were grown at the Company's greenhouse in Rochester, Washington and subsequently transplanted into the nursery beds at Aurora and Mima. In the 1985 trials, MPT's and 2+0's stock were from both Aurora and Mima while 1+1's and 2+1's stock were from Aurora and Mima, respectively. In the 1986 and 1987 trials, all the stock tested at the Washington regions were from Mima while those tested at the Oregon regions were from Aurora. The only exceptions were the stock outplanted at the Longview region in 1986, when MPT's were from Aurora, 2+1's from Aurora (SCT) and Turner (FPT's and RBP), 1+1's from Aurora and 2+0's from Mima.

The SCT was a replicated row planting of several stock types and followed a randomized block design. It consisted of 100 trees/stock type (four blocks x 25 trees in 1985 trials and five blocks x 20 trees in 1986 trials). The approximate distance between rows was three feet and distance between trees within a row was two feet. All the stock types operationally used at a given region were included in the SCT at that region so the number of stock types varied from one region to the other. The SCT was enclosed by a fence and was protected from animal damage pressure in order to study maximum survival and growth potential. The fence was specially installed for the 1985 SCT's while progeny test sites with existing fences were used for the 1986 SCT's.

The FPT was also a replicated row planting with the same spacing between rows and trees within a row as SGT, It was a completely randomized design with four blocks each with 25 trees for a total of 100 trees/stock type. The two major differences between SCT and FPT were that (1) the FPT was not enclosed by a fence and was subject to animal damage pressure and (2) the FPT generally compared the performance of MPT's with that of one or two other stock types operationally used at the site where the FPT was located.

The RBP was a larger scale trial consisting of two 3-6 acre blocks. One block represented MPT's and the second block the other stock type operationally used in that area. Trees were planted with operational spacing of 10 x 10 feet. The trial was replicated two to three times in the 1987 installations in Chehalis, Twin Harbors and Longview. Special emphasis was placed in selection of sites so that two stock types were tested under uniform environments.

We installed a total of 68 trials during the 1985, 1986 and 1987 period. A breakdown of installations by types of trials at each region is shown in Table 1. A breakdown is also shown according to the year of installation in Table 2. Study sites used for these trials are shown in Table 3 by region and year of installation. The names of sites are accompanied by the method of site preparation in parenthesis -- burned (B), scarified (S) or no site preparation (N).

All the trials were installed at the beginning of each installation year and trees were assessed for vigor, survival, type and location of damage and height in the fall of each year following installation. Vigor, survival and damage were also assessed in early summer in many of the trials. Assessments were made on all the trees in SCT's and FPT's. In RBP's, permanent transects encompassing all areas of blocks were established and about 100 tagged trees were monitored in each stock type.

Trees were classified into one of five vigor classes using the following Weyerhaeuser western forestry seedling assessment code.

Vigor Classes	Vigor Category	Description
1	High	Green needles, no loss of foliage
2	High	Green needles, 751+ foliage retention
3	Medium	Some chlorosis, 501+ foliage retention
4	Low	Chlorotic, dying
5	Dead	Brown stem and foliage

Table 1.--Number of trials installed in each of three trial types at six regions in Washington and Oregon.

Region	SCT[1]	FPT[2]	RBP[3]	Total
Cascade	1	6	6	13
Chehalis	1	4	5	10
Twin Harbors	1	4	6	11
Longview	2	6	3	11
Springfield	4	10	0	14
Coos Bay	1	8	0	9

[1] Stock comparison test.

[2] Field performance trial.

[3] Region block planting.

Table 2.--Number of trials installed in each of three years at six regions in Washington and Oregon.

Region	1985	1986	1987	Total
Cascade	1	9	3	13
Chehalis	0	7	3	10
Twin Harbors	0	8	3	11
Longview	1	6	4	11
Springfield	2	6	6	14
Coos Bay	0	5	4	9
Total	4	41	23	68

Table 3.--Study sites used for MPT trials at 6 regions in 1985-1987.

Region	Year of Installation	Sites
Cascade	1985	Bald Hills (B)[1]
"	1986	Boyles Lake (N), Carnation (N), Deer Creek (S), Bayne Junction (N)
"	"	Orting Lake (N), Bald Hills (B), 3950 Road (N)
"	"	Kings Lake (N), Rhodes Lake (N)
"	1987	Barr Hill (N), Highrock (N), Greenwater (N)
Chehalis	1986	Garrard Creek (S), Bloomquist (B), Deer Creek (B and N)
"	1987	Ceres Hill (N), Deer Creek (B and N)
Twin Harbors	1986	Church Road (B), Wishkaw (N), Mayors Brother (B) Delezenne (B), Fall River (N)
"	1987	Satsop (B), Hippi Camp (N), Wiekswood (B)
Longview	1985	Mt. Brynion (B)
"	1986	Finkas (B), 1390 Road (N), 4534 Road (N), 0020 Road (B), 0518 Road (B), Tower Road (B)
"	1987	4830 Road (B), 1890 Road (B), Sucker Creek (S)
Springfield	1985	5330 Road (B), 5540 Road (B)
"	1986	Wendling (S), Shoestring (S), 3330 Road (B) 5180 Road (S), 114 Road (N), 9300 Road (B)
"	1987	7010 Road (N), 1060 Road (S), 6260 Road (B), 410 Road (B), 2340 Road (B), 5305 Road (N)
Coos Bay	1986	3394 Road (S), 8300 Road (N), 8312 Road (S)
"	1987	9120 Road (S), 9100 Road (N), 3360 Road (N), 3367 Road (N)

[1] Notations between parenthesis show methods of site preparation:

(B) = Burning (S) = Scarification (N) = None

The data was analyzed using analyses of variance procedure (Steel and Torrie, 1960). Percentage values were transformed into arcsin f% prior to analyses. In comparing three or more stock types, if F values were significant at the 5% risk level, the treatment differences were tested using Duncan's new multiple range test.

Because of a large amount of data from all the assessments, in the present paper we'll be only reporting selected pertinent information predominantly from the fall 1987 assessment, focusing on total survival, percent of trees with high and medium vigors and animal damage of all trials. Yearly changes of total height in 1985 and 1986 SCT are also reported.

RESULTS Survival and Vigor

1985 Trial:

MPT's from Mima and Aurora exhibited excellent survival, 96% and 94%, respectively at Mt. Brynion, Longview after three growing seasons in the field (Table 4). Survival of Mima MPT's was significantly higher than that of 2+0's from Mima (78%) and Aurora (83%). The 2+1's from Mima showed an intermediate survival of 87%.

Table 4.--Survival of four stock types after three growing seasons in 1985 trials at four sites.

Stock Type	Nursery	Mt. Brynion[1]	Bald Hills[2]	5330 Road[3]	5540 Road[3]
MPT	Mima	96 a[4]	73 a	79 a	70 a
MPT	Aurora	94 ab	75 a	80 a	65 b
2+0	Mima	78 b	35 b	-	-
2+0	Aurora	83 b	56 ab	-	-
2+1	Mima	87 ab	31 b	-	-
1+1	Aurora	-	-	81 a	96 a

[1] Longview region, assessed in the fall of 1987.

[2] Cascade region, assessed in the fall of 1987.

[3] Springfield region, survival after two growing seasons assessed in the fall of 1986.

[4] Means followed by the same letters within each column are not significantly ($p < .05$) different.

At Bald Hills, Cascade, overall survival was lower than at Mt. Brynion due to harsh conditions of southern exposure and shallow soils. The survival trend, however, was the same as Mt. Brynion with MPT's from Mima (73%) and Aurora (75%) outperforming 2+0's from Mima (35%) and Aurora (56%) and 2+1's from Mima (31%).

At 5330 Road, Springfield where the field condition was also harsh (southern exposure) overall survival was also lower than at Mt. Brynion. MPT's from Mima (79%) and Aurora (80%) showed a similar level of survival as did 1+1's from Aurora (81%).

At 5540 Road, a milder site with northern exposure, survival of MPT from Mima (70%) and Aurora (65%) was greatly reduced as compared with 1+1's (96%). The survival difference was significant between Aurora MPT's and 1+1's. The reduction was mainly due to browsing by a deer which had entered the fenced area, becoming trapped and causing damage for an extended period of time. The larger 1+1's were able to withstand the browsing more than the MPT's.

1986 Trial:

Cascade -- MPT's performed as well as 2+1's, low density 2+0's, plug+l's and 2+1's at all FPT's except at Bayne Junction (Figure 1). Percent of MPT's with high and medium vigor was substantially reduced at this site due to rabbit clipping in the first year and big-game browsing in the second year.

As in the 1985 trial, survival of MPT's (76%) and 2+0's (68%) stock was substantially lower at Bald Hills due to harsh conditions. Although not significant, percent of trees with high and medium vigor was greater for MPT's (72%) than for 2+0's (53%).

In RBP's, survival of MPT's was significantly higher than that of 2+0's (99% vs. 85%) and low density 2+0's stock (96% vs. 87%) at Rhodes Lake and Kings Lake, respectively. At 3950 Road, both MPT's (97%) and plug+l's (94%) showed an equally high survival.

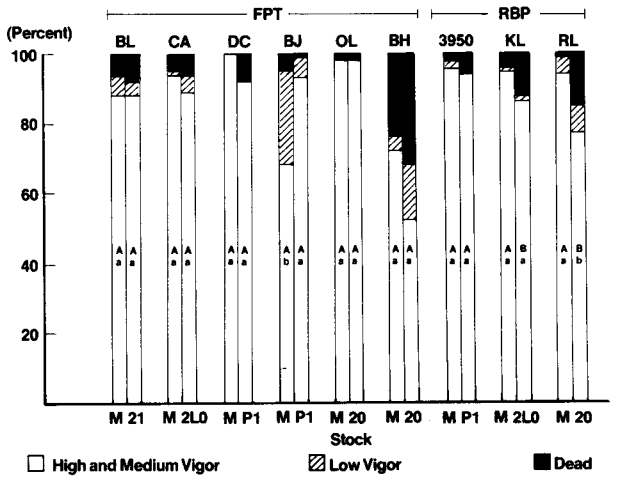

Figure 1.--Survival and vigor of mini-plug transplant (M) compared with those of low density 2+0 (2L0), plug+l (P1) or 2+0 (20) in 1986 trials after two growing seasons at Cascade region, Washington: BL = Boyles Lake, CA = Carnation, DC = Deer Creek, BJ = Bayne Junction, OL - Orting Lake, BH = Bald Hills, 3950 - 3950 Road, KL = Kings Lake, RL = Rhodes Lake. Within each site, stock types followed by the same letters are not significantly ($p<.05$) different in total survival (capital) and high and medium vigor (small letter).

Chehalis, -- In SCT's and FPT's, MPT's showed high survival rates of over 90% and did as well as 2+0's, 2+1's, 1+1's or plug+l's at all sites (Figure 2). In the RBP's, plug+l's survived significantly better than MPT's (96% vs. 82%) at Deer Creek burned site while an opposite trend was observed at Deer Creek which received no site prep. (82% vs. 89%, not significant).

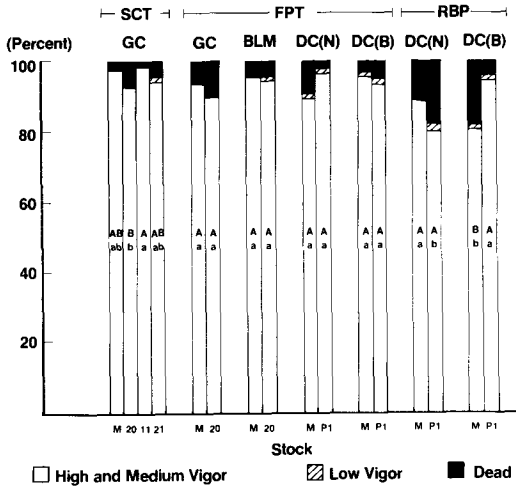

Figure 2.--Survival and vigor of mini-plug transplant (M) compared with those of 2+0 (20), 1+1 (11), 2+1 (21) or plug+l (P1) in 1986 trials after two growing seasons at Chehalis region, Washington: CC = Garrard Creek, BLM = Bloomquist, DC(N) = Deer Creek, no site preparation, DC(B) = Deer Creek, burned. Within each site, stock types followed by the same letters are not significantly ($p<.05$) different in total survival (capital) and in high and medium vigor (small letter).

Twin Harbors -- Survival of MPT's and plug+l's was substantially reduced (to less than 75%) at Delezenne FPT and RBP (Figure 3). Although the difference in survival or percent of trees with high and medium vigor was not significant, the impact of the damage tended to be greater for the smaller MPT's. Survival of MPT's was also significantly reduced by big-game browsing as compared with 2+0's (61% vs 91%) at Fall River RBP. MPT's performed equally well or better than other stock types where animal damage pressure was low.

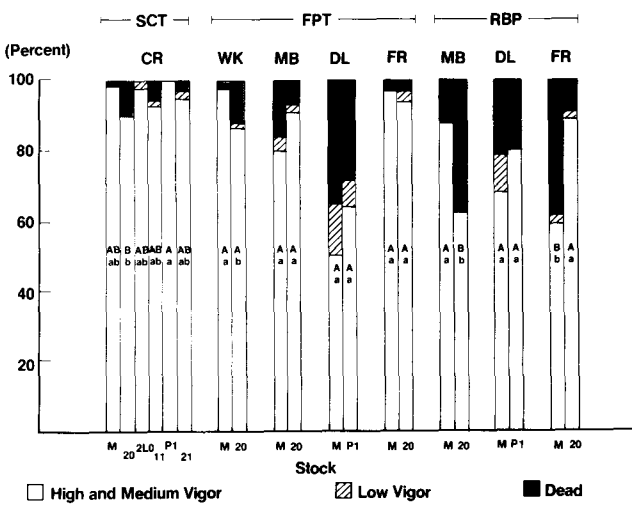

Figure 3.--Survival and vigor of mini-plug transplant (M) compared with those of 2+0 (20), low density 2+0 (2L0), 1+1 (11), plug+l (P1) or 2+1 (21) in 1986 trials after two growing seasons at Twin Harbors region, Washington: CR = Church Road, WK - Wishkaw, MB = Mayor Brother, DL = Delezenne, FR = Fall River. Within each site, stock types followed by the same letters are not significantly ($p<.05$) different in total survival (capital) and high and medium vigor (small letter).

Longview -- MPT's generally had lower survival (75%-87%) at this region than at Cascade, Chehalis and Twin Harbors (Figure 4). Poorer performance is attributed to unusually severe winter damage from freezing and desiccation while in the nursery beds at Aurora. Many lots of transplants from Aurora showed less than normal survival in 1986. In contrast, 2+1's stock from Turner, which did not suffer winter injury, showed high survival rates of mostly over 90%. The difference between survival of MPT's and 2+1's was significant at 1390 Road FPT (95% vs 77%) and at 4534 Road FPT (95% vs. 75%). At Finkas SCT, however, MPT's survived as well as 2+1's or 1+1's from the same nursery. Damage caused by big-game browsing significantly reduced the percent of trees with high and medium vigor as compared with 2+1's (29% vs. 85%) at Tower Road RBP.

Oregon -- As in Longview, overall survival of MPT's, 1+1's and 2+0's stock was relatively low and variable at Springfield (Figure 5) and at Coos Bay (Figure 6) due to the winter nursery damage. MPT's survived as well as 1+1's and 2+0's stock at eight out of 11 trials in these regions.

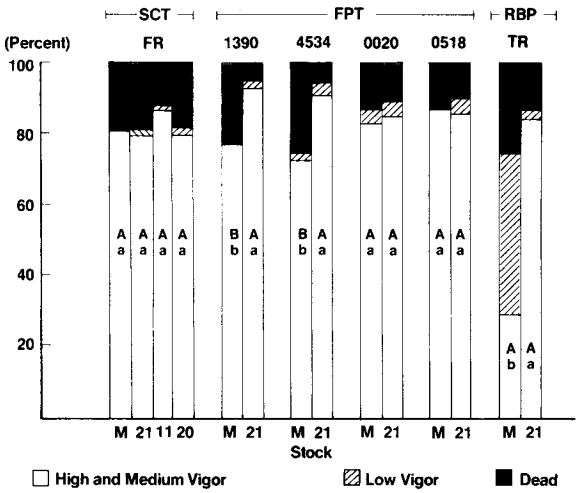

Figure 4.--Survival and vigor of mini-plug transplant (M) compared with those of 2+1 (21), 1+1 (11), or 2+0 (20) in 1986 trials after two growing seasons at Longview region, Washington: FR = Finkas road, 1390 = 1390 Road, 4534 = 4534 Road, 0020 = 0020 Road, 0518 = 0518 Road, TR = Tower Road. Within each site, stock types followed by the same letters are not significantly ($p<.05$) different in total survival (capital) and high and medium vigor (small letter).

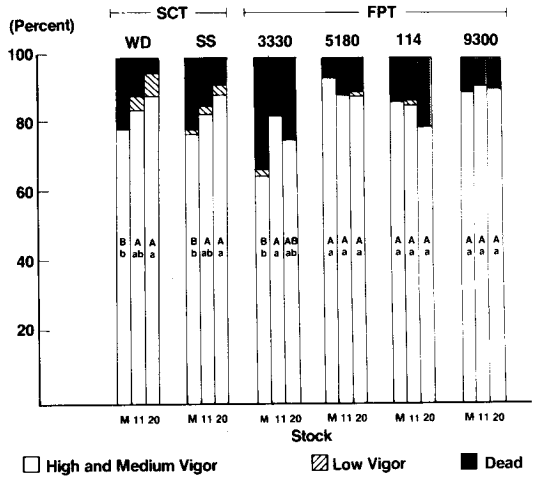

Figure 5.--Survival and vigor of mini-plug ™ transplant (M) compared with 1+1 (11) or 2+0 (20) in 1986 trials after two growing seasons at Springfield region, Oregon: WD = Wendling, SS = Shoestring, 3330 = 3330 Road, 5180 = 5180 Road, 114 = 114 Road, 9300 = 9300 Road. Within each site, stock types followed by the same letters are not significantly ($p<.05$) different in total survival (capital) and high and medium vigor (small letter).

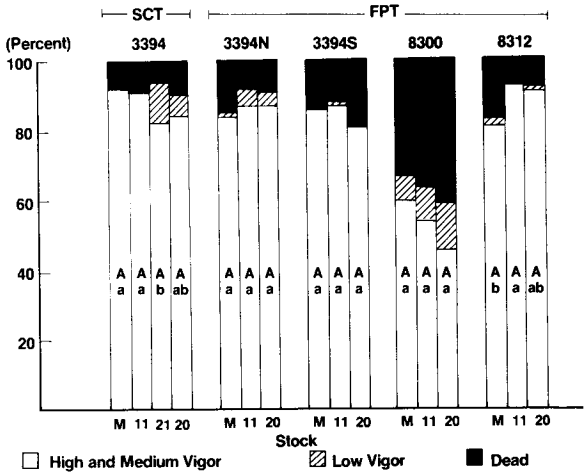

Figure 6.--Survival and vigor of mini-plug ™ transplant (M) compared with those of 1+1 (11), 2+1 (21), or 2+0 (20) in 1986 trials after two growing seasons at Coos Bay region, Oregon: 3394S = 3394 Road south facing slope, 8300 = 8300 Road, 8312 = 8312 Road. Within each site, stock types followed by the same letters are not significantly ($p<.05$) different in total survival (capital) and high and medium vigor (small letter).

1987 Trial:

Cascade -- MPT's performed as well as 1+1's stock at Barr Hill and Greenwater and slightly better than low density 2+0's stock at Highrock (Figure 7).

Chehalis and Twin Harbors -- The frequency of animal damage was relatively high at most sites (30% - 70%). However, browsing and clipping were mostly on lateral branches and generally had no significant impact on survival after one growing season. MPT's did as well as 2+0's, 1+1's and 2+1's stock at all sites except at Deer Creek (with no site prep.) where 1+1's survived significantly better than MPT's (100% vs. 95%). (Figure 8)

Longview -- MPT's and 1+1's showed an excellent performance of survival over 95% in both FPT's and RBP's at all three sites (Figure 9). At Sucker Creek RBP, survival of MPT's was reduced to 79% as compared with 2+1's (92%) due to rabbit clipping; however, the difference was not significant because of the large variability within stock types.

Springfield -- All three stock types including MPT's, 1+1's and plug+l's showed excellent performance at all six FPT's sites in Springfield with survival exceeding 95% (Figure 10).

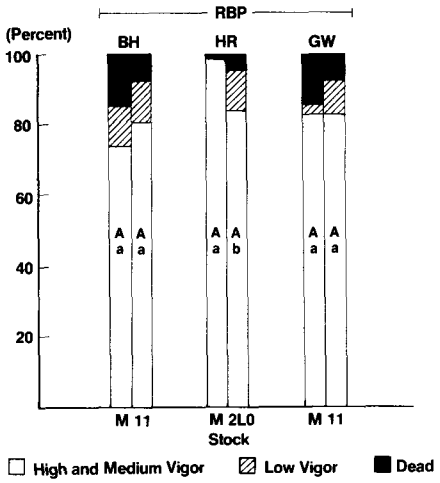

Figure 7.--Survival and vigor of mini-plug transplant (M) compared with those of 1+1 (11), or 2+0 (20) low density 2+0 (2L0) in 1987 trials after one growing season at Cascade region, Washington: BH = Barr Hill, HR = Highrock, GW = Greenwater. Within each site, stock types followed by the same letters are not significantly (p<.05) different in total survival (capital) and high and medium vigor (small letter).

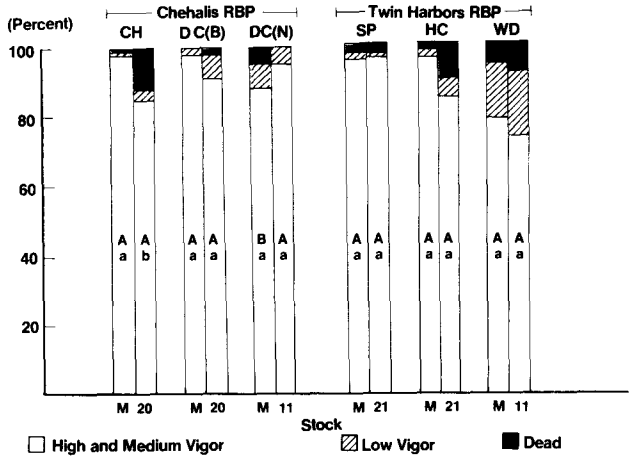

Figure 8.--Survival and vigor of mini-plug transplant (M) compared with 2+0(20), 1+1(11) or 2+1(21) in 1987 trials after one growing season at Chehalis and Twin Harbors regions, Washington: CH = Ceres Hill, DC(B) = Deer Creek burned site, DC(N) - Deer Creek no site preparation, SP = Satsop, HC = Hippi Camp, WD - Wiekswood. Within each site stock types followed by the same letters are not significantly (p < .05) different in total survival (capital) and high and medium vigor (small letter).

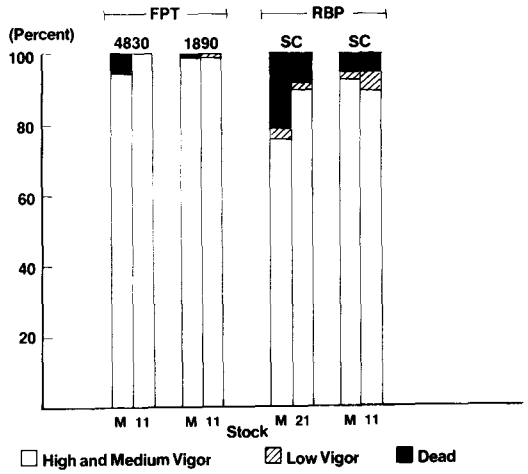

Figure 9.--Survival and vigor of mini-plug transplant(M) compared with those of 1+1(11) or 2+1(21) in 1987 trials after one growing season at Longview region, Washington: 4830 = 4830 Road, 1890 = 1890 Road, SC - Sucker Creek. Within each site, the differences between stock types were not significant (p < .05) in total survival or in high and medium vigor.

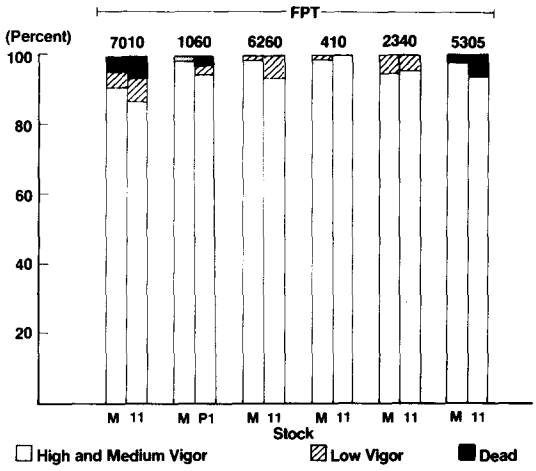

Figure 10.--Survival and vigor of mini-plug transplant(M) compared with those of 1+1(11) or plug+l(pl) in 1987 trials after one growing season at Springfield region, Oregon: 7010 - 7010 Road, 1060 = 1060 Road, 6260 = 6260 Road, 410 - 410 Road, 2340 = 2340 Road, 5305 - 5305 Road. Within each site, the differences between stock types were not significant (p < .05) in total survival or high and medium vigor.

Coos Bay -- Overall survival was somewhat lower at Coos Bay than at Springfield (Figure 11). The 1+1's tended to perform slightly better than MPT's and 2+0's, but the differences among stock types were not significant.

HEIGHT GROWTH

Height growth of MPT's paralleled that of 2+0's and 2+1's at Mt. Brynion 1985 SCT site (Figure 12). After three growing seasons in the field, the height differences among three stock types were about the same as those at the time of outplanting.

The observations from 1986 SCT's showed that the height growth rate of MPT's was greater than that of 2+0's with both stock types attaining the same total height (73 cm) after two growing seasons in the field, although the original height of 2+0's (30 cm) was greater than that of MPT's (19 cm) (Figure 13). A similar trend was also observed in the 1986 FPT's and RBP's (unpublished data).

The 1986 SCT's also showed that the total height after two growing seasons was greater for 2+1's (92 cm) and 1+1's (91 cm) than for MPT's. But the growth rate of MPT's was the same or slightly greater than those of 2+1's or 1+1's as evidenced by slightly smaller differences in total height between stock types after two growing seasons.

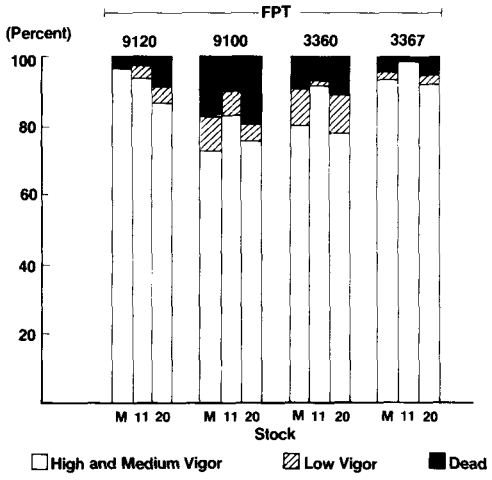

Figure 11.--Survival and vigor of mini-plug transplant(M) compared with those of 1+1(11) or 2+0(20) in 1987 trials after one growing season at Coos Bay region, Oregon: 9120 - 9120 Road, 9100 = 9100 Road, 3360 = 3360 Road, 3367 = 3367 Road. Within each site, the differences between stock types were not significantly ($p < .05$) different in total survival or high and medium vigor.

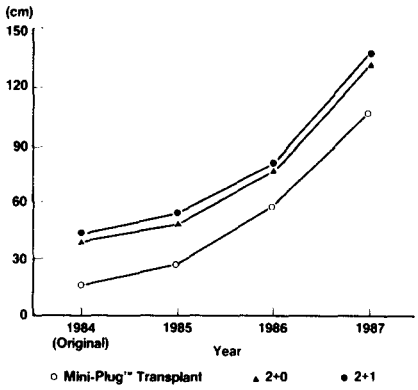

Figure 12.--Total height of three stock types at Mt. Brynion, Longview. All measurements were done in the fall of each year.

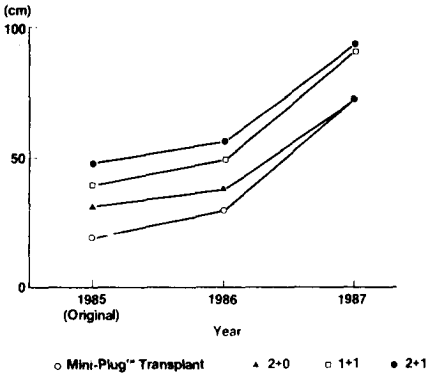

Figure 13.--Total height of three stock types. Mean of three stock comparison tests installed in 1986. All measurements were done in the fall-of each year.

ANIMAL DAMAGE

The above survival and vigor data showed that the impact of animal damage was greater on MPT's than on other stock types due to their smaller original size. There was no distinct preference of MPT's over other stock types based on the frequency of animal damage in 1986 (Table 5) and 1987 (Table 6) trials, the browsing just caused more damage to the smaller MPT's.

With respect to site preparation, animal damage of MPT's tended to be greater on burned sites than on scarified sites or sites with no preparation in both 1986 (Table 7) and 1987 (Table 8) trials.

Table 5.-Percent of animal-damaged trees by stock type during the first (1986) and second (1987) year after outplanting in 1986 FPT and RBP.

	FPT		RBP	
STOCK TYPE	86 (%)	87 (%)	86 (%)	87 (%)
MPT	12	17	38	21
2+0	6	16	17	18
1+1	6	21	-	-
2+1	28	20	12	-
P+1	18	25	22	12

Table 6.-Percent of animal-damaged trees by stock type during the first (1987) year after outplanting in 1987 FPT and RBP.

STOCK TYPE	FPT	RBP
	(%)	(%)
MPT	13	25
2+0	11	12
1+1	15	15
2+1	-	42
P+1	28	65

Table 7.-Percent of animal-damaged trees by site preparation during the first (1986) and second (1987) year after outplanting in 1986 FPT and RBP.

	FPT		RBP	
SITE PREP	86	87	86	87
	(%)	(%)	(%)	(%)
BURN	31	20	44	29
SCARIFIED	6	15	-	-
NONE	7	10	28	16

Table 8.-Percent of animal-damaged trees by site preparation during the first (1987) year after outplanting in 1987 FPT and RBP.

STOCK TYPE	FPT	RBP
	(%)	(%)
BURN	20	42
SCARIFIED	1	-
NONE	10	8

DISCUSSION

Based on survival, vigor and height growth, MPT's performed as well as or better than other bareroot stock types including 2+0's, low density 2+0's, 1+1's, plug+l's and 2+1's at a majority of sites. Superior performance of MPT's was particularly evident at a shallow, harsh site at Bald Hills, Cascade Washington, where larger 2+0's and 2+1's stock showed lower survival rates. It was also noted that MPT's do not appear to suffer from transplant shock as much as other stock types as was evidenced by their generally comparable or superior height growth over the other larger stock types. In terms of the percent of the original height, height growth of MPT's was significantly greater than that of other stock types.

Good survival and height growth of MPT's are attributed to their morphological characteristics.. They have a high root to shoot (R/S) dry weight ratio and fibrous root system. Measurements of stock outplanted in 1987 showed that R/S ratio of MPT's (0.62) was greater than that of 2+0's (0.38), 1+1's (0.38), 2+1's (0.42) or plug+l's (0.47) (Table 9). The MPT's are also characterized by a mop-type fibrous root system which results from many growing tips created by air-pruning of roots near the root collar while growing in the containers (Hee et al 1988).

Use of MPT's increases flexibility of reforestation planning because of their short production time of one year. Changes in logging schedules or an unexpected fire could create a need for a readily available planting stock such as MPT's. MPT's are also less costly to produce than 2+1's or plug+l's, although their production costs are currently similar to that of 1+1 because of a somewhat variable yield. We expect, however, that the cost of MPT's will be less than that of 1+1's in the near future because they require a short production time, transplanting is highly mechanized and they are grown at a higher density.

Table 9. Morphological characteristics of five stock types used in 1987 installation.

Stock type	Avg. Height	Avg. Diameter	Dry Weight		
			Shoot	Root	R/S ratio
	(cm)	(mm)	(g)	(g)	
MPT	23	4.7	3.8	2.3	0.62
2+0	38	5.1	5.5	2.0	0.38
1+1	46	6.7	11.4	4.3	0.38
2+1	54	7.8	15.8	6.6	0.42
P+1	40	6.1	8.2	3.3	0.47

While height growth in percentage of original height was the greatest of all stock types, total height of MPT's at the end of the first, second and third year in the field was generally smaller than that of other stock types due to their smaller original size. Because of this factor, MPT's were often unable to withstand big-game browsing and rabbit clipping as well as the larger stock types especially if damage occurred prior to budbreak. Survival, vigor and growth of MPT's were significantly reduced in areas of heavy animal pressure in Twin Harbors and Longview in 1986. Further observations suggested, however, that there was no preference of MPT's over other stock types based on the frequency of animal damage.

In order to minimize such animal damage, it appears to be advantageous to use larger MPT's than the ones currently produced without compromising the root to shoot balance and fibrosity of roots. Nursery trials have been in progress with promising results. Crops started in mid-summer and subsequently (1) transplanted in fall or (2) stored in a cooler or freezer before transplanting the next May have shown larger and more uniform size than the current crop. This crop requires an additional halfyear to produce but may perhaps be more desirable for use in the areas with heavy animal damage pressure.

It has been pointed out that tree planters have difficulty in maintaining spacing between trees in the field due to poor visibility of small MPT's. However, this advantage may be offset by the fact that the root system of MPT's is compact and easy to plant. This seems to be particularly true in poorly prepared sites or rocky sites where stock with a larger root system is difficult or sometimes impossible to plant.

The present study indicated that the frequency of animal damage of MPT's was greater in burned areas than in areas with no site preparation. Additional observations from specifically designed trials would be needed to ascertain this trend since the present study was not intended to test the differences of site preparation under similar field conditions. The observations, however, are in agreement with those of others (Campbell 1982). If the above trend is proven to be true it may be possible to reduce the level of animal damage by planting MPT's in areas with minimum site preparation.

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LITERATURE CITED

Campbell, D. L. 1982. Influence of site preparation on animal use and animal damage to tree seedlings. Proc. Symposium Site preparation and fuels management on steep terrain, Spokane, Washington, February 15-17, 1982.

Hee, S. M., D. Walch, and T. S. Stevens. 1988. Production aspects of mini-plug transplants. Paper presented at the joint meeting of Western Nursery Council and Forest Nursery Association of British Columbia, Vernon., B.C. Canada, August 9-11, 1988.

Steel, R.G.D. and J. H. Torrie. 1960. Principles and Procedures of Statistics, McGraw-Hill Book Co., New York, Toronto, London, 418 pp.