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Leachate Conductivity: A Rapid Nondestructive Test for Pine Seed Quality

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Simple measurements of leachate conductivity from 100-seed samples can be used to roughly estimate viability or to assign seed quality classes of shortleaf (Pinus echinata Mill.), sand (P. clausa [Chapm ex Engelm.] Vasey ex Sarg.), Virginia (P. virginiana Mill.), jack (P. banksiana Lamb.), and Scotch pines (P. sylvestris L.). Results with red pine (P. resinosa Ait.) were unsatisfactory. This nondestructive test can provide 24-hour estimates of seed quality when germination tests are not possible. Tree Planters' Notes 42(2):41-44; 1991.

The need for a rapid yet simple method of estimating seed viability is readily apparent to all who grow tree seedlings. Laboratory germination tests are always preferable, of course, but time constraints frequently prevent their use.

A simple procedure based on the electrical conductivity of seed leachates has recently been developed for the southern pines (3). This test is based on the principle that seeds leach numerous substances when soaked in water and that because of membrane deterioration the amounts leached will increase as the seeds deteriorate. Although several chemical constituents can also be determined, the electrical conductivity of the leachate can be measured more quickly and easily.

In earlier work (3), the poorest results were obtained with shortleaf pine (*Pinus echinata* Mill.), perhaps because of its small size. Small seeds have less embryo tissue mass for potential loss of ions than larger seeds. This paper reports new results for shortleaf, as well as results with five other pines with small seeds (more than 40,000/lb): sand pine (*P. clausa* [Chapm. ex Engelm.] Vasey ex Sarg.), Virginia pine (*P. virginiana* Mill.) jack pine (*P. banksiana* Lamb.), Scotch pine (*P. sylvestris* L.), and red pine (*P. resinosa* Ait.). Comparisons of germination and leachate conductivity for jack pine have also been reported by Pitel (5).

Materials and Methods

The seedlots used in these tests were of various ages and from many different locations. All had been cleaned and stored at 2 °C at the Forestry Sciences Laboratory in Starkville, MS. Test procedures were similar to those used previously (3):

1. Two samples of 100 seeds each were counted out. All attached wing fragments were removed.
2. Samples were weighed to 2 decimal places.
3. Samples were rinsed in running tapwater for 15 seconds in a strainer, then placed in beakers with a measured amount of deionized water.
4. The samples were stirred with a Teflon spatula to break surface tension, and the beakers were covered with petri dish halves or watch glasses.
5. All beakers were placed in a dark incubator set for 20 ± 1 °C. Two blanks (beakers of deionized water without seeds) were also placed in the incubator.
6. After 24 hours, the contents of each beaker were poured through a mesh strainer to remove the seeds. The leachate was poured back into the original beaker for measurement of electrical conductivity with a YSI Model 32 conductivity meter manufactured by Yellow Springs Instruments.
7. The mean of the two blanks was subtracted from the readings and divided by the sample weight to obtain conductivity as microsiemens per gram (μS/g).

Three water volumes (100, 50, and 25 ml) were tested with 20 samples each of 100 seeds for each species-water combination (table 1). The objective was to see if lower water-seed ratios would improve accuracy with these small seeds. Conductivity tests with peas and soybeans typically use 25 seeds to 75 ml of water (2). The water volume that yielded the best regression for each species (highest R^2) (table 1) based upon the 20

The USDA Forest Service National Tree Seed Laboratory, Macon, GA, supplied many of the samples used in this study.

Table 1—*Regression model* fits (R^2) for 25, 50, and 100 ml of water to a sample of 100 seeds*

Water volume (ml)	R^2
Sand pine	
100	.481
50	.143
25	.068
Shortleaf pine	
100	.379
50	.283
25	.343
Virginia pine	
100	.609
50	.337
25	.491
Jack pine	
100	.224
50	.367
25	.469
Red pine	
100	.178
50	.165
25	.339
Scotch pine	
100	.673
50	.382
25	.433

*Percentage germination = a + b (μS/g).

samples of 100 seeds was then used exclusively for subsequent studies of that species.

Seed samples were then germinated in the laboratory according to test prescriptions of the Association of Official Seed Analysts (1). Germination percentages were regressed on corresponding conductivity values for each seedlot within species (table 2). Several transformations of data were used to obtain the best fitting linear models based on R^2 values and standard errors of estimate for the regressions for each species using the water volume that yielded the best model in table 1.

Results and Discussion

Based on R^2 values for the regressions, 100 ml of water was best for shortleaf, sand, Virginia, and Scotch pines, while the lowest volume of 25 ml was best for jack and red pines (table 1). There are no obvious reasons for these species differences; it may be simply seed coat thickness or permeability, or embryo composition of the individual species.

Transformation of germination and conductivity data produced moderately good fits for all species except red pine (table 2). Only 19 seedlots were tested; more data are apparently needed to develop a good model for this species. The shortleaf model gave a better fit than previously reported (3). The best fit was with Scotch pine (R^2 = .751) and the worst with red pine (R^2 = .339).

As in the previous work with southern pines (3), empty and dormant seeds were only a minor problem. Empty seeds have few electrolytes to leach, so they do not produce high leachate conductivity. Properly cleaned pine seedlots should have few or no empty seeds, but exceptions will occur. Cutting tests or x-rays can be used to determine the number

Table 2—*Regression models with the best fit (highest R^2) for each species*

Species	Best model*	R^2	SE of estimate	No. of seedlots
Sand pine	$\sqrt{G} = 12.8\,[\pm 1.13] - 1.42\,[\pm .33]\sqrt{x}$	.504	1.17	20
Shortleaf pine	$\sqrt{G^\dagger} = 12.3\,[\pm 0.67] - 1.02\,[\pm .14]\sqrt{x}$	.504	1.74	51
Virginia pine	$G = 52.5\,[\pm 2.87] + 194\,[\pm 29.55]\ 1/x$	.683	6.45	22
Jack pine	$(G)^2 = 9329\,[\pm 463.4] - 1.00\,[\pm .18]\ x^2$	.501	1140	33
Red pine	$G = 101\,[\pm 9.12] - 0.049\,[\pm .17]\ x$	.339	16.14	19
Scotch pine	$G^\dagger = 160\,[\pm 14.03] - 74.7\,[\pm 8.6]\log x$	.751	14.02	27

*G = germination percentage; x = conductivity in μS/g. Coefficients of standard deviations are in brackets.

†G includes dormant, abnormal, and empty seeds.

Table 3—*Seed quality classes of five pine species based on leachate conductivity measurements*

Seed quality class	Approximate germination ranges (%)*	Leachate conductivity (μS/g)				
		Sand pine	Shortleaf pine	Virginia pine	Scotch pine	Jack pine†
High	85–100	<6.5	<9	<6	<6	<45
Medium	65–85	6.5–11	9–17	6–15	6–10	45–70
Low	40–65	11–21	17–34	15–40	10–35	>70
Poor	<40	>21	>34	>40	>35	ND

*Includes dormant and empty seeds and abnormal germination for shortleaf and Scotch pines.
†100 seeds to 25 ml deionized water.
ND = no measurements in this range.

of empty seeds, which can then be subtracted from the germination percentage calculated with the model. Depending on the species and lot, 2 or 3% could also be subtracted for abnormal seedlings.

The standard errors are sufficiently large in these models that accurate prediction of germination with conductivity measurements is uncertain. An alternate approach is to use this technique to group seedlots into quality classes. Such a grouping is suggested in table 3 for 5 of the species (excluding red pine).

A major source of variation in this method is the difference among seed sources within species. Pitel's earlier work with accelerated aging of jack pine (S) demonstrates this fact. Accelerated aging treatments are short (2 or 3 days) periods of high humidity and temperature, which simulate natural aging in seeds (2). Pitel aged a single seedlot and paired measurements of leachate conductivity and germination produced an RZ of 0.907, much higher than the 0.501 for jack pine in table 2. Even so, Pitel's data fit very well with the quality classes for jack pine in table 3. The effect of mixed seedlots on model fits has also been noted in our laboratory with spruce (Picea) (4).

It should be emphasized that this test is nondestructive. Another application could be periodic evaluation of seed quality in stored lots. If baseline measurements are taken when fresh seeds go into storage, subsequent rising conductivity values would alert managers that something was wrong. Following measurements, samples can be redried and returned to storage. In this way, quality can be estimated on small but valuable seedlots without sacrificing seeds. The technique could thus be used to track viability decline in extended storage of germplasm conservation collections.

As an example, assume that a measurement on a lot of jack pine yields a conductivity of 40. Seed quality class would be "high" (germination of 85 to 100%) according to table 3. If the regression model or table 1 is used, predicted germination would be 87, with a range of 83 to 92%.

Conclusion

Accurate predictions of viability usually require models of individual seedlots. Most nursery managers or other seed users are not in a position to acquire these models, so they can use table 3 to quickly estimate seedlot quality. Anyone with a conductivity meter can follow the procedures outlined in steps 1 to 7 in this article to arrive at the estimate. Accuracy also can be improved if the percentage of empty seeds in the lot is known.

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Seedling Submergence Tolerance of Four Western Conifers

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Submergence tolerance of 2-year-old conifer seedlingsDouglas-fir (Pseudotsuga menziesii (Mirb.) Franco), lodgepole pine (Pinus contorta Dougl. ex Loud.), Engelmann spruce (Picea engelmannii Parry ex Engelm.), and blue spruce (P. pungens Engelm.)-was determined by submerging entire seedlings for 0, 3, 7, 10, 14, 21, and 28 days under non-aerated and aerated conditions. Less than a third of the seedlings of all species survived for 14 days, and all seedlings except some blue spruce died after 21 days of submergence. Forty percent of submerged blue spruce survived 21 days of submergence, No seedling of any species tolerated 28 days of submergence. Aeration did improve survival in some cases. Tree Planters' Notes 42(2):45-48; 1991.

Under natural conditions conifer seedlings can be completely submerged by melt or flood water in natural basins or near streams. For example, parts of Idaho's Targhee National Forest are occasionally flooded so that planted seedlings are entirely submerged for periods of up to 2 to 3 weeks (6). Because seedling mortality occurs in these areas, land managers need to know how long conifers can tolerate submergence, whether there are tolerance differences between species, and whether the aeration of moving water results in higher survival than in stagnant water.

We determined the tolerance of actively growing Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), and blue spruce (*Picea pungens* Engelm.) seedlings to total submergence in water for varying period under aerated and non-aerated conditions. The aeration treatments simulated flooded sites with fresh water flowing through them, while the non-aerated treatments mimicked flooded areas with stagnant water.

Methods

Three conifer species were tested for submergence tolerance under non-aerated conditions in 1986 and four species were tested under both non-aerated and aerated conditions in 1987. Douglas-fir, lodgepole pine, and Engelmann spruce seedlings came from seed sources in south-central Montana, whereas blue spruce seedlings were obtained from southeastern Idaho. All seedlings in the test were dormant 2-year-old bareroot stock and were planted singly in 2.5-cm-diameter by 25-cm-long containers in a sandy-loam medium. Trees were planted in a greenhouse until the initiation of vegetative growth, as determined by bud break.

In 1986, 24 seedlings each of Douglas-fir, lodgepole pine, and Engelmann spruce were used to determine submergence tolerance in non-aerated water. Four seedlings of each species were subjected to each of six treatments: controls (0 days), and 3, 7, 14, 21, and 28 days of submersion. The experiment was repeated in 1987 with an additional species (blue spruce), a seventh submergence treatment (10 days), and a parallel series of aeration treatments. Five seedlings of each species per treatment were used. Thus, we tested 72 seedlings (6 submergence treatments x 4 seedlings x 3 species) in 1986 and 280 (7 submergence treatments x 5 seedlings x 4 species x 2 aeration treatments) in 1987.

Seedlings were completely submerged in water-filled tanks that were 0.6 m wide by 1.2 m long by 0.9 m deep. Seedlings were aerated by bubbling ambient air through the water with a fish tank aeration unit. The tanks were kept in a greenhouse with day and night air temperatures of 24 and 13 °C, respectively.

We removed seedlings from the tanks after treatment, kept them under normal greenhouse conditions, and determined how many seedlings were dead or alive after 8 weeks. Dead seedlings were easily distinguished by dry brittle stems and needles. No statistical analysis was done and there was no within-year replication.

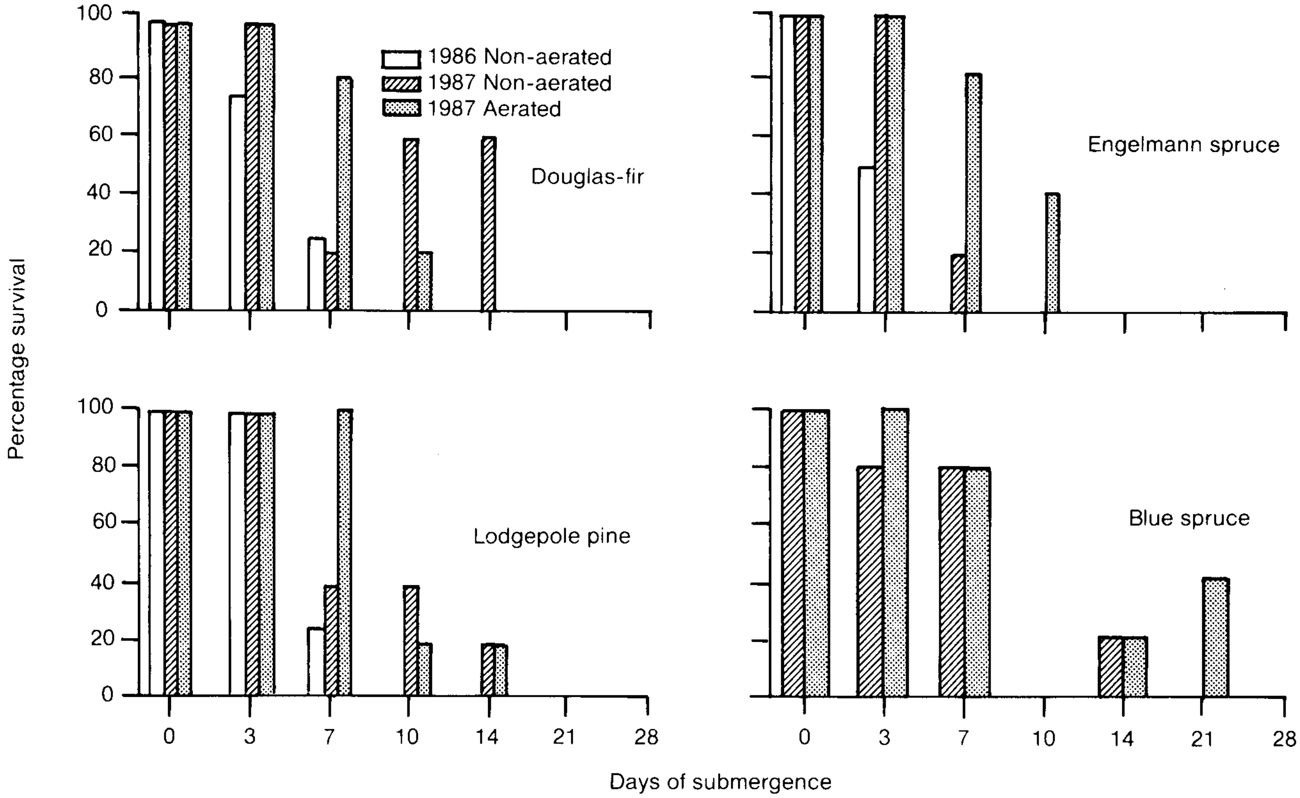

Figure 1—*Percentage survival of Douglas-fir, lodgepole pine, Engelmann spruce, and blue spruce seedlings under 1986 non-aerated, 1987 non-aerated, and aerated treatments under various periods of submergence.*

Results and Discussion

Effects of non-aeration. In non-aerated water, some seedlings of Douglas-fir, lodgepole pine, and blue spruce tolerated and survived complete submergence for at least 14 days while Engelmann spruce tolerated submergence for 10 days or less (fig. 1). Patterns of decreasing survival percentage with increasing length of submergence were consistent between species from year to year. Differences in the vigor of seedlings obtained from the nursery probably attributed to the inconsistences in submergence tolerance between years within species.

A search of the literature turned up no information on the effects of complete submergence on conifer seedlings but did produce findings on the impact of root flooding. Foliage and tree stems are not submerged during root flooding, and oxygen transport in the non-flooded portions of the tree is possible (2). Actively growing Sitka spruce *(Picea sitchensis* (Bong.) Carr.) seedlings were alive after 22 days of root flooding (3). After 4 weeks of root flooding, Douglas-fir suffered high mortality, Sitka spruce, and western hemlock *(Tsuga heterophylla* (Raf.) Sarg.) showed intermediate mortality; and western redcedar *(Thuja plicata* Donn ex D. Don) and lodgepole pine showed high resistance to the effects of root flooding (7). Balsam fir *(Abies balsamea* (L.) Mill.), black spruce *(Picea mariana* (Mill.) B.S.P.), white spruce (*P. glauca* (Moench) Voss), eastern white pine *(Pinus strobus* L.), and red pine *(P. resinosa* Ait.) all tolerated root flooding for up to 48 days (1). Baldcypress *(Taxodium distichum* (L.) Rich) and redwood *(Sequoia sempervirens* (D. Don) Endl.) grow well even when their roots are flooded for long periods (5, 9). Although baldcypress and redwood can tolerate root flooding very well, most hardwoods are better able to tolerate flooding than conifers (4).

In our study, lodgepole pine and Douglas-fir tolerated submergence only slightly better than did Engelmann spruce (14 versus 10 days, respectively). Lodgepole pine tolerated root flooding much better than Sitka spruce in a study by Philipson and Coutts (8). The greater flood tolerance of lodgepole pine in Philipson and Coutts' study was attributed to its transport of oxygen in the xylem and bark while oxygen transport was confined to the bark for spruce and probably produced deficit O_2 levels. Our observations of lodgepole pine mortality after only 7 to 14 days of submergence are consistent with this hypothesis because pine seedlings that are submerged lose the ability to acquire oxygen for transport through the xylem tissues. Coutts (3) found that Sitka spruce survived longer periods of root flooding when dormant than when actively growing. We measured the tolerance of actively growing seedlings; it is possible that dormant plants would have shown greater tolerance to total submergence.

Effects of aeration. In 1987, seedlings of Engelmann (7 days' submergence), blue spruce (3 days' submergence), and Douglas-fir (7 days' submergence) survived longer periods of total submergence under aerated than non-aerated conditions whereas the opposite occurred for Douglas-fir (10 days' submergence) (fig. 1). Aeration increased short-term root flooding tolerance of Douglas-fir and Norway spruce *(Picea abies* (L.) Karst.) seedlings in experiments by Zaerr (10). However, Minore (7) reported that aeration of Douglasfir roots may reduce flood tolerance in some situations.

Except for 2 blue spruce seedlings that survived with aeration for 21 days, all other seedlings survived less than 21 days of total submergence. Engelmann spruce did not tolerate submergence for more than 10 days under aerated or non-aerated conditions. It was unknown why no blue spruce seedlings survived the 10-day submergence treatment while others survived the 14- and 21-day treatments.

Conclusion

Most actively growing seedlings of western conifers are killed after 10 to 14 days of submergence. Managers seeking to prevent mortality of conifer seedlings should therefore avoid planting in areas where flooding is expected and should attempt to drain flooded areas before 10 days. Engelmann spruce appears to tolerate total submergence less than Douglas-fir, lodgepole pine, and blue spruce. Aeration did in some cases improve survival.

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Nine-Year Outplanting Test of Cottonwood and Hybrid Poplar Clones in Northwestern Ontario

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Twenty-two poplar clones (Populus deltoides Bartr. ex Marsh., P. balsamifera L., and their hybrids), selected for frost resistance and growth in nursery trials, were outplanted and compared for nine growing seasons in a randomized complete block experiment in northwestern Ontario (49° 20' N, 82° 05' W). Fifteen of the clones were moderately to severely infected with stem cankers by their ninth growing season. Five relatively disease free clones, ramets of which were 6 to 7 meters in height at year 9, were selected for further testing and pilot-scale use in northwestern Ontario. Tree Planters' Notes 42(2):49-51; 1991.

Although the greatest potential for increased production of poplar in the boreal forest region exists in managing natural stands of aspen, there are some opportunities for planting rapidly growing, climatically adapted material from *Populus deltoides* Bartr. ex Marsh (eastern cottonwood), *P. balsamifera* L. (balsam poplar), and their hybrids. The Ontario Forest Research Institute began informal nursery adaptability tests during the 1970's with the objective of developing suitable clones for northern plantings (latitudes higher than 47°). These were followed by formal clonal tests of material exhibiting good survival and growth under northern nursery conditions. Here we report 9-year results from such a clonal test planted in 1981 near Kapuskasing, ON (49° 20'), about 2° above the northern edge of *P. deltoides'* range in eastern North America.

Methods

Twenty-two clones (table 1) were selected for the test after being informally evaluated in Swastika and Thunder Bay, ON, nurseries for initial growth, frost hardiness, and freedom from diseases. These 22 clones were the best of the several hundred clones evaluated. Detailed information on their origin can be obtained from the senior author; nomenclature is that of the Ontario Ministry of Natural Resources.

The soil on the old-field site where the test was established has a sandy loam A horizon about 30 cm deep, a sandy clay loam B horizon from 31 to 45 cm, and a sandy clay C horizon. The site is moderately well drained. The site was ploughed and disked several times prior to being planted in the spring of 1981.

Unrooted 25-cm-long cuttings were planted flush with the soil surface in a randomized complete block design that included four replications of 4-ramet-square plots planted at 3-m by 2-m spacing. During the first two growing seasons, the planting was kept free of weeds by disking between rows and hand cultivation around trees. In later years, the test site was mowed at least once a year to control competition until crown closure.

Height was measured and observations of frost and disease damage were noted in 1982, 1983, and 1985 by the Ontario Forest Research Institute. In 1986, the forest genetics group at Lakehead University, financed by a Canada-Ontario Forest Resources Development Agreement grant, assumed responsibility for measurement and analysis. Observations of height, diameter and apparent frost damage, and incidence of canker disease were recorded annually in late September and October from 1986 to 1989. Mean clone height and dbh were used to compute relative volume using D^2H (dbH^2 x height) (table 2).

Table 1—*Survival, frost damage, and disease characteristics of poplar* (Populus) *clones tested at Bonner Tree Improvement Center, Ontario*

		Percent survival		Percent with frost damage	Percent forked	Percent with major stem cankers
Clone	Origin of clone	1986	1989	1986	1989	1989
D189	*P. deltoides* cv Brooks #1, AB	94	94	0	6	13
D190	*P. deltoides* cv Brooks #4, AB	100	100	0	25	0
D191	*P. deltoides* cv Brooks #6, AB	94	94	0	20	0
D195	*P. deltoides* cv Walker, SK	87	62	0	0	70
D198	*P. deltoides* cv *angustifolia,* SK	94	94	6	47	0
D207	*P. deltoides* cv Brooks #1, AB	94	94	0	0	6
DN41	*P. euramericana* Grand Falls, NF	100	100	0	25	25
DN42	*P. euramericana* Grand Falls, NF	100	100	12	37	25
DTACN1	*P. candicans* × *berolinensis,* PQ	100	100	0	19	6
JAC14	*P.* × *jackii* Grand Falls, NF	87	75	19	0	25
JAC22	*P.* × *jackii* Quebec City, PQ	100	100	0	12	0
JAC23	*P.* × *jackii* Quebec City, PQ	94	94	6	0	25
JAC25	*P.* × *jackii* Charlesbourg, PQ	100	100	12	0	0
JAC27	*P.* × *jackii* Charlesbourg, PQ	100	100	0	0	70
JAC28	*P.* × *jackii* Winnipeg, MB	100	94	6	13	0
JAC29	*P.* × *jackii* Winnipeg, MB	94	87	6		25
JAC30	*P.* × *jackii* Winnipeg, MB	87	81	12	0	17
JAC31	*P.* × *jackii* Winnipeg, MB	100	100	0	6	6
JAC35	*P.* × *jackii* Timmins, ON	94	94	21	0	13
TAC10	*P. tacamahaca* Winnipeg, MB	100	94	12	0	0
TAC9	*P. tacamahaca* Winnipeg, MB	69	56	33	0	high mortality due to canker
TACN1	*P.* × *berolinenis* cv Berlin Poplar, SK	94	94	0	6	0

Results and Discussion

Mean clone heights throughout the test period are presented in table 2, where clones are ranked by 1989 (9-year) height. During the period, height increment of individual clones had a mostly uniform linear relationship with time. Therefore, relative shoot growth rates (2) for the 7-year period from 1982 to 1989 were calculated (table 2) using clone means; these ranged from .19 to .28 m/m/yr. Coefficients for linear correlations of clone means for height in 1989 and earlier years were as follows: 1982, .62; 1983, .75; 1985, .90; 1986, .94; and 1987, .98. Clone means for diameter at breast height (dbh) in 1989 ranged from 2.4 to 9.8 cm.

With three exceptions (D195, JAC14, and TAC9), all of the clones exhibited good survival (> 80%). Fifty percent of the clones exhibited some evidence of frost damage by 1986 (table 1). This took the form of necrosis on the current year's annual shoot growth, which subsequently caused some deformity to the stem.

None of the clones were killed back to the ground by freezing. Fifty percent of the clones exhibited forking near the ground level, which resulted in dual stems on 6 to 47% of their ramets (table 1). Mechanical pruning to a single stem during the first year's growth will eliminate this tendency, which is probably a function of the number of cutting buds sprouting after

Table 2—*Growth characteristics of poplar clones tested at Bonner Tree Improvement Center*

Clone	Height (m) 1982	1983	1985	1986	1987	1988	1989*	Relative ht growth rate (m/m/year)	dbh (cm) 1989	Volume 1989 D^2H	dm^3
JAC31	1.18	2.20	3.99	4.77	5.39	6.37	7.42 a	0.26	9.68	695	23.33
D191	1.00	2.04	3.48	4.44	5.04	5.96	7.02 ab	0.28	9.19	593	19.88
D190	1.10	2.02	3.70	4.51	5.13	5.98	6.93 ab	0.26	8.65	518	17.38
DTACN1	1.24	1.95	3.61	4.22	4.79	5.48	6.46 ab	0.24	9.76	615	20.60
JAC27	1.27	2.04	3.37	4.06	4.75	5.49	6.27 ab	0.23	7.68	370	12.38
DN41	1.49	2.27	4.01	4.32	4.75	5.37	6.24 ab	0.20	9.32	542	18.14
D195	1.33	2.44	4.32	4.85	5.02	5.59	6.10 abc	0.22	5.99	219	7.32
TACN1	1.14	1.89	3.32	3.95	4.43	5.17	6.02 abc	0.24	8.77	463	15.49
D207	1.54	1.48	3.05	3.56	4.14	5.01	5.88 abc	0.19	7.15	300	10.05
JAC30	1.08	1.92	3.20	3.85	3.96	4.54	5.59 abcd	0.23	4.81	129	4.32
JAC25	1.10	1.95	3.08	3.55	4.22	4.99	5.57 abcd	0.23	6.12	208	6.97
JAC29	0.87	1.64	2.74	3.11	3.79	4.53	5.49 bcd	0.26	6.59	238	7.96
D189	0.86	1.95	3.23	3.77	4.18	4.75	5.46 bcd	0.26	6.44	226	7.56
JAC22	1.22	2.17	3.10	3.47	4.05	4.92	5.40 bcd	0.21	6.96	262	8.74
D198	1.04	1.74	2.85	3.34	4.01	4.58	5.36 bcd	0.23	7.18	276	9.23
JAC23	1.07	1.95	2.93	3.46	3.90	4.59	5.33 bcd	0.23	6.65	236	7.87
DN42	1.16	1.75	2.79	3.13	3.64	4.25	5.00 cd	0.21	6.26	196	6.54
TAC10	1.01	1.88	2.75	3.06	3.44	3.96	4.38 cd	0.21	4.67	96	3.18
JAC28	1.04	1.85	2.67	2.89	3.36	3.85	4.19 cd	0.20	4.85	98	3.28
JAC14	0.61	1.41	2.40	2.77	3.11	3.51	3.92 d	0.27	6.22	152	5.05
JAC35	0.92	1.56	2.37	2.59	2.97	3.40	3.78 d	0.20	4.41	74	2.45
TAC9	0.47	0.97	1.41	1.82	1.91	1.95	2.32	0.23	2.36	13	0.43

*Clone heights for 1989 with the same letter in common do not differ significantly at 0.05 level of probability.

planting rather than disease or frost damage. However, by 1989 there were moderate to severe stem cankers (probably due to *Septoria)* on 68% of the clones. In the most severe cases (for example, D195, JAC27, and TAC9), canker disease is resulting in elimination of susceptible clones from the test.

Growth and freedom from disease and frost damage were considered in selecting five clones that show promise for use in northern plantings: D190, D191, JAC31, TACN 1, and DTACN 1. Of these, JAC31 and DTACNI had at least one ramet with a moderately severe canker in 1989. All will require further observation before their operational use can be recommended. It is noteworthy, however, that 9-year height of the five clones equals that of quaking aspen *(P. tremuloides* Michx.) on good sites (site class 70 to 80) in northern Ontario (1). Considering that the aspen is usually recruited as root sucker stands with early support by extensive root systems, the juvenile performance of these clones planted as unrooted cuttings is good relative to natural stands of aspen. The poplars' good performances are undoubtedly due, in part, to excellent weed control during initial years, an essential condition for establishment of poplar plantations. Thus, although disease susceptibility remains reason for caution, it appears that some clones of *P. deltoides and* its hybrid with *P. balsamifera* may be suitable for planting on better sites in northwestern Ontario, well beyond the normal range of *P. deltoides.*

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Effect of Fall Planting Date on Survival and Growth of Three Coniferous Species of Container Seedlings in Northern Idaho

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Timing of fall planting was evaluated in terms of effect on survival and growth of Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco, western white pine (Pinus monticola Dougl.), and ponderosa pine (P. ponderosa Laws.). First-year data indicate that container seedlings can be planted early in the fall season if soil moisture conditions permit. Tree Planters' Notes 42(2):52-55; 1991.

The success of fall planting of conifers in the northern Rocky Mountains varies widely compared to spring planting. Spring planting has therefore been preferred, despite important constraints. The planting window is limited, because the snowpack often covers the site or the roads. Thus planting is concentrated into short periods, often creating a severe work load for planting crews and their supervisory personnel. These constraints lead to increased costs and reduce the opportunities for accomplishing large annual regeneration programs.

Fall planting lengthens the planting season, allows easier site access, reduces storage costs, and spreads the work load. These advantages can result in significant cost reductions (2).

Although the relative merits and reasons for increased variability of fall planting have long been debated, information is lacking on the biological response and reasons for variation in survival of fall-planted conifers in the northern Rocky Mountains. Studies comparing survival of spring and fall plantings of bareroot seedlings in the region have indicated higher first-year survival of spring-planted seedlings and greater variability in the survival of fall-planted seedlings (3, 4). Miller's (2) comparison of fall and spring plantings of container seedlings indicated that survival varied by species, and that fall planting resulted in reduced first-year height growth. Specific reasons for the lower and variable success in the fall have not been defined.

This study was designed to evaluate the effect that timing of fall planting has on the performance of three species. First-year survival and growth were evaluated for container-grown seedlings of Douglas-fir *(Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco.), western white pine *(Pinus monticola* Dougl.), and ponderosa pine *(Pinus ponderosa* Laws.) planted on six dates in northern Idaho.

Methods

Two identical studies were established. A long-term study will eventually evaluate fall planting over a 5-year period and was also used for determining first-year survival. The short-term study reported here evaluates fall planting for the first growing season.

Seedlings were planted at six different dates from late August to early November 1988, at intervals of 2 weeks at the Priest River Experimental Forest in northern Idaho. The site is on a *Thuja plicata/Clintonia uniflora* habitat type (1) and has a well drained, coarse loamy, mixed frigid typic xerochrept soil. The study site is very uniform and was located so that moisture could be controlled as a variable. Before planting, the area was entirely cleared of competing vegetation, mechanically tilled, and fenced to prevent animal damage.

One-year-old Douglas-fir, western white pine, and ponderosa pine seedlings were grown in 4-cubic-inch (62.5-cm^3) containers at the University of Idaho Research Nursery at Moscow, Idaho. Bud set occurred in July, before planting.

The seedlings were planted with a container-shaped dibble to reduce planting variability, and the site was irrigated to field capacity before and after the first planting in late August to minimize soil moisture stress. No additional watering was necessary due to fall rains.

The experiment was established in a randomized complete block design with 4 replications and 6 treatments for each of the 3 species. Each block-treatment combination consisted of a 16-tree row plot. Rows were 1 m apart and trees were outplanted at 0.5-m spacing within rows.

Height and stem diameter 1 cm above root collar were measured on all seedlings immediately after planting. Seedlings were excavated for analysis at 6-week intervals through the first (1989) growing season (4/14, 6/01, 7/15, 8/29). At each excavation, one-fourth of the trees were selected by randomly identifying 4 trees of each species from each row, for a total of 288 seedlings. These excavations provided data on seedlings at different growth stages during the first growing season after fall planting.

Measurements on each excavated seedling included length of root system, distance from root collar to tip of longest lateral, root weight, shoot height, top weight, and stem caliper 1 cm above the root collar (all weights oven-dry).

An analysis of variance was used to detect any differences due to the planting dates on survival, height, root length, stem diameter, and dry weight for each species. Scheffe's procedure was used to compare means and to detect significant differences between fall planting dates in survival and growth. Initial height and initial stem diameter were investigated as covariates but were not statistically significant at the .05 level of probability.

Results

First-year survival did not vary significantly between fall planting dates for the three species tested. Survival ranged from 95 to 100% for Douglas-fir, 99 to 100% for western white pine, and 98 to 100% for ponderosa pine. High survival on this uniform nursery site is due, in part, to protection from rodents, lack of vegetative competition, and adequate soil moisture. However, planting date accounted for significant differences for certain excavation dates, in shoot height, stem diameter, total-dry weight, shoot and root dry weight, and root length. Differences were most evident for the July and August excavations. The first two excavations were too early in the season to show much differentiation.

For the last excavation date, the earliest planting produced the tallest seedlings, largest stem diameter, and heaviest seedlings for Douglas-fir and western white pine, although most differences were not significant (fig. 1). The response of ponderosa pine to fall planting time was less pronounced. However, a pattern that early planting is better than late planting is evident for ponderosa pine; the first three planting dates all have greater total dry weights than the last three planting dates when observed on the final excavation date (first-year total dry weight results for the three species are shown in figure 1). Seedling height, caliper, and root length had similar patterns.

Discussion

Why did the August and September plantings, in most cases, produce the largest seedlings? With plenty of available soil moisture and warm soil temperatures, one can expect prompt root growth and contact with the soil providing a source of nutrients and moisture. The early planted seedlings responded with the growth patterns shown; they were taller with larger

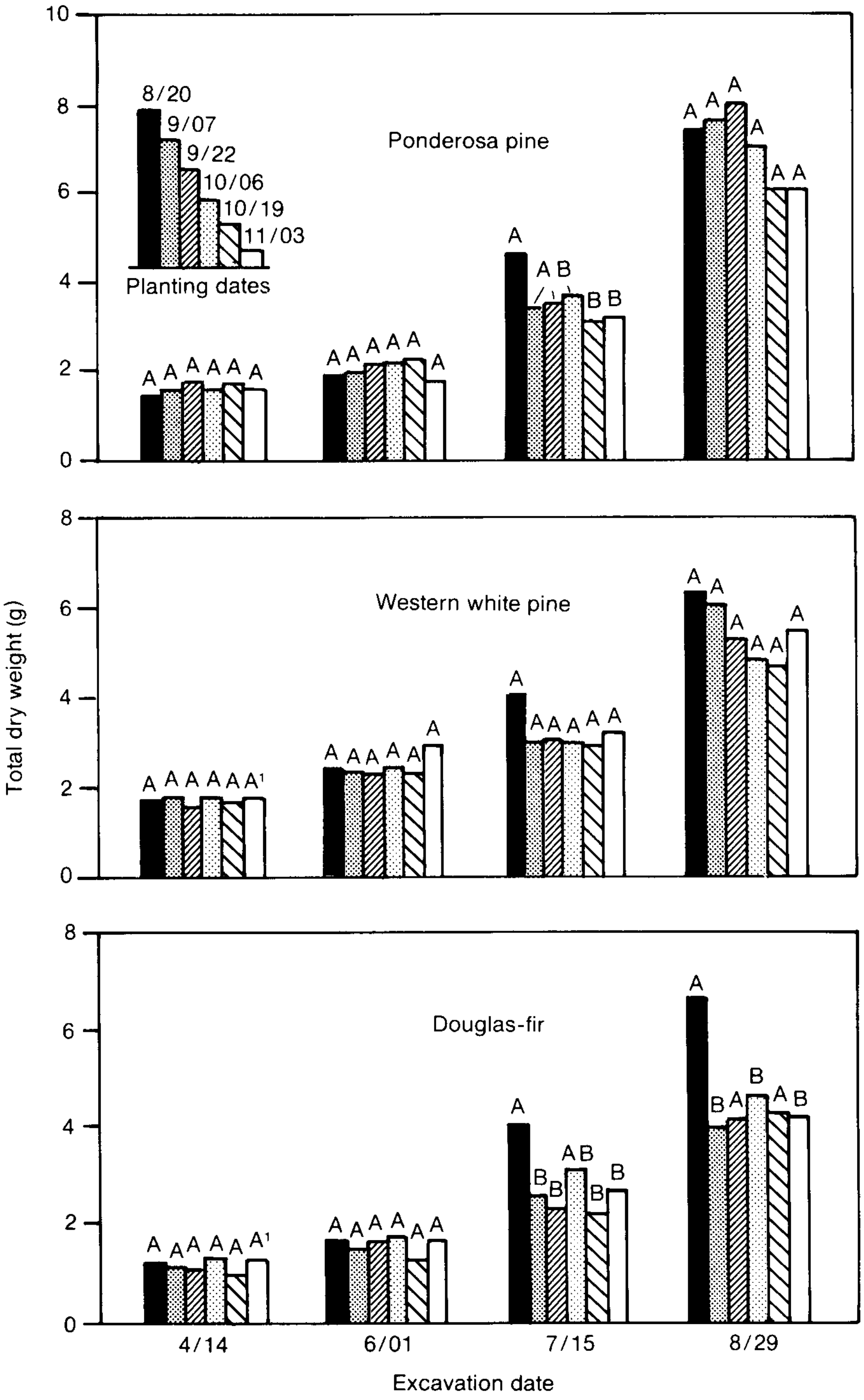

Figure 1—*Total dry weight means by planting and excavation dates. Bars labeled by different letters are significantly different at the 5% level (using Scheffe's procedure).*

stem diameters and had longer roots and more total dry weight. As the planting period progressed into the fall, photoperiod decreased, air and soil temperatures declined, and environmental conditions gradually became less favorable for growth. With a shorter fall period for root establishment, the seedlings with less extensive root systems or low carbohydrate reserves were unable to utilize nutrients for growth promptly the next season and were therefore smaller when observed at the end of the season. Also, seedlings planted later in the fall are more prone to over-winter stress and may not grow as well as seedlings planted earlier in the fall.

One year is a small climatic sample from which to draw valid general conclusions. However, the climatic conditions that were recorded during this study period were close to the averages of the long-term weather records of northern Idaho. In addition to the study reported here, a long-term study was established concurrently that will be monitored for 5 seasons, and similar fall planting trials will be established in subsequent years.

Conclusions

First-year survival and growth data indicate that container-grown Douglas-fir, western white pine, and ponderosa pine can be planted early in the fall season if soil moisture conditions permit. The earliest (August 20) planting appears to favor height growth, root growth, stem diameter growth, and total biomass (dry weight) growth for Douglas-fir and western white pine for seedlings excavated on July 15 and August 29. Ponderosa pine seems to be more flexible in that it responds less to time of fall planting.

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Building a Hand-Held Dispenser for Top-Dressing Containers

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A "gritter," a hand-held dispenser for top-dressing containers with perlite, vermiculite, or grit, can be built according to simple plans. Tree Planters' Notes 42(2):56-61; 1991.

Growers of container seedlings routinely cover seed with a layer of perlite, vermiculite, or grit to hold the seed in contact with moist medium, to prevent the seed from splashing out of the container during irrigation, and to reduce growth of algae and moss. At the University of Idaho, we have designed a hand-held dispenser (fig. 1) for top-dressing our containers that gives us an easily applied, uniform covering. The device, which we call a "gritter," is the last step in our sowing line. We use it to top-dress about 120,000 cells per day with white grit (fig. 2).

General Description and Materials

The model was designed to top-dress pine cells and is therefore 12 inches wide; gritters to cover other widths can also be built. The operator uses the gritter to scoop material from a container and then spread it over the block. The gritter is positioned on the block with the stout rubber strip resting on the block. When the handle is squeezed, the piano hinge along the bottom opens, releasing the material. Pulling the gritter along the top of the block while squeezing the handle allows the rubber strip to spread the falling grit uniformly across the block.

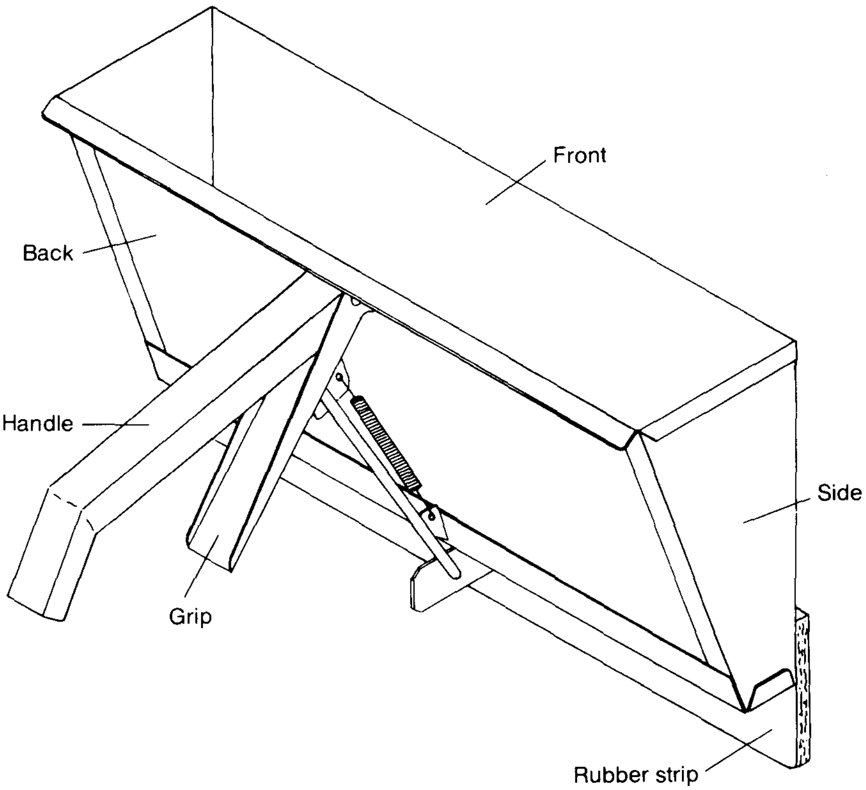

Figure 1-*Isometric drawing of the gritter.*

Making the gritter requires the following 4 pieces of 16-gauge sheet metal:

?? one 7$^{1}/_{2}$- by 18$^{1}/_{8}$-inch piece (front and sides of the bin; fig. 3)

?? one 7$^{1}/_{2}$- by 12$^{1}/_{8}$-inch piece (back of the bin)

?? one 2$^{1}/_{4}$- by 4$^{1}/_{4}$-inch piece (handle) plus a similar small piece to make three small tabs (fig. 4).

Contribution 573 of the Idaho Forest, Wildlife, and Range Experiment Station.

Figure 2—*Using the gritter to dispense white gravel on containers.*

plus the following items:

?? 8 inches of $^{3}/_{4}$-inch square steel tubing
?? 6 inches of $^{1}/_{4}$-inch-diameter steel rod
?? one 2-inch by 12$^{5}/_{8}$-inch-long piano hinge
?? one 2 by 12-inch piece of $^{5}/_{16}$-inch-thick rubber, from a piece of old conveyor belt or truck mudflap or other suitable source
?? five $^{3}/_{16}$-inch steel pop rivets with large flanges
?? one 2-inch helical tension spring

Constructing the Bin

To make the front and side piece of the bin, hem the largest piece of sheet metal $^{1}/_{4}$ inch along its long (18$^{1}/_{8}$-inch) side. Trim off the excess metal, hem and bend as shown in figure 3.

To make the back, hem the next large piece of sheet metal $^{1}/_{4}$ inch on all four sides and fold the top back across the top at about a 90° angle.

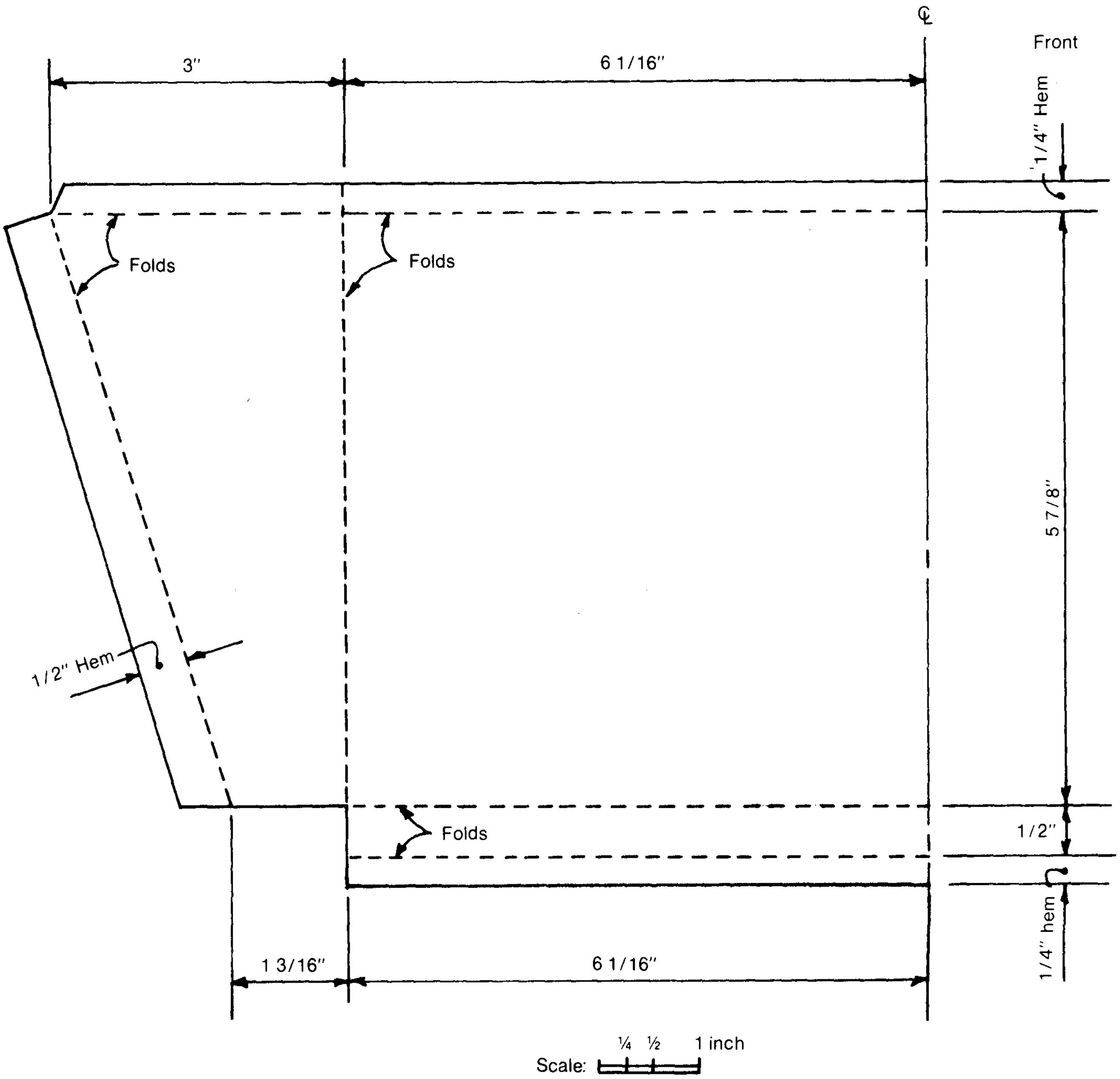

Figure 3—*Half template for cutting the 16-gauge sheet metal for the front and sides of the gritter.*

Bend the outer metal tabs of the piano hinge over about $^1/_4$ inch. Weld the hinge onto the base of the smaller piece of sheet metal, and fill the holes in the hinge with the welder. Attach the rubber to the larger piece of sheet metal with pop rivets, with about $1^3/_8$-inch of the rubber extending below the bottom of the larger piece of sheet metal (fig. 5). Then weld together the two pieces of sheet metal.

Constructing the Handle

Make the trigger release from the third piece of 16-gauge sheet metal (figs. 4- 6). Cut three tabs from the last piece of sheet metal and weld them to the trigger release or piano hinge (fig. 5). Note that the hinge tab, a hemmed piece of metal, is offset below the trigger release. Cut the $^3/_4$-inch steel tubing into two pieces with dimensions as indicated in figure 5 and weld together. Then weld the handle onto the back of the bin as shown in figs. 5 and 6. Connect the trigger release to the handle with an inch-long piece of steel rod. Connect the trigger release tab to the piano hinge tab with a steel rod as indicated in fig. 5. Attach the spring between the trigger release tab and the upper piano hinge tab.

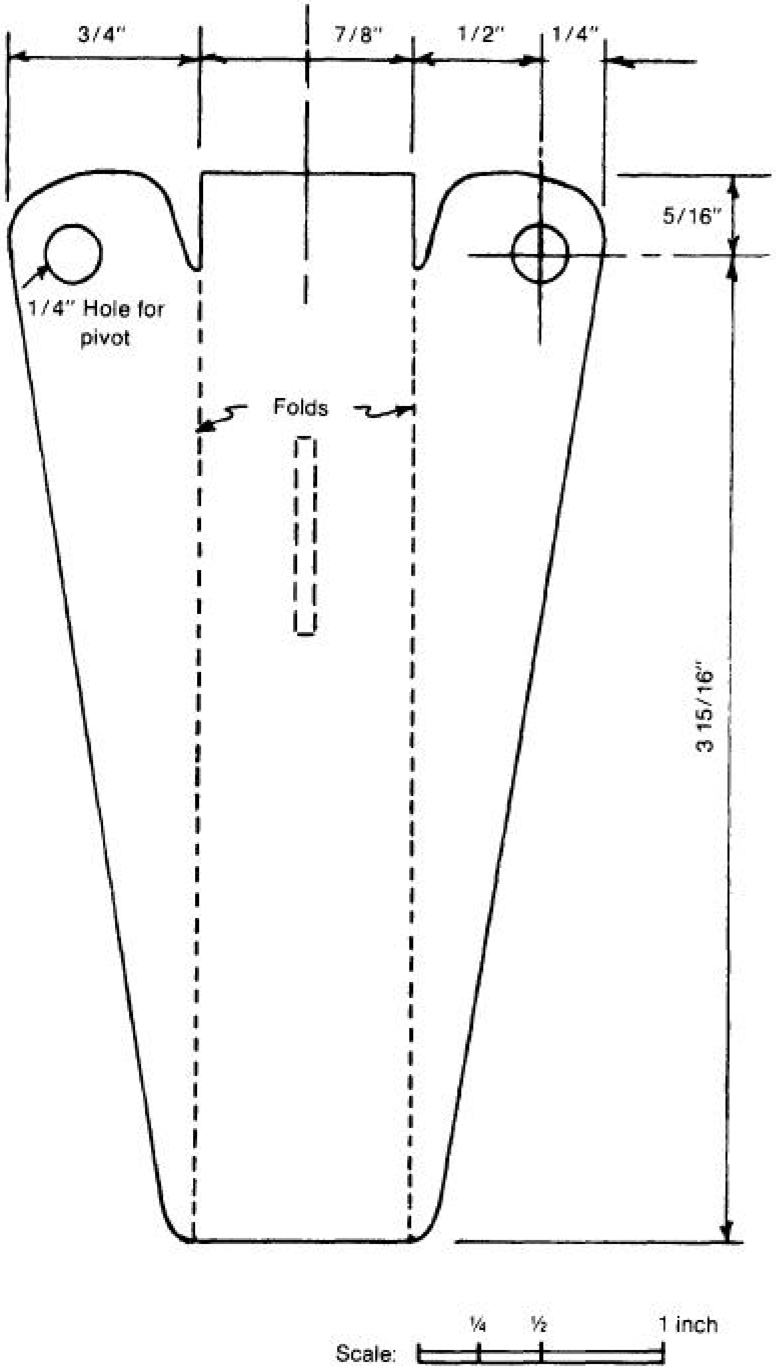

Figure 4—*Template for cutting the 16-gauge sheet metal for the handle of the gritter.*

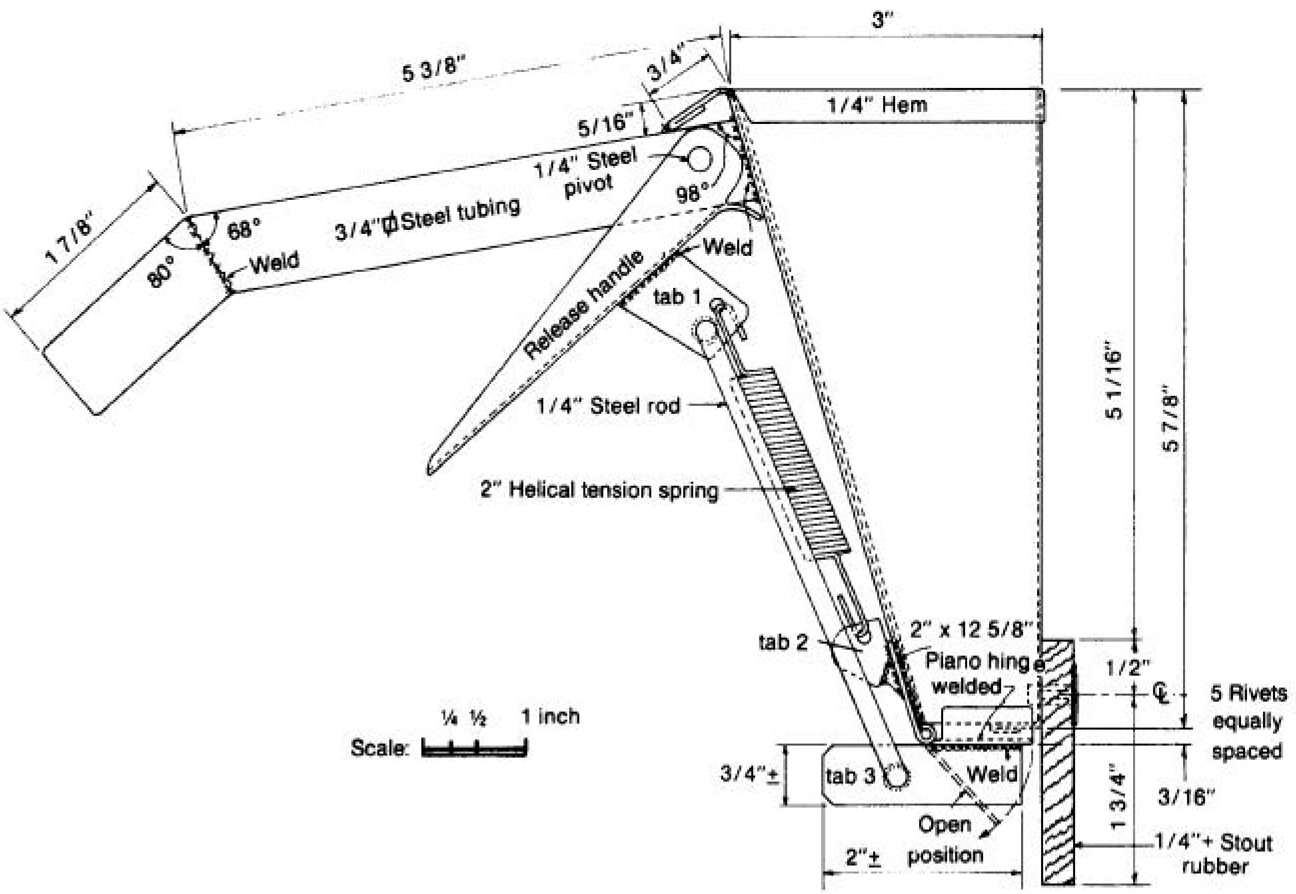

Figure 5—*Side elevation of the gritter.*

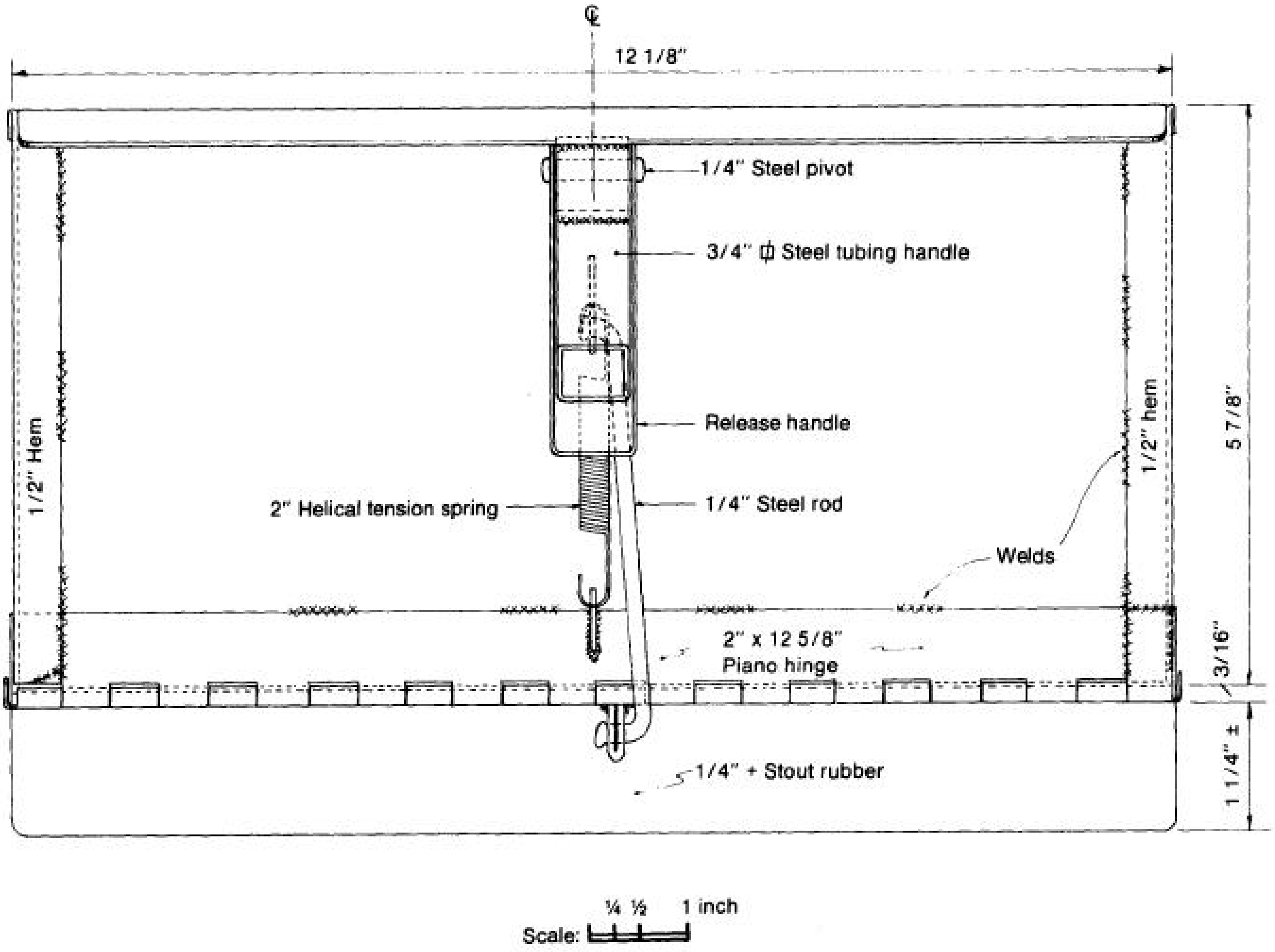

Figure 6—*Rear elevation of the gritter.*

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Modification of Gravity Seed Separator Allows Adjustment During Operation

Richard Felden

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Modification of a gravity seed separator allows adjustment of the side slope and end slope during operation. Set-up time is reduced and a wider range of deck height and tilt settings are possible. Working drawings are available. Tree Planters' Notes 42(2):62-64; 1991.

With five variable controls, gravity separators are versatile enough to provide a wide range of seed separations. However, making the adjustments necessary to achieve good separation is time-consuming, because many gravity separators must be shut down to adjust the side slope (that is, to alter the side-to-side tilt) or end slope (the front-to-rear tilt).

The gravity table at the L.A. Moran Reforestation Center in Davis, CA, has been modified so that both slopes can be adjusted during operation (figs. 1 and 2). These modifications reduce set-up time for each seedlot and allow a wider range of deck height and tilt settings. The cost for modification was less than $400.

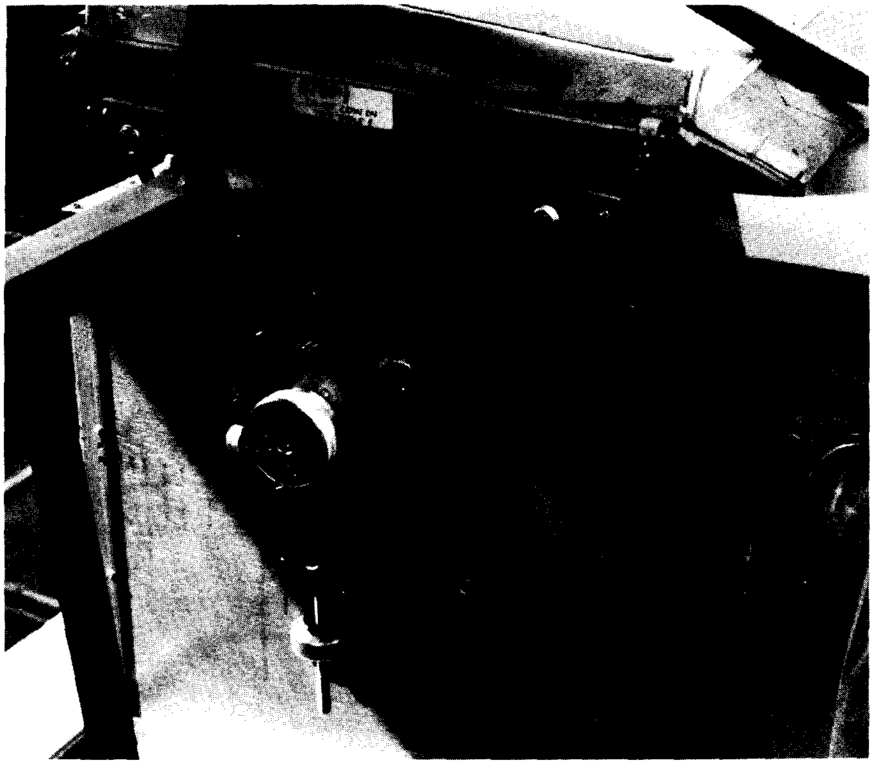


Figure 1—*Frontal view of modification to gravity seed separator.*

A Forsberg 10-M2 was modified, but other gravity separators should be amenable to modification. The staff of the Missoula Technology and Development Center of the USDA Forest Service has provided working drawings (fig. 3). Copies of the drawings may be obtained by contacting

USDA Forest Service
Missoula Technology and
Development Center
Fort Missoula
Missoula, MT 59801
(406) 329-3900

or

California Department of
Forestry and Fire Protection
L.A. Moran Reforestation
Center
PO Box 1590
Davis, CA 95616
(916) 753-2441

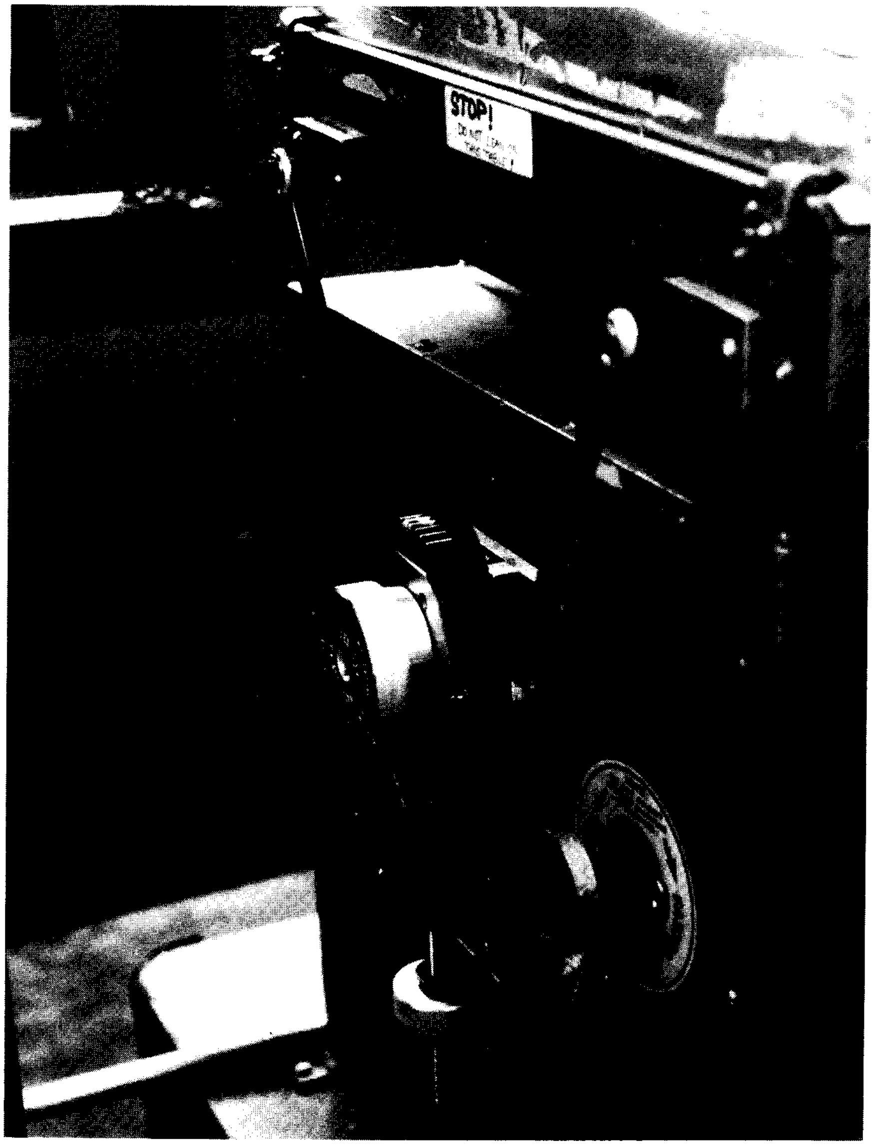
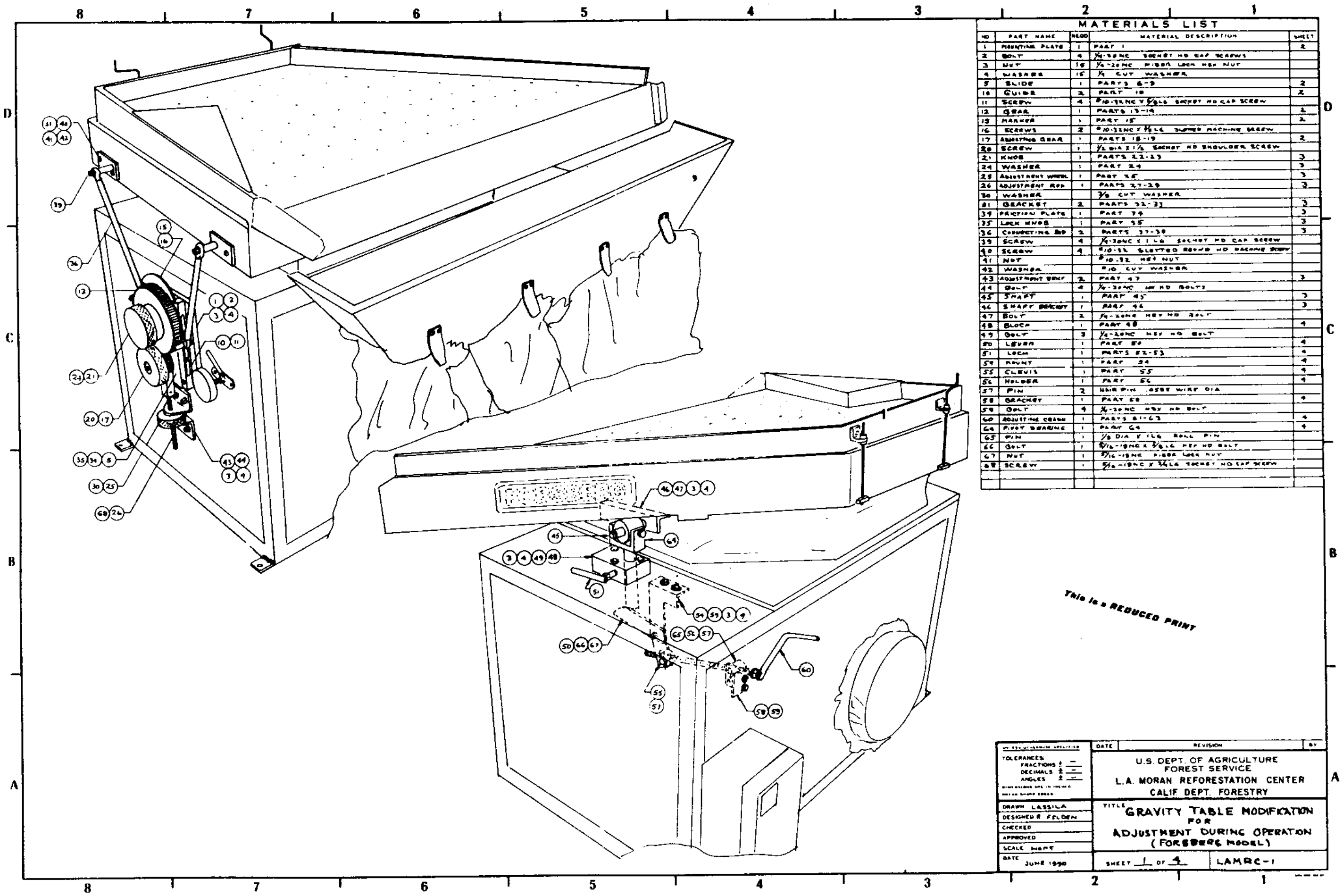


Figure 2—*Close-up side view of modification to gravity seed separator.*



MATERIALS LIST

NO	PART NAME	REQD	MATERIAL DESCRIPTION	SHEET
1	MOUNTING PLATE	1	PART 1	2
2	BOLT	4	¼-20NC SOCKET HD CAP SCREWS	
3	NUT	16	¼-20NC FIBER LOCK HEX NUT	
4	WASHER	16	¼ CUT WASHER	
5	SLIDE	1	PARTS 6-9	2
10	GUIDE	2	PART 10	2
11	SCREW	4	#10-32NC × ⅝ LG SOCKET HD CAP SCREW	
12	GEAR	1	PARTS 13-14	2
15	MARKER	1	PART 15	2
16	SCREWS	2	#10-32NC × ⅜ LG SLOTTED MACHINE SCREW	
17	ADJUSTING GEAR	1	PARTS 18-19	2
20	SCREW	1	½ DIA × 1½ SOCKET HD SHOULDER SCREW	
21	KNOB	1	PARTS 22-23	3
24	WASHER	1	PART 24	3
25	ADJUSTMENT WHEEL	1	PART 25	3
26	ADJUSTMENT ROD	1	PARTS 27-29	3
30	WASHER		⅜ CUT WASHER	
31	BRACKET	2	PARTS 32-33	3
34	FRICTION PLATE	1	PART 34	3
35	LOCK KNOB	1	PART 35	3
36	CONNECTING ROD	2	PARTS 37-38	3
39	SCREW	4	¼-20NC × 1 LG SOCKET HD CAP SCREW	
40	SCREW	4	#10-32 SLOTTED ROUND HD MACHINE SCREW	
41	NUT		#10-32 HEX NUT	
42	WASHER		#10 CUT WASHER	
43	ADJUSTMENT BRKT	2	PART 43	3
44	BOLT	4	¼-20NC HEX HD BOLTS	
45	SHAFT	1	PART 45	3
46	SHAFT BRACKET	1	PART 46	3
47	BOLT	2	¼-20NC HEX HD BOLT	
48	BLOCK	1	PART 48	4
49	BOLT	3	¼-20NC HEX HD BOLT	
50	LEVER	1	PART 50	4
51	LOCK	1	PARTS 52-53	4
54	MOUNT	1	PART 54	4
55	CLEVIS	1	PART 55	4
56	HOLDER	1	PART 56	4
57	PIN	2	HAIR PIN .0585 WIRE DIA	
58	BRACKET	1	PART 58	4
59	BOLT	4	¼-20NC HEX HD BOLT	
60	ADJUSTING CRANK	1	PARTS 61-63	4
64	PIVOT BEARING	1	PART 64	4
65	PIN	1	⅛ DIA × 1 LG ROLL PIN	
66	BOLT	1	5/16-18NC × ⅝ LG HEX HD BOLT	
67	NUT	1	5/16-18NC FIBER LOCK NUT	
68	SCREW	1	5/16-18NC × ¾ LG SOCKET HD CAP SCREW	

UNLESS OTHERWISE SPECIFIED
TOLERANCES:
FRACTIONS ± —
DECIMALS ± —
ANGLES ± —
DRAWN LASSILA
DESIGNED R. FELDEN
CHECKED
APPROVED
SCALE NONE
DATE JUNE 1990

DATE | REVISION | BY

U.S. DEPT. OF AGRICULTURE
FOREST SERVICE
L.A. MORAN REFORESTATION CENTER
CALIF. DEPT. FORESTRY

TITLE GRAVITY TABLE MODIFICATION
FOR
ADJUSTMENT DURING OPERATION
(FORSBERG MODEL)

SHEET 1 OF 4
LAMRC-1

Figure 3—*Line drawing of gravity seed separator.*