Improved Container Sowing With an Electronically Controlled Optical Seeder

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The efficiency and accuracy of an electronically controlled optical seeding machine was evaluated. This system required less than one-fourth of the labor needed to perform sowing with a vacuum seeder. Seed of coniferous forest species were sown with a high accuracy that filled all cells with undamaged seed. The seeder significantly increased the efficiency of sowing small-seeded species that are difficult to sow with a vacuum seeder. Efficient sowing of large pine and fir seed would require modification of the equipment. Tree Planters' Notes 42(3):4-8; 1991.

Sowing seed in container forest nurseries is highly labor intensive. Although the advent of vacuum equipment has increased the rate of placing seeds in cells (Hartman et al. 1990), considerable labor is still needed to ensure accurate sowing. At the University of Idaho Forest Research Nursery in Moscow, conifer sowing into Ray Leach® pine cells (200 cells per tray) has required 1 person to operate a Gleason® vacuum seeder and about 12 additional workers to add or withdraw seed to achieve the assigned number of seeds per cell, cover the sown trays with grit, and place the trays on benches.

An efficient vacuum seeder can sow large-seeded species with approaching 100%o accuracy when only 1 or 2 seeds per cell are required. However, vacuum seeders lose their accuracy when placing more than 2 seeds in a cell and when sowing smaller seed. Moreover, small seed such as those of spruce and larch tend to bury themselves into the sowing medium, making quick inspection for accuracy difficult. Accuracy also decreases when sowing lots with small amounts of seed if the operator cannot maintain a uniform layer of seed under the vacuum plate.

Some irregularly shaped seed pose special problems. Western redcedar is commonly hand sown (Macdonald 1986) because its small, light, flake-like seeds often form clumps of varying size on the vacuum plate or drum. The seeds are also difficult to separate by hand, so hand sowing is inexact, slow, and expensive.

A more accurate, automated sowing method would increase efficiency and reduce costs. This paper reports the accuracy and labor needs for sowing a conifer crop with an electronically controlled, optical seed-counting system mounted over a conveyor.

Materials and Methods

Machine description and operation. A greenhouse flat seeder (model 615-3), manufactured by the Old Mill Company® of Savage, Maryland, was installed in the University of Idaho Research Nursery in Moscow, Idaho, in March 1990. Utilizing the machine's flexibility to accommodate many tray types, we adjusted settings to sow trays of Ray Leach® pine cells comprising 20 rows of cells with 10 cells per row.

The seeder (figure 1) operates on 120 volt AC and 60 pounds per square inch compressed air to power the integrated seeding and tray-conveyor systems (Old Mill Company 1990). Seed poured into a vibrating bowl at the top of the machine move up a spiral path on the inside wall of the bowl, across a section of adjustable-width track, and into the top of a distribution tube. The distributor continuously dispenses seed into an upper bank of 10 storage tubes by optically counting 1 seed at a time (up to the preset number of seeds per cell) into a storage tube and then rotating to the next tube. When the upper bank has its seed allotment, a gate opens and seed drop into a lower bank of 10 tubes. A photoelectric control detects the leading edge of a tray and stops it when a row of cells is directly under the lower tubes. When this row is filled with seed a stepper motor advances the conveyor until the next row of cells is under the feeder tubes.

The rate at which trays are sown depends ultimately on the rate of seed supply. The machine operator selects the correct seed-size setting, adjusts the width of the seed delivery track in the feeder bowl to supply seed one at a time, assigns a target number of seeds to be sown per cell, and adjusts the

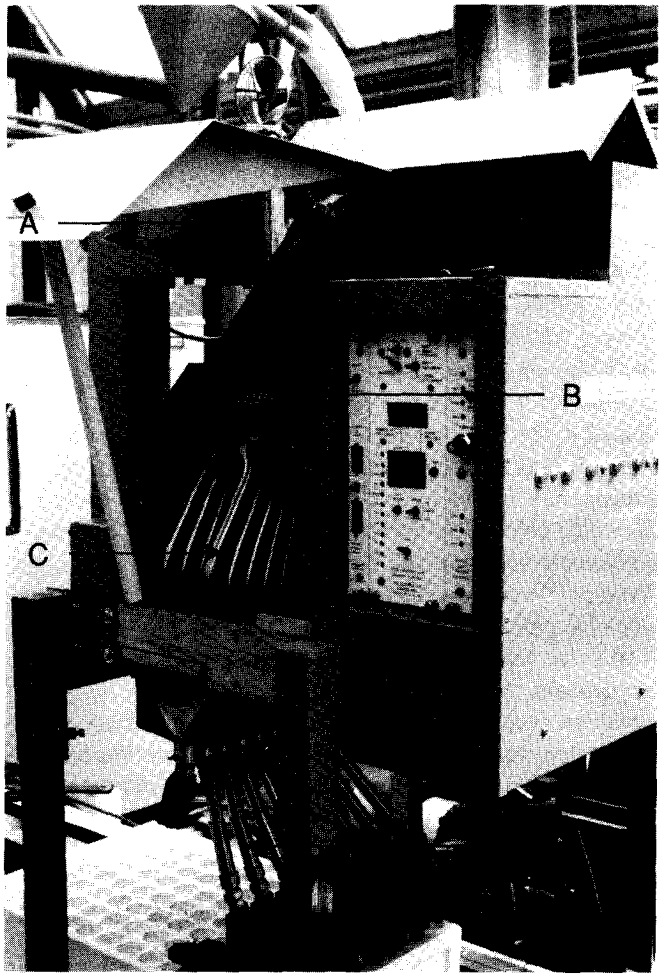

Figure 1—*Side view of the Oldmill® optical seeder and its conveyor. A = vibratory feeder bowl, B = rotary seed distribution tube, C = upper bank of storage tubes, D = lower storage bank.*

vibration frequency of the feeder bowl to control the rate of seed supply.

Materials. A total of 14 species of conifers were sown with the optical seeder at the Moscow nursery in 1990 and 1991. We present sowing data for western larch (*Larix occidentalis* Nutt.), grand fir (*Abies grandis* (Dougl.) Lindl.), Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Biessn.) Franco), western redcedar *(Thuja plicata* Donn.), Norway spruce (*Picea abies* (L.) Karst.), ponderosa pine (*Pinus ponderosa* Laws. var. *ponderosa*), and western white pine (*Pinus monticola* Dougl.).

Trials conducted. *Trial 1-seed distribution versus solving speed and seeds/cell*. We evaluated sowing accuracy by determining the seed distribution in the cells at various sowing speeds and a fixed target number of seeds per cell. The "sowing speed," defined as the sowing time in seconds per tray (s/tray), was varied by changing the frequency setting of the feeder bowl. Douglas-fir seed was sown at a target rate of 2 seed/cell into 3 groups of 32 trays of Ray Leach" pine cells (200 cells/tray) at sowing speeds of 88, 63, and 43 s/tray, respectively. The seeds in each cell of each timed tray were counted and their frequency distribution recorded as mean percentages.

The seed distributions of western larch, western redcedar, and Norway spruce were recorded at target rates of 2, 3, and 4 seeds/cell and a constant sowing speed of 88 s/tray.

Trial 2 sowing speed versus seeds/cell. The sowing speeds of ponderosa pine and western larch seed lots were determined as the target number of seeds/cell was increased from 1 to 4. The seed supply was held constant at a vibration setting of 420 as 10 trays were timed at random for each sowing target number.

Trial 3-sowing speed versus time of operation. This test timed the sowing of a tray every 15 min over a period of 6 h of continuous machine operation. Ponderosa pine was sown at a target of 3 seeds/cell and a seed supply setting of 420.

Results and Discussion

Machine operation. A total of 816,400 cells were sown in 4,082 trays during ten 8-h shifts from April 1 to April 9, 1991. Table 1 lists the number of cells sown at optimal operational machine settings with all the spring-sown species previously mentioned, except for grand fir. Since the optimal seed supply settings fell within a relatively narrow range (420 to 540), the operator must carefully adjust the sensitive control of seed-bowl vibrations for efficient sowing. The production of cells sown in an 8-h period generally decreased with an increase in the number of seed sown per cell. The optimal sowing speeds for ponderosa pine at 1 to 2 seed/cell and for Norway

Table 1—*Optimal vibration settings of the seed bowl and the resulting sowing speeds for various target numbers of seeds/cell and species sown under stable operating conditions*

Species	Seed feeder setting	Sow rate achieved (seed/cell)	Sowing speed (s/tray)	Cells sown/ 8 h
WL	520	3–4	70	82,000
DF	490	2–3	45	128,000
WR	442	4–5	64	90,000
NS	490	2–3	45	128,000
WP	540	2–3	60	96,000
PP	420	1–2	42	137,000
PP	420	3–4	120	48,000

WL = western larch, DF = Douglas-fir, WR = western redcedar, NS = Norway spruce, WP = western white pine, PP = ponderosa pine.

spruce and Douglas-fir at 2 to 3 seed/cell were comparable. However, production varied between some species at high sow rates per cell. For instance, the differences in sowing speeds between ponderosa pine and western larch of 3 to 4 seed/cell results in production of 48,000 and 82,000 cells, respectively.

A 2-person crew operated the seeder, inspected the sown trays for accuracy, covered them with grit, and moved the trays onto benches. Although a third person was required at sowing speeds faster than 45 s/tray, the overall labor requirement was less than one-fourth that used in vacuum sowing.

Trial 1-seed distribution versus sowing speed and seeds/cell. Douglas-fir seed, sown at the speed of 88 s/tray, resulted in 94.5% of the cells filled with the target number of 2 seed/cell (figure 2). In a major improvement over vacuum seeders, which often fail to pick up seed and thus leave blank cells, the electronic counter rarely produced an empty cavity. We found pitch fragments and detached wings in most of the blank cells. Seed purity may be a limiting factor in achieving further gains in accuracy with this equipment.

Increased sowing speed sacrificed accuracy. Since the seed counter tallied two or more seeds as one object at high rates of seed supply, the seed distributions were consistently skewed above the target setting. The accuracy in sowing Douglas-fir decreased from 94.5 to 52.5% as sowing speed increased (that is, the seeder spent less time per tray) from 88 to 43 s/tray (figure 2). Furthermore, a sowing speed of 43 s/tray filled 1.5% of the cells with 1 seed, 52.5% with 2 seed, 35% with 3 seed, 9.5% with 4 seed, and 1.5% with 5 seed to produce a target rate of 2.57 seed/cell.

A similar degree of accuracy was attained with the small-seeded species (table 2) sown at 88 s/tray, where 90 and 95%, respectively, of the western larch and Norway spruce were sown at the target rate of 2 seeds per cell. However, accuracy declined at 3 and 4 seed/cell targets with correspondingly wider frequencies of seed distributions. Vacuum plates commonly fail to lift all of the small angular seed of western larch. An increase in the efficiency of sowing western larch has value to nursery managers, because larch seed is expensive and often in short supply.

Western redcedar was also sown efficiently and accurately by the seeder. Hand sowing of 4 to 5 western redcedar seed/cell may take more than 3 min/tray. In contrast, the optical seeder sowed a target of 4.5 western redcedar seed/cell, at a sowing speed of 64 s/tray (table 1) and 75% accuracy (table 2).

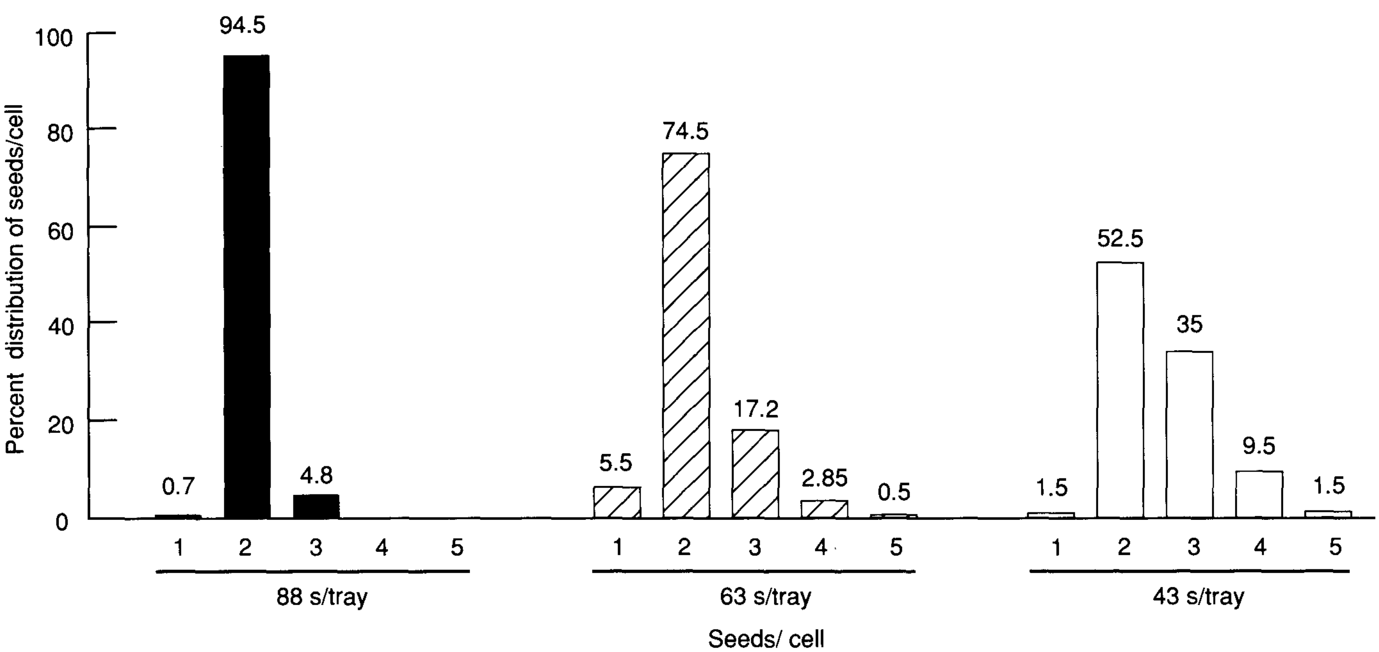

Figure 2—*Frequency distribution of seed/cell of Douglas-fir, at 3 sowing speeds (88, 63, and 43 s/tray), sown at a constant target rate of 2 seed/cell into 200-cell trays (trial 1).*

Table 2—*The frequency of seed distribution versus the target number of seeds/cell at a constant sowing speed of 88 s/tray (trial 1)*

Target (seed/cell)	Distribution of seeds/cell (%) 0	1	2	3	4	5	6	7
western larch								
2	0	3	90	6	1	0		
3	0	2	4	84	5	2	0	
4	0	0	2	6	76	12	2	0
western redcedar								
2	0	4	85	9	1	0		
3	0	2	6	80	11	1	0	
4	0	0	1	4	75	15	4	0
Norway spruce								
2	0	3	95	2	0			
3	0	0	3	90	6	0		
4	0	0	2	4	86	7	3	0

Trial 2-sowing speed versus seeds/cell. The target numbers of 1 and 4 ponderosa pine seeds/cell resulted in sowing speeds of 43 and 172 s/tray, with standard deviations of 8 and 7, respectively (figure 3). The machine placed an additional seed per cell across a tray in about 40 s as the sowing rate increased from 1 to 4 seeds/cell.

In contrast, despite the comparable sowing speeds of western larch and pine at 1 seed/cell, each additional larch seed per cell was placed in about 20 s. The pine was sown at a machine setting of "large seed" and the larch at a setting of "small seed." The electric eye of the seeder takes longer to make multiple counts of large seed per cell than small seed, because more small seed can be supplied to the distributor tube per unit time than large seed.

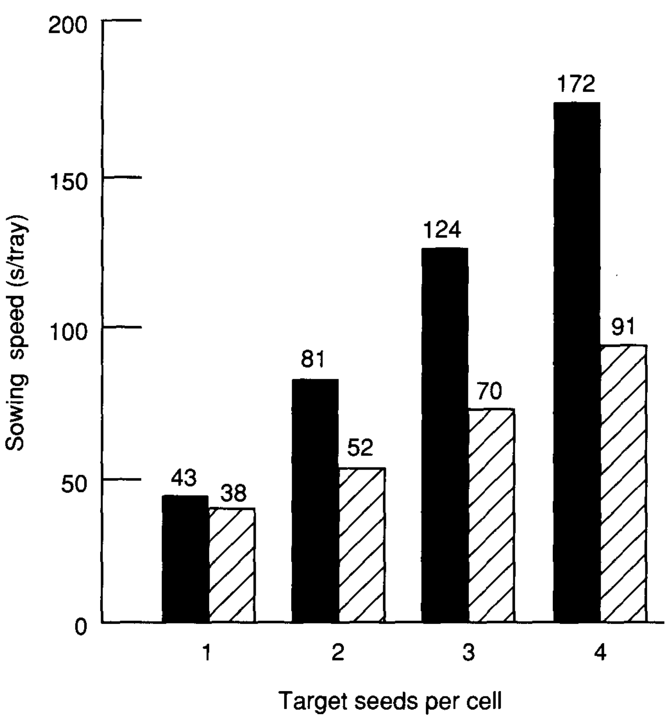

Figure 3—*Sowing speed (s/tray) versus the target number of seed/cell for ponderosa pine (solid bars) and western larch (hatched bars) at a constant seed-supply setting of the vibrating feeder bowl (trial 2).*

Trial 3--sowing speed versus time of operation. The sowing production slowly but steadily increased from 25 to 35 trays/h over a 6-h period from a cold start-up (a statistically significant correlation with a p-value <.0001). In addition, most malfunctions occurred in the first 2 h of a shift. We speculate that some physical factor such as moisture accumulated overnight or lower morning temperatures possibly influenced the mechanical and electronic systems, and that the heat generated by the operating equipment stabilized those systems over time.

Operational observations. The operator quickly and efficiently changed seed lots either by detaching, emptying, and replacing the feeder bowl or by feeding the remaining seed into the storage tubes and manually dropping them into a retrieval bowl on the conveyor. The system was rapidly cleaned with almost no seed loss.

Two types of malfunction occurred. Either several seed clogged the base of the distributor tube and the machine stopped sowing, or one or more of the gate shutters jammed leaving an equivalent number of blank rows in a tray. Most blockage could be attributed to supplying the machine with more seed than it could count. Once the operator had adjusted the seed bowl to deliver seed one at a time and found the maximum vibration rate setting controlling seed supply that did not overload the seed counting mechanism, blockages occurred only rarely, and the machine ran almost continuously for 16 h/day. These adjustments matched with a selected degree of accuracy defined an "optimal operational seed supply."

The machine treated the seed more gently than seeders using a vacuum plate. Operators frequently gently slide or bounce the vacuum plate to enhance seed pickup, a practice that can damage seed at the edges of the plate. We found no evidence of crushed seed, a common occurrence in the sowing of white pine and Douglas-fir with a vacuum plate.

Some large seed of ponderosa pine (up to 10 mm long and 6 mm wide) tended to clog the tapered, rectangular lower end of the distribution tube (inside dimensions 9.1 by 7.0 mm). However, all but the largest pine seed were sown successfully by slowing the seed supply. Grand fir seed has an angular form (Franklin 1974) and length up to 11 mm, exceeding the inside diameter of the lower tubes. These qualities, combined with a high incidence of gum impurity, caused grand fir seeds to frequently block the distributor tube and both sets of gates. Grand fir was therefore hand sown.

Conclusions

The major advantages of the optical sowing system over vacuum sowing include lower labor requirements, a capacity for continuous machine operation, few blank cells, less physical damage to the seed, higher accuracy and faster sowing of small-seeded species, and more control in sowing fractional seed/ cell targets. The optical seeder could probably successfully sow all but the largest conifer seed in forest nurseries. Some equipment modifications will be necessary before grand fir and large-seeded ponderosa pine can be sown efficiently.

Literature Cited

Franklin, J. 1974. *Abies* Mill.-fir. In: Schopmeyer, C.S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: USDA Forest Service: 168-183.

Hartmann, H.T.; Kester, D.E.; Davies, F.T. 1990. Plant propagation: principles and practices. Englewood Cliffs, NJ: Prentice-Hall. 727 p.

Macdonald, B. 1986. Practical woody plant propagation for nursery growers, vol. 1. Portland, OR: Timber Press. 669 p.

Old Mill Company. 1990. Instructions for assembly, operation, and maintenance of the greenhouse flat seeder, model 615-3. Savage, MD. 33 p.