Seed Sowing

Many commercially important tree species used in reforestation can be grown from seeds, and because maintenance of genetic diversity is so important in ecosystem management, seed propagation is encouraged wherever possible (Landis et al. 1998). However, profitability in forest seedling production depends on the ability to produce a high proportion of the crop within target sizes. To accomplish this one strives to reduce variability.

Propagation by seeds ensures that genetic diversity is maintained by allowing genetic recombination to occur through sexual reproduction. It also lends itself well to mechanization (**Figure 80**), allowing substantial gains in the accuracy and speed of seed placement and efficiency of seed use. Crops sown quickly aid in initiation of crop uniformity, allowing optimization of inputs later in the crop cycle. This holds true for seeds sown in growing media in containers as well as in soil in an open field. Generally, when seeds are sown in containers, it is easier to provide optimum, uniform, and controlled growing conditions, leading to greater seed use efficiency. In a field situation, weather, soil, competing organisms, and plant spacing are less controllable, increasing variability in growing conditions and lowering seed use efficiency.

Propagation by seeds ensures that genetic diversity is maintained by allowing genetic recombination to occur through sexual reproduction

Seeds are normally sown after stratification and prior to radicle emergence. If germination capacity (GC) or vigour is below desired levels, it may be possible to upgrade seed quality by separating non-viable or less vigorous seeds from viable and/or more vigorous seeds (see "Cone and Seed Processing" chapter for discussion on seed upgrading).

In containers it is imperative that virtually every cavity produces a seedling. With the trend to bigger cavities this is especially true since the investment of nursery inputs per cavity is also larger, although the cost of seed forms a smaller proportion of the final seedling production cost. If non-viable seeds are not separated out, a nursery generally increases the **sowing factor (SF)** or number of seeds sown per cavity (**Figure 81**) so that the probability of obtaining a viable seedling in each cavity is closer to 100%. Given the GC of a seedlot, the sowing factor can be determined using appropriate probability equations (Schwartz 1993).

Even when a viable seedling is growing in every cavity, not all will meet contract specifications at the end of the production cycle. To account for non-productive cavities (**Figure 82**), extras are sown. The ratio of extra cavities sown is termed the correction or **oversow factor (OF)** and is expressed as a percent. It varies with grower expertise relative to insect and disease pressures, seedlot characteristics, space, available container type, and contract specifications required by the seedling buyer. If seedling specifications are challenging the nursery may choose to sow a higher number of extra cavities from which to select the best trees.

Seeding equipment is not 100% accurate or efficient. Some seeds are lost during operation and sowing equipment has a minimum requirement for seeds just to allow complete and accurate sowing of a single block, in particular the last few blocks of a request. This means some seeds are continually lost and some will be left over. To facilitate this a small amount of extra seeds, termed the nursery-handling factor, is normally allocated (**Figure 83**).

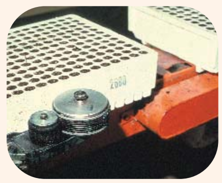
Taking all the factors into account, the actual number of seeds supplied per seedling is calculated as follows: (sowing factor × oversow factor) + (nursery-handling factor × oversow factor). Multiplying the seeds supplied per seedling by the GC of a seedlot yields the number of viable seeds supplied per seedling. The number of viable seeds is valuable if contemplating a change in sowing procedures and/or seed upgrading at the nursery.

Sowing Guidelines

Seed returns, simulations and nursery surveys form the basis for average seed use. From this information sowing guidelines are formulated and included in the Seed Planning and Registry system (SPAR) to calculate grams of seeds required for the growth of a specific quantity of seedlings. At the nursery these facilitate the most efficient use of seeds in the production of forest seedlings. The guidelines are designed to create a consistent relationship between GC and the number of seeds supplied per requested seedling (compare 1999, 2001 guidelines with 1996 in **Figure 84**). The Ministry of Forests guidelines are the SPAR default, but these can be overwritten by the client, preferably in consultation with the nursery.

The flatter curve and more consistent relationship represented in the 1999 and 2001 lines (**Figure 84**) required the use of more accurate input variables (i.e., GC ranges of 2%, fractional

Seed Sowing Flow Chart (containers)

Process	Objectives	
Growing media preparation	Provide uniform mixing and maintenance of structural integrity	  
Container filling	Insert equal volumes of media into each cavity at a uniform predetermined density	 
Clean and tamp individual cavities	Provide a firm seedbed and a space at the top of each cavity for the placement of a seed cover (grit)	 
Seed sowing	Place the prescribed number of seeds in the centre of each growing cavity	  
Gritting	Place a uniform depth of seed cover on each cavity such that seed is not visible but mechanical impediment to germination is minimized	 
Seedlot tracking	Seedlot identification on Styroblock® containers	
Sowing line watering	Maintain seed imbibition until irrigation system in the growing facility can take over	
Transport and layout in growing area	Maintain central seed placement and seed cover integrity	

Overall Strive to achieve the above as quickly as possible to facilitate uniform germination

Figure 80
Flow chart of activities in a mechanized seed sowing system.

Figure 81 Multiple sown cavities prior to thinning.

Figure 82 Empty, "non-productive" cavities in a crop.

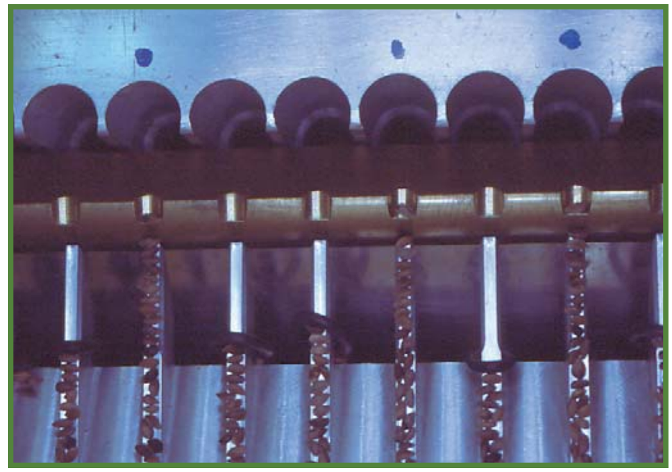


Figure 83 Loaded cams on a cam-drop seeder illustrating the requirement for a nursery-handling factor.

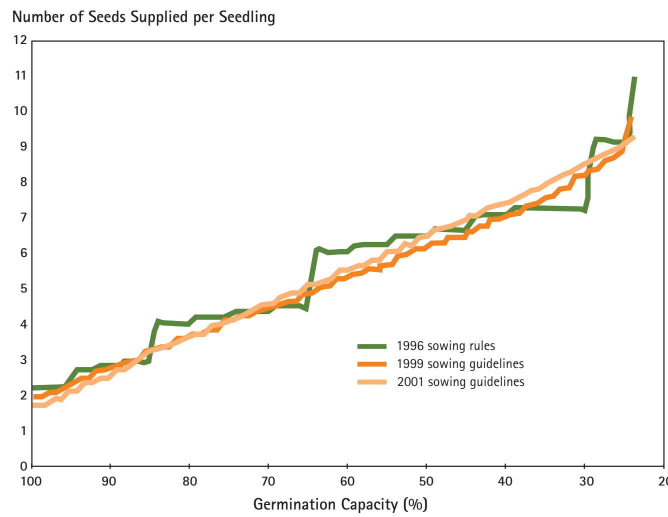


Figure 84 Comparison between 1996 sowing rules and 1999 and 2001 sowing guidelines.

sowing factor increments of 0.1 seeds per cavity, and OF intervals of 1%). Adjustments in 2001 have included a decrease in seed allocated to seedlots with GC values greater than 88% and an increase in seed allocation for seedlots below 80% GC (**Figure 84**).

Using probability equations, sowing factors (number of seeds supplied per growing cavity) are adjusted for each GC range to minimize the number of empty cavities generated. Taking 92% germination as an example (**Table 11**), it follows that sowing 1.8 seeds per cavity generates empty cavities with a probability of 2.11%. The oversow factor (suggested extra cavities to sow over and above request) is subsequently adjusted to achieve "cavities with a green tree count" of 125% of the number of seedlings requested. In this case, sowing 1.28 or 28% extra cavities is required to yield a 125% "green tree" count. This means the nursery produces 25% extra trees over and above the requested amount from which to select those seedlings which will be shipped to the customer. In addition, 0.2 extra seeds are supplied per cavity sown ("nursery-handling factor") to allow for sowing equipment minimum operating requirements and inefficiencies.

Following the guidelines in conjunction with the application of appropriate growing techniques and seedling specifications should allow the selection of 100% of requested seedlings. However, if between the nursery and the seed owner a different formula for seed deployment is desired, this can be instituted. The Ministry of Forests sowing guidelines is the default used by SPAR.

If nurseries wish to upgrade sowing requests or change sowing and/or correction factors to suit individual preferences, information on "seeds supplied per seedling requested" is available (**Table 11**). For example, a seedling request comes with 3000 grams of seeds at 72% GC that after upgrading yield 2000 grams of seeds at 92%. Using the guidelines at 72% GC, we know that 4.58 seeds will be allocated per requested seedling (3.28 viable seeds per seedling). To obtain a 125% green tree count the guidelines

Table 11 Factors and seeds per seedling by germination capacity (%)

Germ %	Sowing factor	Empty cavities (%)	Desired green stem count (%)	OF # of extra cavities to sow	NHF extra # seeds/ cavity sown	Total seeds/ seedling 1996	Total seeds/ seedling 1999	Total seeds/ seedling 2001	Viable seeds/ seedling 2001
100	1.2	0.00	125	1.26	0.20	2.25	2.00	1.76	1.75
99	1.2	0.80	125	1.26	0.20	2.25	2.00	1.76	1.75
98	1.3	1.41	125	1.28	0.20	2.25	2.13	1.92	1.87
97	1.3	2.13	125	1.28	0.20	2.25	2.13	1.92	1.86
96	1.5	2.08	125	1.28	0.20	2.25	2.39	2.18	2.09
95	1.5	2.63	125	1.28	0.20	2.78	2.39	2.18	2.07
94	1.7	2.05	125	1.28	0.20	2.78	2.52	2.43	2.29
93	1.7	2.44	125	1.28	0.20	2.78	2.52	2.43	2.26
92	1.8	2.11	125	1.28	0.20	2.89	2.77	2.56	2.36
91	1.8	2.45	125	1.28	0.20	2.89	2.77	2.56	2.33
90	2	1.00	125	1.27	0.20	2.89	2.90	2.78	2.49
89	2	1.21	125	1.27	0.20	3.00	2.90	2.78	2.49
88	2.2	1.19	125	1.27	0.20	3.00	3.03	3.04	2.68
87	2.2	1.40	125	1.27	0.20	3.00	3.03	3.04	2.65
86	2.4	1.29	125	1.27	0.20	3.00	3.28	3.30	2.84
85	2.4	1.49	125	1.27	0.20	4.09	3.28	3.30	2.81
84	2.5	1.48	125	1.27	0.20	4.09	3.41	3.43	2.88
83	2.5	1.69	125	1.27	0.20	4.09	3.41	3.43	2.85
82	2.7	1.38	125	1.27	0.20	4.09	3.66	3.68	3.02
81	2.7	1.56	125	1.27	0.20	4.09	3.66	3.68	2.98
80	2.8	1.44	125	1.27	0.20	4.25	3.79	3.81	3.05
79	2.8	1.62	125	1.27	0.20	4.25	3.79	3.81	3.01
78	3	1.06	125	1.27	0.20	4.25	3.92	4.05	3.14
77	3	1.22	125	1.27	0.20	4.25	3.92	4.05	3.13
76	3.1	1.28	125	1.27	0.20	4.25	4.18	4.19	3.19
75	3.1	1.45	125	1.27	0.20	4.41	4.18	4.19	3.14
74	3.2	1.50	125	1.27	0.20	4.41	4.31	4.32	3.20
73	3.2	1.68	125	1.27	0.20	4.41	4.31	4.32	3.15
72	3.4	1.56	125	1.27	0.20	4.41	4.44	4.58	3.29
71	3.4	1.75	125	1.27	0.20	4.41	4.44	4.58	3.25
70	3.6	1.57	125	1.27	0.20	4.58	4.58	4.83	3.38
69	3.6	1.75	125	1.27	0.20	4.58	4.58	4.83	3.33
68	3.7	1.72	125	1.27	0.20	4.58	4.71	4.97	3.37
67	3.7	1.91	125	1.27	0.20	4.58	4.71	4.97	3.32
66	3.9	1.60	125	1.27	0.20	4.58	4.97	5.22	3.44
65	3.9	1.78	125	1.27	0.20	6.15	4.97	5.22	3.38
64	4	1.68	125	1.27	0.20	6.15	5.11	5.35	3.41
63	4	1.87	125	1.27	0.20	6.15	5.11	5.35	3.36
62	4.2	1.83	125	1.28	0.20	6.15	5.36	5.61	3.46
61	4.2	2.03	125	1.28	0.20	6.15	5.36	5.61	3.44
60	4.3	2.10	125	1.28	0.20	6.36	5.50	5.76	3.46
59	4.3	2.33	125	1.28	0.20	6.36	5.50	5.76	3.40
58	4.4	2.39	125	1.28	0.20	6.36	5.65	5.90	3.42
57	4.4	2.64	125	1.28	0.20	6.36	5.65	5.90	3.36
56	4.6	2.49	125	1.29	0.20	6.36	5.79	6.16	3.44
55	4.6	2.75	125	1.29	0.20	6.57	5.79	6.16	3.41
54	4.7	2.78	125	1.29	0.20	6.57	6.06	6.31	3.41
53	4.7	3.07	125	1.29	0.20	6.57	6.06	6.31	3.35
52	4.9	2.82	125	1.29	0.20	6.57	6.21	6.57	3.42
51	4.9	3.12	125	1.29	0.20	6.57	6.21	6.57	3.36
50	5	3.13	125	1.29	0.20	6.78	6.37	6.72	3.35
49	5	3.45	125	1.29	0.20	6.78	6.37	6.72	3.29
48	5.1	3.62	125	1.30	0.20	6.78	6.53	6.88	3.31
47	5.1	3.99	125	1.30	0.20	6.78	6.53	6.88	3.24
46	5.3	3.96	125	1.31	0.20	6.78	6.70	7.18	3.29
45	5.3	4.35	125	1.31	0.20	7.21	6.70	7.18	3.24
44	5.4	4.54	125	1.32	0.20	7.21	6.88	7.35	3.23
43	5.4	4.98	125	1.32	0.20	7.21	6.88	7.35	3.18
42	5.5	5.19	125	1.33	0.20	7.21	7.06	7.53	3.16
41	5.5	5.68	125	1.33	0.20	7.21	7.06	7.53	3.11
40	5.6	5.91	125	1.34	0.20	7.42	7.26	7.73	3.09
39	5.6	6.47	125	1.34	0.20	7.42	7.26	7.73	3.03
38	5.7	6.72	125	1.35	0.20	7.42	7.47	7.94	3.00
37	5.7	7.35	125	1.35	0.20	7.42	7.47	7.94	2.95
36	5.8	7.65	125	1.36	0.20	7.42	7.69	8.15	2.92
35	5.8	8.35	125	1.36	0.20	7.42	7.69	8.15	2.86
34	5.9	8.69	125	1.38	0.20	7.42	7.93	8.38	2.84
33	5.9	9.49	125	1.38	0.20	7.42	7.93	8.38	2.78
32	6	9.89	125	1.40	0.20	7.42	8.20	8.65	2.76
31	6	10.79	125	1.40	0.20	7.42	8.20	8.65	2.69
30	6	11.76	125	1.42	0.20	9.28	8.49	8.84	2.64
29	6	12.81	125	1.42	0.20	9.28	8.49	8.84	2.57
28	6	13.93	125	1.46	0.20	9.28	8.81	9.06	2.52
27	6	15.13	125	1.46	0.20	9.28	8.81	9.06	2.46
26	6	16.42	125	1.51	0.20	9.28	9.18	9.35	2.42
25	6	17.80	125	1.51	0.20	11.13	10.00	9.35	2.36

suggest these seeds be sown at 3.4 seeds per cavity at 1.27 oversow (carrying 1.56% empties). After upgrading we are left with 2/3 of the seed remaining or 4.88 × 2/3 = 3.05 seeds supplied per seedling (3.05 × 0.92 = 2.8 viable seeds per seedling). This is more seeds than would have been allocated by SPAR had the seedlot been 92% GC to begin with (2.56 total seeds). Hence to obtain a 125% green stem count the latter can be sown at 1.8 seeds per cavity, 1.28 oversow (carrying 2.11% empties) with some seeds left over. By removing damaged, diseased, or low vigour seeds, the upgraded seeds may display more vigour, resulting in increased germination speed and subsequent improvements in crop uniformity and health.

The nursery has a huge range of sowing strategies at its disposal. For the original 72% seedlot one can choose to single sow at a correction factor up to 3.82 giving a green stem count of **275%**. However, to obtain a more reasonable green stem count of 125%, a correction factor of 1.74 is all that is required if single sowing each cavity (note that single-seed sowing results in carrying 28% empty cavities). Moving to the other end of the scale one could sow 4 seeds per cavity at a correction factor of **1.09** since that is as far as the seeds supplied will "stretch." The proportion of empty cavities is minimal at 0.61% but the limited green stem count may increase the difficulty of making request numbers if cull rates are high.

Note from the "seed use" column in Table 12 that certain strategies result in substantial quantities of seeds left over compared to seeds supplied per seedling.

For a given number of seeds supplied per seedling, the combination of sowing and correction factor chosen is up to the grower. There may be situations where a nursery is willing to accept a higher proportion of empties in order to have a larger oversow from which to select final crop trees or generate overruns. Accomplished growers might wish to reduce the oversow factor in favour of increasing the sowing factor, thereby reducing the percent empties and total space allotted to growing an individual request. The latter scenario leaves growing area available for the production of request seedlings under other contracts.

Negotiating seed requirements between the seed owner and nursery can result in increased seed use efficiency

Sowing Guideline Calculations

Use Table 11 to determine the number of seeds per seedling based on the GC of a seedlot. The GC and seeds per gram for all seedlots are available from SPAR. Next, use the following formula to calculate 'grams of seeds' required for a seedling request. Based on the Ministry of Forests *Sowing Guidelines* (2001):

$$\text{Grams of seeds} = \frac{\#\text{ of seedlings requested} \times \text{Seeds supplied per seedling}}{\text{Seeds per gram}}$$

Alternatively the number of potential seedlings from a given quantity of seeds can be calculated by rearranging the equation as shown below. The trees per gram available on SPAR is the total potential seedlings divided by the total grams in a seedlot.

$$\text{Potential seedlings} = \frac{\text{Grams of seeds} \times \text{Seeds per gram}}{\text{Seeds supplied per seedling}}$$

Table 12 Some seed-use scenarios at 72 and 92% germination capacity.

Germination capacity (%)	Seeds per seedling		SF*	OF	% empties	GSC %	Seed use
72	4.58	(from Table 11)	3.4	1.27	1.56	125	4.58
		option	4	1.09	0.61	108	4.58
		option	3	1.28	2.2	125	4.10
		option	2	1.36	7.8	125	2.99
		option	1	1.74	28.0	125	2.09
			1	3.82	28.0	275	4.58
92	2.96	(from Table 11)	1.8	1.28	2.11	125	2.56
		option	1.5	1.31	4.32	125	2.23
		option	1	1.36	8.0	125	1.63
			1	2.13	8.0	196	2.56

Seed use = (SF*OF) + (0.2*OF)
% empties = $(1\text{-GC}/100)^{SF}$
Green stem count = OF – (% empties*OF)

*SF = sowing factor
OF = oversow factor
GSC = greenstem count

Sample calculation

Number of seedlings requested = 15 200
Seedlot # 60277, GC = 91%, Seeds per gram = 349

$$\text{Grams required} = \frac{15\,200 \text{ seedlings} \times 2.56 \text{ seeds supplied per seedling}}{349 \text{ seeds per gram}} = 111.49$$

Note: Seed withdrawals at the Tree Seed Centre are carried out to the nearest gram (whole number). SPAR automatically rounds the calculation upward to the nearest whole gram. You may see the message *'Potential trees have been recalculated'* in SPAR when entering a seedling request, due to the rounding factor.

Figure 85 Proper seed storage upon arrival at the nursery.

Practical Sowing Hints/General Guidelines

To help ensure that allotted seeds meet the goals and objectives set out, there are some general guidelines one can follow.

Upon arrival at the nursery seeds should be inspected for mould, colour, moisture status, debris, damage, and deterioration to determine acceptability. If a problem is identified that could compromise the ability of seeds to produce the requested crop, the supplier should be contacted immediately to discuss options. A nursery may choose to address the problem if time and facilities are available. To ensure that enough seeds are available, they should be weighed. (Note that sowing request labels are based on storage moisture content [i.e., dry seed]). If stratified seeds are received, the weight will be appreciably higher due to the moisture imbibed by the seeds. If there are insufficient seeds, the seed owner should be contacted to authorize the release of additional seed. The seedling customer needs to be notified if seedling requests will be compromised. The area where seeds are received, inspected, stratified, and stored should be clean.

Once accepted, it may still be necessary to clean the seeds and re-bag them. If there is suspicion of disease, a sample should be sent to a pathology laboratory. Moisture content should be checked upon arrival and monitored until sowing. This can be carried out using the target moisture content calculations described in the "Seed Pretreatment" chapter (page 53). One needs to know the storage moisture content and the weight of the seeds. With this information you can rapidly evaluate the moisture content of seeds upon receipt, dry them back to a target moisture content if required, and control moisture content during stratification and interim storage. One benefit of using this method to calculate moisture content is that no seeds have to be sacrificed.

Upon arrival at the nursery seeds should be inspected for mould, colour, moisture status, debris, damage, and rot

Large shipments are better split into smaller bags of equal proportions to facilitate handling and maintenance of quality. Bags need to be flattened for efficient storage to maintain uniform moisture content. Bags containing stratified seeds require an opening for gas exchange (Figure 85). Current lab germination and fungal assay results are supplied on the request labels. However, any previous nursery records on a seedlot should be checked to determine its history, other characteristics, and possible problems. The value of keeping your own records cannot be overemphasized. Based on the above, make plans for additional testing, remedial action, and/or performance upgrading.

During sowing, it helps to divide seeds for large requests into halves, thirds, or quarters and monitor their use. If the number of cavities or blocks being sown is also monitored it is easy to determine if seed use is appropriate. For instance, when 50% of allotted seeds are used up the number of cavities sown should total 50% or slightly greater. If half the seeds are consumed to sow only 40% of the required cavities, an adjustment in sowing factor is required for the remaining seeds.

Splitting bags of seeds and keeping only the currently needed seeds out also reduces the risk of seed viability losses through exposure to sub-optimal conditions, which may be present at the sowing line. Heat and drying conditions or exposure to disease inoculum are not uncommon.

Wetting containers (Figure 86) immediately after sowing and seed cover (gritting) ensures that seed imbibition is not lost or compromised prior to arrival in the growing area (Figure 87) where misting/irrigation systems are in place. The application of moisture at the end of the sowing line is recommended.

Wetting containers immediately after sowing and gritting application ensures that seed imbibition is not lost or compromised prior to arrival in the growing area

Pelletized western redcedar seeds are not imbibed prior to pelleting and wetting containers will mark the beginning of imbibition while on the sowing line. This will require the input of greater quantities of water compared to other species that are already fully imbibed. Once water is applied, the maintenance of imbibition (seed moisture) is especially critical because the applied pellet coating dries easily and can extract moisture from the seeds. Drying also seems to cement the pellet to the germinant, with obvious negative results.

Seeding Equipment

Seeding equipment mechanizes the placement of seeds into growing cavities. The objective is to sow quickly and accurately, gently placing each seed in the centre of its growing cavity. Centring seeds in containers allows seedlings to develop a more symmetrical (balanced) root system (**Figure 88**). Sowing large crops within short timeframes allows all seedlings to germinate together (**Figure 89**) thereby establishing a more even-aged crop that responds more uniformly to further management.

Most seeders use vacuum to pick up individual seeds from a common reservoir and transfer them to their respective growing cavities. Vacuum may be applied to small holes from the inside of a drum, back of a flat plate, or hollow needles mounted on a bar or plate (**Figure 90**). Seeds are released to drop into the growing cavity simply by interrupting the vacuum at the right time, when the orifice holding the seed is positioned precisely over the centre of the growing cavity, and close enough to it so that air currents and vibration will not carry it off course. To ensure that sticky or very light seeds fall off at the appropriate moment, depending on equipment capability a small burst of positive air pressure or a drop of water may be applied in addition to interrupting the vacuum.

The objective is to sow quickly and accurately, gently placing each seed in the centre of its growing cavity

Cam-drop seeders employ a rocking cam to place seeds individually into tubes directed to individual growing cavities (**Figure 83**). Gentle vibration moves seeds from a common

Figure 86 Applying moisture immediately after seeding, prior to transporting containers to the growing area.

Figure 87 Laying out containers in the growing area.

Figure 88 Balanced vs. side-grown root systems.

Figure 89 Uniform germination vs. late germinants (circled).

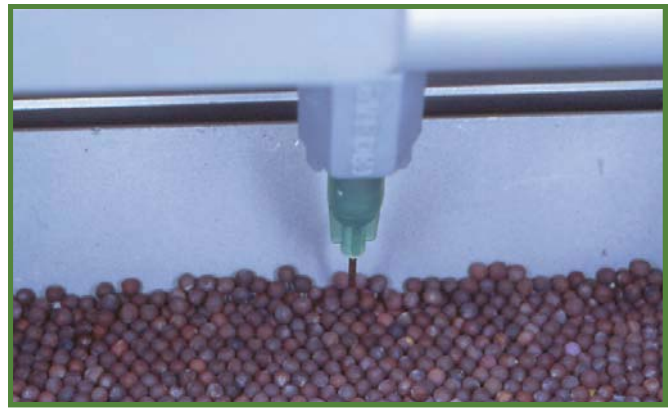


Figure 90 Pelletized seeds being picked up by vacuum from a needle seeder prior to placement.

reservoir into single seed-sized slots cut into the cam. Each "rock" of the cam collects a complement of seeds and drops them into their respective cavities.

Fractional Sowing Strategies

Sowing is performed mechanically to ensure seeds are sown as quickly as possible, thereby establishing maximum crop uniformity.

Fractional sowing means that on average, the number of seeds sown per cavity is not an integer. For example, if the fractional sowing factor is 2.2 seeds per cavity that means that 80% and 20% of the cavities contain two and three seeds respectively. The challenges are how to accurately set up sowing machinery to perform this way and how to distribute the cavities with extra seeds through a crop.

One way to fractionally sow a crop is in two parts. For the above example, 80% and 20% of the cavities are sown at two and three seeds per cavity respectively. All seeding machines available on the market are capable of this (suggested ratios per integer value for sowing factors up to five seeds per cavity are found in Table 13). This method creates two crops within a particular seedling request, each with its own sowing factor. This may make them behave somewhat differently, possibly requiring separate management strategies. However, the strategy may be desirable for sowing factors between one and two seeds/cavity since that portion of the crop sown at one seed per cavity will not require thinning. This method is time consuming if it requires changing or taping seed drums. However, some nurseries possess more than one seeding machine, allowing placement in series. The extra seeding machine merely functions as a conveyor when not being used.

Fractional sowing means that on average, the number of seeds sown per cavity is not an integer

If the fractional sowing factor is greater than two, the whole crop is thinned anyway and distributing cavities with higher integer seeds evenly throughout a crop is desirable. It will make the crop more uniform, simplifying further management. It does, however, require altering the seeder somewhat or changing sowing line procedures. With the vacuum drum seeder a drum with the higher integer value can be utilized and as in our example, with 80% of the extra (third) holes sealed (taped) (Figure 91). The pattern chosen is up to the grower. Linear patterns using tape, or random patterns using small round "stickies," are options. The cam-drop seeder uses small o-rings to interrupt seed placement into selected cavities (Figure 83).

Another way to obtain the same result requires running the crop through the seeder at two seeds per cavity, and then again at 0.2 seeds per cavity. The second time through, the seeder is taped to drop one seed in only 20% of the cavities per block. This is cumbersome but may be an option for some. It can also be done with two seeding machines set up in series. On vacuum drum seeders that employ an airbrush, the operator may use the airbrush to finesse the number of seeds per cavity instead of stopping production to change drums or

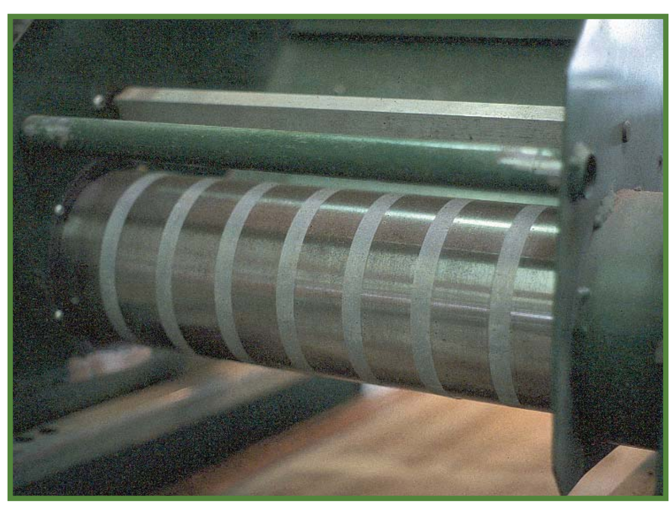


Figure 91 Vacuum seeder drum with proportion of holes taped.

Table 13 Proportion (%) of cavities to sow at a given sowing factor to produce various fractional sowing factors

Fractional sowing factor	Sowing factor (seeds per cavity)				
	1	2	3	4	5
1.0	100				
1.1	90	10			
1.2	80	20			
1.3	70	30			
1.4	60	40			
1.5	50	50			
1.6	40	60			
1.7	30	70			
1.8	20	80			
1.9	10	90			
2.0		100			
2.1		90	10		
2.2		80	20		
2.3		70	30		
2.4		60	40		
2.5		50	50		
2.6		40	60		
2.7		30	70		
2.8		20	80		
2.9		10	90		
3.0			100		
3.1			90	10	
3.2			80	20	
3.3			70	30	
3.4			60	40	
3.5			50	50	
3.6			40	60	
3.7			30	70	
3.8			20	80	
3.9			10	90	
4.0				100	
4.1				90	10
4.2				80	20
4.3				70	30
4.4				60	40
4.5				50	50
4.6				40	60
4.7				30	70
4.8				20	80
4.9				10	90
5.0					100

tape holes. The intended purpose of the airbrush is to increase seeder accuracy by ensuring that only one seed adheres to each hole in the seed drum. However, to increase the number of seeds deposited per cavity above the number of holes in the drum, one can turn down the airbrush thereby promoting multiple seeds adhering to a single hole. Conversely one can utilize a drum with more holes per cavity than required and turn up the airbrush to "blow off" a portion of the seeds. These are very coarse adjustments and require constant monitoring to ensure seed consumption is at the appropriate rate. In the case of high airbrush settings be aware that all holes for certain cavities can easily be blown free of seeds, resulting in the generation of empty cavities.

Vacuum plate and needle seeders can be obtained with plates and needle set-ups containing more than one orifice per cavity to be sown. In this case a three-hole vacuum plate can be taped to 2.2 seeds per cavity. Vacuum needle seeders are available with single, double, and triple needle per cavity designs, which can be mixed on the same plate. Triple needle per cavity designs can be substituted into 20% of an otherwise double needle per cavity plate to achieve the above-stated example.

It is also conceivable to order/manufacture plates and drums with a "fractional" number of holes drilled in them (e.g., 1.5 holes per cavity would mean 50% of the cavities would have two holes drilled in them).

Choosing which Cavities to Multiple-sow

Some cavities by virtue of container design have more growing space at their disposal. Trees supplied with more growing space are generally shorter and produce greater stem diameters than the crop average. The objective is to equally distribute the growing space available per seedling so that overall crop growth is as uniform as possible and photosynthesis per unit growing area is maximized. Depending on the stocktype (species, container size, age, planting window combination) being produced and the type of culls anticipated (based on experience), one chooses which cavities should definitely have a seedling remaining in them after thinning and therefore be preferentially multiple sown. Generally these are the cavities around the perimeter of the block. After they are multiple sown, depending on how many more are needed, one moves toward the centre of the block. Blocks with different numbers of cavities will have different percentages of edge cavities. A 45 cavity block has 24 (53%) edge cavities, a 112 block has 40 (36%) edge cavities, and a 160 block has 48 (30%) edge cavities. If edge cavities in a particular block traditionally yield underheight culls due to excessive drying, one might conclude that these cavities should not be preferentially multiple sown. However, doing this would result in even drier conditions for the remaining edge seedlings, ensuring their demise, as well as effectively moving "edge" conditions further into the centre. It would be better to fill edge cavities and leave some blanks in the centre, and couple this with altered culture to promote more uniform climatic conditions between the centre and perimeter of individual blocks.

Different blocks lend themselves to different patterns. Below are two examples of fractional sowing a 77 cavity block, including achieved fractional sowing rates (Figure 92).

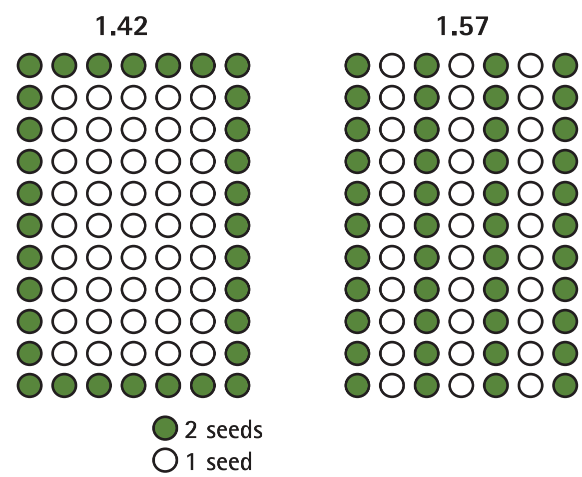


Figure 92 Actual fractional sowing rates through the use of two different configurations for single and double sowing in a 77 cavity block.