

## **Seed Sowing Strategies for Container Nurseries**

**by:**

**Patrick A. Glass and John T. Harrington**

Many factors impact a container growers seed sowing decision. These factors include target crop numbers, greenhouse space, labor resources, previous practices and seed quality. To achieve a target crop number a container grower must evaluate the costs and benefits of; sowing multiple seeds per cell, oversowing the number of cells or some combination of these two strategies (Tinus and McDonald 1979; Pepper and Barnett 1981). The container grower then decides upon a particular strategy, most commonly some iteration of the last option.

The benefits of sowing multiple seeds per cell include: almost guaranteeing that every cell will contain a seedling and the minimal amount of greenhouse space is used providing additional space for other crops. Additional benefits are no excess media or container costs. Several limitations and false assumptions exist with this approach. First, the added cost of thinning increases dramatically as the number of cells requiring thinning and the number of seedlings per cell increase. Secondly, the cost of media is a relatively small component in the cost of producing a seedling (Mexal and Harrington 1995). Assuming that reducing the amount of growing space results in an equal reduction of production costs is only valid if the free growing space is occupied with another crop. If the space saving results in empty production area in a heated greenhouse, then production costs are only nominally reduced.

Oversowing the number of cells is another option a grower can use to help ensure crop numbers. This approach is often used when seed is scarce, as is the case with restoration projects, where there is adequate greenhouse space and the crop value is relatively high. Thinning costs are reduced when this system is employed to guarantee crop numbers. In movable container systems such as the Ray-Leach Super Cell system, crops can be condensed to recover the "lost" greenhouse space associated with non-germinants. However, there are limitations to oversowing the number of cells. Few production systems have the latitude for the use of spare production space. The excess space required can be quite formidable when dealing with seedlots with poor germination percentages. For example: If a grower needing to produce 10,000 seedlings, uses a fixed container system such as a styroblock system with 40 cells per square foot; and a seedlot with 90% germination. The grower sows 11,200 cells ( $10,000/0.90$ ) with one seed to produce 10,000 germinants. If the target 90% germinate, there are still 1,200 empty cells or a 30 square foot loss in production space. As germination

percentage of a seed lot decreases the loss of greenhouse space increases in fixed container systems.

As stated earlier, most container growers use a combination of both systems to ensure crop numbers. This method is usually employed based on system constraints and tradition. For instance; if a grower has the capability to sow 20% more containers than the required crop number, the grower might sow only two seeds per cell; if space is limited the grower might oversow the number of containers required by 1% with three seeds per cell. Regardless of the system used, using seed and greenhouse space efficiently results in cost savings.

Starting with seed having a high germination percentage is essential (Tinus and McDonald 1979). Using seed with low germination capacity will always result in added costs. These costs would include greenhouse costs, sowing costs, resowing costs and thinning costs associated with the sowing system employed. Using "modern" methods of determining how many seeds to sow per cell can significantly reduce these costs.

The first "modern" technique was using "rules of thumb" based on information about the seedlot. For instance, Tinus and McDonald (1979) developed rules of thumb based on probabilities. Germination percentage is a mathematical probability (Lipschultz 1968). A 90% germination percentage can be interpreted as 9 out of 10 seeds will germinate; or a seed picked from that seedlot has a 90% chance of germinating. Because there are only two possible outcomes for the seed, germinating or not germinating, this is called a binomial probability. These "rules of thumb" included: 1) If the germination percentage is greater than 85 then sow 1 seed per cell; 2) If the germination percentage is between 75 and 85 then sow 2 seeds per cell; 3) If the germination percentage is between 60 and 75 then sow 3 seeds per cell; and 4) If the germination percentage is less than 50 then do not use the seed.

As growers became more efficient, they found they had time to spare, so they turned to using binomial probability tables to determine how many seeds to sow. This was effective in improving seed sowing efficiency, however, the binomial probability tables were often cumbersome and incomplete (Wenny 1993). Frustrated, many growers went back to the "rules of thumb" approach.

The advent of micro-computers provides a valuable tool to container growers in reducing costs associated with starting a crop. Using information about the seedlot, specifically the germination percentage or germination capacity, a grower can calculate the number of seed to sow per cell to attain target crop numbers regardless of greenhouse space available. Instead of using a binomial probability table to determine the number of seeds to sow, a container grower

can use a spreadsheet program. Wenny (1993) wrote a spreadsheet program to calculate binomial probabilities for sowing up to five seeds per cell. Entering his spreadsheet formulation, included as appendix C, in any commercially available spreadsheet allows a grower to generate their own binomial probability tables. Although a spreadsheet programmed to calculate binomial probabilities is a drastic improvement it still requires a not so inconsiderable effort to enter the program and check it for accuracy. Additionally, interpreting binomial probabilities can be difficult.

When the amount of growing space is limited, a container grower is often just concerned with knowing how many seeds to sow per cell to minimize the number of empty cells. What is needed is a way to use the germination percentage and the percentage of empty cells acceptable to calculate the number of seeds per cell to sow. The geometric function meets these requirements.

The following example demonstrates how the geometric function answers the question. Suppose a grower needs to produce a minimum of 10,000 seedlings but has enough growing space available to produce 10,500. The grower has an acceptable empty cell percentage of 5%, (500/10,000). If the seedlot the grower uses has a germination capacity of 90% then he would need to sow 1.3 seeds per cell to produce 10,000 seedlings. However, because only whole seeds can be sown, the grower should sow 2 seeds per cell and produce 10,400 seedlings.

When maximizing the number of germinants is the only criteria for determining the number of seeds to sow per cell, then the geometric function provides the answer. Appendix A provides a spreadsheet formulation to perform the computations. If other factors such as costs are used in conjunction with maximizing the number of occupied cells to make the decision of how many seeds to sow per cell, then a two step approach is recommended. The first phase is to calculate the optimum number of seeds per cell using the geometric function. Then using the whole number of seeds on either side of the geometric result, apply the binomial probabilities. Appendix B describes a spreadsheet formulation combining the geometric and binomial probability density functions as described above.

## Literature Cited

Lipschultz, S. 1968. Schuam's Outline of Theory and Problems of Probability. New York. McGraw-Hill, Inc. pp. 153.

Mexal, J.G., J.T. Harrington. 1995. The Ideal growing medium or what works for you. In Proceedings 2<sup>nd</sup> Meeting of the Southwestern Container Growers Association. June, 1995. Las Vegas, New Mexico.

Pepper, W. D., J. P. Barnett. 1981. Seed Sowing Strategies for Containerized Seedling Operations. In Proceedings of the Southern Containerized Forest Tree Seedling Conference. Savannah Georgia. August 25 - 26, 1981. USDA For. Serv. General Technical Report SO-37. pp 29 - 32. Southern Forest Experiment Station. New Orleans, Louisiana.

Tinus, R. W., S. E. McDonald. 1979. How to Grow Seedlings in Containers in Greenhouses. USDA For. Serv. General Technical Report RM-60. 256 pp. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Wenny, D. L. 1993. Calculating Filled and Empty Cells Based On Number of Seeds Sown per Cell: A Microcomputer Application. Tree Planters' Notes. 44(2):49-52.

## APPENDIX A

This spreadsheet formulation can be used with any commercially available spreadsheet that has the natural logarithm and exponential functions. This particular formulation was developed for users of with @FUNCTION capability.

Format column A for text with a width of 50 characters. Format column B as fixed with 2 decimal places.

| <u>Cell</u> | <u>Entry</u>                                    |
|-------------|---|
| A1          | Determining Seed/Cell Requirements              |
| A2          | From the Geometric Probability Density Function |
| A4          | Seedlot Germination %                           |
| A6          | Delivery Failure %                              |
| A8          | Acceptable Number of Empty Cells per 100        |
| A10         | Calculated Probability of a Deliverable Plant   |
| A12         | Exact Number of Seeds to Sow per Cell           |
| A14         | Ceiling Number of Seeds to Sow                  |
| A16         | Floor Number of Seeds to Sow                    |
| A18         | Ceiling Percentage of Empty Cells               |
| A20         | Floor Percentage of Empty Cells                 |
| B10         | $(B4/100)*(1-(B6/100))$                         |
| B12         | $((@LN(B8)-@LN(B4/100))/@LN(1-(B4/100)))$       |
| B14         | $@INT(B12)+1$                                   |
| B16         | $@INT(B12)$                                     |
| B18         | $((1-(B4/100))^(B14))*100$                      |
| B20         | $((1-(B4/100))^(B16))*100$                      |

Three numeric entries are made to the spreadsheet. The first entry is made in cell B4 where the germination percentage of the seedlot is input as an integer. The second entry is made in cell B6 where the percentage of germinants failing to meet delivery standards is input as an integer. The allowable number of empty cells per 100 cells sown can be input as either an integer or real number into cell B8.

## APPENDIX B

This spreadsheet formulation can be used with any commercially available spreadsheet that has the natural logarithm and factorial functions. This particular formulation was developed for users of with **@FUNCTION** capability.

Format column A for text with a width of 50 characters. Format columns B through L as fixed with 4 decimal places.

| <u>Cell</u> | <u>Entry</u>   |
|-------------|--|
| A1          | Determining Seed/Cell Requirements Combining   |
| A2          | the Geometric Probability Density Function   |
| A3          | and the Binomial Probability Density Function  |
| A5          | Seedlot Germination %  |
| A7          | Delivery Failure %   |
| A9          | Acceptable Number of Empty Cells per 100   |
| A11         | Calculated Probability of a Deliverable Plant  |
| A13         | Ceiling Number of Seeds to Sow   |
| A15         | Floor Number of Seeds to Sow   |
| A17         | Ceiling Percentage of Empty Cells  |
| A19         | Floor Percentage of Empty Cells  |
| A23         | Floor Number of Seeds  |
| A24         | B15  |
| A25         | Ceiling Number of Seeds  |
| A26         | B13  |
| B11         | $(B4/100)*(1-(B7/100))$  |
| B13         | $(@INT((LN(B9/100)-@LN(B11/100))/@LN(1-(B11/100))))+1$                                   |
| B15         | $B13-1$  |
| B17         | $((1-(B11/100))^(B13))*100$  |
| B19         | $((1-(B11/100))^(B15))*100$  |
| B21         | Binomial Probability Densities of Number of Germinants                                   |
| B22         | 0  |
| B24         | $B19/100$  |
| B26         | $B17/100$  |
| C22         | 1  |
| C24         | $@IF((A24-C22)>-1,(@FACT(A24)/(@FACT(A24)*@FACT(A24-C22)))*B11^C22*(1-B11)^(A24-C22), )$ |
| C26         | $@IF((A26-C22)>-1,(@FACT(A26)/(@FACT(A26)*@FACT(A26-C22)))*B11^C22*(1-B11)^(A26-C22), )$ |
| D22         | 2  |
| D24         | $@IF((A24-D22)>-1,(@FACT(A24)/(@FACT(A24)*@FACT(A24-D22)))*B11^D22*(1-B11)^(A24-D22), )$ |
| D26         | $@IF((A26-D22)>-1,(@FACT(A26)/(@FACT(A26)*@FACT(A26-D22)))*B11^D22*(1-B11)^(A26-D22), )$ |

E22 3  
 E24 @IF((A24-E22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-E22)))\*B11^E22\*(1-B11)^(A24-E22), )  
 E26 @IF((A26-E22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-E22)))\*B11^E22\*(1-B11)^(E26-C22), )

F22 4  
 F24 @IF((A24-F22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-F22)))\*B11^F22\*(1-B11)^(A24-F22), )  
 F26 @IF((A26-F22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-F22)))\*B11^F22\*(1-B11)^(A26-F22), )

G22 5  
 G24 @IF((A24-G22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-G22)))\*B11^G22\*(1-B11)^(A24-G22), )  
 G26 @IF((A26-G22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-G22)))\*B11^G22\*(1-B11)^(A26-G22), )

H22 6  
 H24 @IF((A24-H22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-H22)))\*B11^H22\*(1-B11)^(A24-H22), )  
 H26 @IF((A26-H22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-H22)))\*B11^H22\*(1-B11)^(A26-H22), )

I22 7  
 I24 @IF((A24-I22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-I22)))\*B11^I22\*(1-B11)^(A24-I22), )  
 I26 @IF((A26-I22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-I22)))\*B11^I22\*(1-B11)^(A26-I22), )

J22 8  
 J24 @IF((A24-J22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-J22)))\*B11^J22\*(1-B11)^(A24-J22), )  
 J26 @IF((A26-J22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-J22)))\*B11^J22\*(1-B11)^(A26-J22), )

K22 9  
 K24 @IF((A24-K22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-K22)))\*B11^K22\*(1-B11)^(A24-K22), )  
 K26 @IF((A26-K22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-K22)))\*B11^K22\*(1-B11)^(A26-K22), )

L22 10  
 L24 @IF((A24-L22)>-1,(@FACT(A24)/(@FACT(A24)\*@FACT(A24-L22)))\*B11^L22\*(1-B11)^(A24-L22), )  
 L26 @IF((A26-L22)>-1,(@FACT(A26)/(@FACT(A26)\*@FACT(A26-L22)))\*B11^L22\*(1-B11)^(A26-L22), )

## APPENDIX C

Wenny's (1993) spreadsheet formulation as taken from Tree Planters' Notes 44(2):49-52; 1993.

Set the following column widths;

A=12, B=4, C=6, D through H=5, I=6, J=15.

Set the numeric format of C7 as percentage with two decimal places and C11..H15 as percentage with zero decimal places.

| <u>Cell</u> | <u>Entry</u>                |
|-------------|-----------------------------|
| A1          | Calculations for optimizing |
| A2          | seeds per cell              |
| A5          | Germination % =             |
| A6          | Seeds per cell =            |
| A7          | Empty cells =               |
| C8          | Probability of occurrence   |
| D9          | Germinants per cell         |
| A10,A19     | Seeds/cell                  |
| C10         | Empty                       |
| A11,A20,D10 | 1                           |
| A12,A21,E10 | 2                           |
| A13,A22,F10 | 3                           |
| A14,A23,G10 | 4                           |
| A15,A24,H10 | 5                           |
| C18         | Thinning required           |
| C19         | Cells                       |
| D19         | Germinants                  |
| J9          | Marginal Return             |
| J10         | per 100 seeds               |
| C7          | $(1-C5/100)^{C6}$           |
| C11         | $1-D11$                     |
| D11         | $(C5/100)^{A11}$            |
| C12         | $+C11^{A12}$                |
| D12         | $2*(C5/100)*(1-C5/100)$     |
| E12         | $(C5/100)^{A12}$            |
| C13         | $+C11^{A13}$                |
| D13         | $3*(C5/100)*(1-C5/100)^2$   |
| E13         | $3*(C5/100)^2*(1-C5/100)$   |
| F13         | $(C5/100)^{A13}$            |
| C14         | $+C11^{A14}$                |
| D14         | $4*(C5/100)*(1-C5/100)^3$   |
| E14         | $6*(C5/100)^2*(1-C5/100)^2$ |
| F14         | $4*(C5/100)^3*(1-C5/100)$   |
| G14         | $(C5/100)^{A14}$            |
| C15         | $+C11^{A15}$                |
| D15         | $5*(C5/100)*(1-C5/100)^4$   |

|     |   |
|-----|---|
| E15 | $10*(C5/100)^2*(1-C5/100)^3$              |
| F15 | $10*(C5/100)^3*(1-C5/100)^2$              |
| G15 | $5*(C5/100)^4*(1/C5/100)$                 |
| H15 | $(C5/100)^{A15}$                          |
| J12 | $(C11-C12)*100$                           |
| J13 | $(C12-C13)*100$                           |
| J14 | $(C13-C14)*100$                           |
| J15 | $(C14-C15)*100$                           |
| C20 | 0   |
| C21 | +E12*100                                  |
| C22 | $(E13+F13)*100$                           |
| C23 | $(E14+F14+G14)*100$                       |
| C24 | $(E15+F15+G15+H15)*100$                   |
| D20 | 0   |
| D21 | +E12*100                                  |
| D22 | $(E13*100)+(F13*200)$                     |
| D23 | $(E14*100)+(F14*200)+(G14*300)$           |
| D24 | $(E15*100)+(F15*200)+(G15*300)+(H15*400)$ |

# **GEOSEED**

## **Calculation Software for Seed Sowing Strategies**

### **Introduction**

The Geoseed program is designed to help container nurseries calculate the seed per cell sowing requirement for a given seed sowing strategy. Geoseed uses the geometric probability density function to compute the number of seeds to sow per container to achieve a desired level of occupied containers. Geoseed does not formulate the overall seed sowing strategy. Geoseed is intended as a tool to assist the decision making process when evaluating different seed sowing strategies.

### **Equipment Required to Run Geoseed**

1. IBM<sup>®</sup>-compatible computer with a 3.5" floppy drive.
2. MS-DOS<sup>®</sup> version 2.1 or greater.
3. The Geoseed program.

Geoseed can be executed from the floppy diskette or can be copied to a hard drive. For specific information on copying the program to the hard drive refer to your users' guide.

### **Information Required to Run Geoseed**

1. The germination percentage of the seedlot being sown.
2. The percentage of empty cells acceptable, the number of cells failing to produce a germinant divided by the number of cells sown multiplied by 100.

### **How to Run Geoseed**

Whether Geoseed is being executed from the floppy diskette or the hard drive, change the drive and directory to the path where GEOSEED.EXE is located. At the prompt type GEOSEED and press <Enter> or <Return>. Geoseed inputs are minimal. The Species input is designed as an identifier for the particular scenario being analyzed. The other two inputs; Germination % and Allowable Emptys % are numeric in context. Each input has an associated help screen which can be accessed by pressing the F1 key while in that field. Other function keys are defined at the bottom of the screen. Directional arrow keys and the <Enter> or <Return> key move between fields. After all input fields contain information press the F5 key to submit the information for processing.

### **Precautionary Note**

Entering a value of zero (0) for either germination percentage or percentage of acceptable emptys will cause an error message to appear stating that zero (0) is an invalid entry. When reasoned out this would be true because only a seedlot with a 100% germination rate would meet the requirements and no calculation is necessary.

### **Technical Support**

For program technical support contact the New Mexico State University, Mora Research Center. Tel. 505.387.2319 or FAX 505.387.9012.