Calculating Filled and Empty Cells Based On Number of Seeds Sown per Cell: A Microcomputer Application

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A personal computer and commercially available software can be used to quickly estimate filled and empty cells in a container nursery if germination and seeds sown per cell are known. Calculation formulas for LOTUS™or QUATRO PRO™ are provided, as are seeds per cell recommendations. Tree Planters' Notes 44(2):49-52; 1993.

Managers of container seedling nurseries sow multiple seeds per cell to increase the probability of having at least one germinant per cell. This ensures that their greenhouses are fully stocked so that seedling contracts may be filled. However, this practice wastes valuable seed and necessitates thinning extra germinants at an additional cost. Multiple sowing, therefore, should be minimized. Many factors influence how many seeds per cell to sow, including species, seed size, seed availability and cost, type and accuracy of sowing equipment, sowing and thinning labor costs, and germination data reliability. The primary factor, however, is greenhouse germination percentage. When germination percentage is known or assumed, nursery managers use various rules of thumb or rely on the probability tables found in Tinus and McDonald (1979) to determine the number of expected empty cells. These tables are complete, sometimes cumbersome, and currently unavailable to new managers. Fortunately, the percentage of empty cells can be obtained using a hand-held calculator (Schwartz 1993). Taking this procedure one step farther, the probability tables of Tinus and McDonald (1979), showing both filled and empty cells, can be recreated on a personal computer.

Microcomputer Application

This LOTUS™ microcomputer application may be used to provide instant data for sowing decisions. The application as presented here calculates up to 5 seeds per cell but could be expanded for any number desired. Enter a germination percentage and the matrix displays the probability of having cells with 0, 1, 2, 3, 4, and 5 germinants when sowing 1, 2, 3, 4, or 5 seeds per cell. In addition, three other calculations are displayed: 1) percentage of cells requiring thinning, 2) number of extra germinants to be thinned per 100 cells, and 3) marginal percentage return (the gain in number of cells containing a germinant for each additional seed sown in 100 cells). This dramatically shows the results of increasing seeds per cell. Data are useful in determining the cost:benefit ratio in sowing additional seeds per cell. In this application, percentage calculations have been rounded to whole numbers.

One additional calculation is provided. This application enables the user to enter either whole or fractional numbers of seeds per cell and determines the probable number of empty cells for any germination percentage. For example, 2 seeds per cell may yield too many empty cells and 3 seeds may be too liberal, so try 2.5 seeds per cell. Calculating seed requirements based upon fractional seeds (that is 2.5) enables accepting either two or three seeds per cell and therefore speeds up sowing operations.

To use this application in a LOTUS or QUATRO PROT™ file, set the following column widths:

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

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

Refer to table 1 and enter the following range labels:

Range	**Label**
A1-	Calculations for optimizing seeds per cell
A5-	Germination % =
A6-	Seeds per cell =
A7-	Empty cells =
C8-	Probability of occurrence
D9-	Germinants per cell

A10, A19-	Seeds/cell
CIO-	Empty
A11, A20, D10-	"1
A12, A21, E10-	"2
A13, A22, 1710-	"3
A14, A23, G10-	"4
A15, A24, 1-110-	"5
C18-	Thinning required
C19-	Cells
D19-	Germinants
J9-	Marginal return
J10-	per 100 seeds

The probabilities of cell occupancy are determined by binomial expansion $(X = Y)^N$, where X^N = *the* probability of all seeds germinating, Y^N = the probability of an empty cell, and N = the number of seeds per cell.

Enter the following range formulas:

Range	**Formula**
C 7-	(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)

Example of Sowing Calculations

Input. Go to range C5 and for "Germination % =" enter 65 (table 2).

Output. The effect of sowing multiple seeds per cell is displayed in ranges C11 through H15. With the above input (65% germination) and 1 seed sown per cell, there will be 35% empty cells (range C11) and 65% cells (range D11) with 1 seed. This is an excessive number of empty cells. If 2 seeds were sown per cell there would be 12% empty, 46% with 1 germinant, and 42% with 2 germinants. Still an excessive number of empty cells. The "Marginal Return" column indicates that by sowing a second seed per cell, 23% additional cells become occupied (range J12). The effects of sowing a third, fourth, and fifth seed per cell are similarly shown. The third seed adds 8 additional occupied cells (range J13), and the fourth seed 3 more cells (range J14). Sowing another 100 seeds, the fifth seed per cell, only contributes 1 additional occupied cell (range J15), an effort that is hardly worthwhile

. If a value such as 4 is entered in range C6 ("Seeds per cell =") the percentage of "Empty cells =" is displayed to two decimal places in range C7 (1.50%).

Thinning requirements are also displayed per 100 cells sown. Sowing 2 seeds per cell will require thinning one germinant from 42% of the cells (range C21) for a total of 42 extra germinants (range D21). The third seed per cell will require thinning 72% of the cells (range C22) and a total of 99 germinants per 100 cells sown (range D22). The fourth and fifth seed thinning calculations are also displayed.

Recommendations

At the University of Idaho Research Nursery, for a given germination percentage, we strive to use a seeds-per-cell value that produces fewer than 1.5% empty cells. With 98.5% filled cells, requested numbers of seedlings are usually met or exceeded with a 10% oversow. The recommendations are based upon this premise when using a precision seeder with reliable greenhouse germination data.

Table 1- *Range labels for sowing calculations*

LOTUS range columns

	A	B	C	D	E	F	G	H	I	J
1	Calculations for optimizing									
2	seeds per cell									
3										
4										
5	Germination % =									
6	Seeds per cell =									
7	Empty cells									
8			Probability of occurrence							
9					Germinants per cell					Marginal return
10	Seeds/cell		Empty	1	2	3	4	5		per 100 seeds
11	1									
12	2									
13	3									
14	4									
15	5									
16										
17										
18			Thinning required							
19	Seeds/cell		Cells	Germinants						
20	1									
21	2									
22	3									
23	4									
24	5									
25										

Table 2 -*Example of calculations for optimizing seeds per cell*

LOTUS range columns

	A	B	C	D	E	F	G	H	I	J
1	Calculations for optimizing									
2	seeds per cell									
3										
4										
5	Germination % = 65									
6	Seeds per cell = 4									
7	Empty cells = 1.50%									
8			Probability of occurrence							
9					Germinants per cell					Marginal return
10	Seeds/cell		Empty	1	2	3	4	5		per 100 seeds
11	1		35%	65%						
12	2		12%	46%	42%					23
13	3		4%	24%	44%	27%				8
14	4		2%	11 %	31 %	38%	18%			3
15	5		1 %	5%	18%	34%	31 %	12%		1
16										
17										
18			Thinning required							
19	Seeds/cell		Cells	Germinants						
20	1		0	0						
21	2		42	42						
22	3		72	99						
23	4		87	162						
24	5		95	226						
25										

Seed lot germination percentage	Recommended seeds per cell
98-100	1.0
95-97	1.5
88-94	2.0
82-87	2.5
76-81	3.0
70-75	3.5
65-69	4.0
60-64	4.5

Literature Cited

Schwartz, M. 1993. Germination math: Calculating the number of seeds necessary per cavity for a given number of live seedlings. Tree Planters' Notes 44(1):19-20.

Tinus, R.W.; McDonald, S.E. 1979. How to grow tree seedlings in containers in greenhouses. Gen. Tech. Rep. RM60. Fort Collins, CO: USDA Forest Service Rocky Mountain Forest and Range Experiment Station.