Tree Planter's Notes Volume 44, No. 1 (1993)

Germination Math: Calculating the Number of Seeds Necessary per Cavity for a Given Number of Live Seedlings

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The hand-held calculator can be an indispensable tool in calculating the number of seeds to sow in a container to optimize seed use. By entering the germinalion failure rate, then keystroking universal power (Y^X), *keystroking the number of seeds expected to be sown per cell, keystroking equals, almost any hand-held calculator can display quickly and accurately the decimal expression of empty cells occurring. Scenarios derived through the use of this simple mathematical calculation can show growers how to get a maximum number of germinates from a finite number of seeds.* Tree Planters' Notes 44(1):19-20; 1993.

Planting a seed is basically an exercise in what can be called binomial probability. A seed either grows or it doesn't. Those are the only two condilions that can occur. Knowing this allows us to calculate the probability of various numbers of seeds germinating when sown in containers. The basis for these calculations is the **binomial expansion.**

Binomial expansions for several sowing condilions are presented below, where X equals the probability of a seed germinating and Y equals the probability of a seed failing to germinate.

$$(X + Y)^2 = X^2 + 2XY + Y^2$$

illustrates the conditions that can occur after 2 seeds have been sown. X^2 is the probability of both seeds germinating, 2XY is the probability of 1 seed germinating and the other failing to germinate, and Y^2 is the condition where both seeds fail to germinate.

$$(X + Y)^3 = X^3 + 3X^2Y + 3XY^2 + Y^3$$

represents the conditions that can occur when 3 seeds are planted.

$$(X + Y)^4 = X^4 + 4X^3Y + 6X^2Y^2 + 4XY^3 + Y^4$$

represents the conditions that can occur when 4 seeds are planted.

$$(X + Y)^5 = X^s + 5X^4Y + 10X^3Y^2 + 10X^2Y^3 + 5XY^4 + Y^5$$

is the mathematical expression of the conditions that can occur when 5 seeds are sown.

Consider the case $(X + Y)^4$. The exponent 4 indicates that 4 seeds were planted.

X^4 indicates the probability of all 4 seeds germinating.

$4X^3Y$ indicates the probability of only 3 seeds germinating and 1 seed failing to germinate.

$6X^2Y^2$ is the probability of 2 seeds germinating and 2 seeds failing to germinate.

$4XY^3$ is the probability of 1 seed germinating and 3 seeds failing to germinate.

All of the above conditions amount to about the same thing, a living seedling in the cell. The condition that concerns us most is the last.

Y^4 is the failure of all 4 seeds to germinate-an empty cell or container with no seedling.

Knowing this allows us to quickly calculate the probability of empty cells, given the number of seeds sown, if we know the germination rate of the seed we are sowing. A hand-held calculator makes this as easy as falling off a log! (Math humor and tree humor at the same time?)

To calculate the number of seeds necessary per cavity to achieve a given number of live seedlings, raise the decimal expression of the percentage germination failure rate to the seeds per cell power.

Any hand-held calculator with a universal power key (figure 1) can be used. Here's what I do: first, key-in the decimal representation of the germination failure rate, then key-in Y^X, key-in number of seeds I might sow, and finally, key in equals.

Try this example: A seed lot has 95% germination, that is 95% of the seeds grow, 5% don't. This is a failure rate of .05. If I plant 1 seed per cavity I would calculate .05 raised to the 1 power = .05 or 5% blanks.

Now try 2 seeds: .05 raised to the 2 (second) power is $.05^2 = .0025$. Only .25% blanks, less than one per hundred.

A second way to look at this example is the first 100 seeds will produce 95 seedlings; sowing an additional hundred seeds in the same cells will yield only 4 to 5 more seedlings. In my judgment, that is not a very wise use of seed.

Now try a seed lot with 78% germination, that is a 22% failure rate. For 1 seed per cell, calculate .22 to the first power: 22% empty cells. For 2 seeds per cell, calculate .22 to the second power: .0484 = 4.84% empty cells. How about 2½ seeds per cell? Calculate $.22^{25} = .0227$ = 2.3% empty cells.

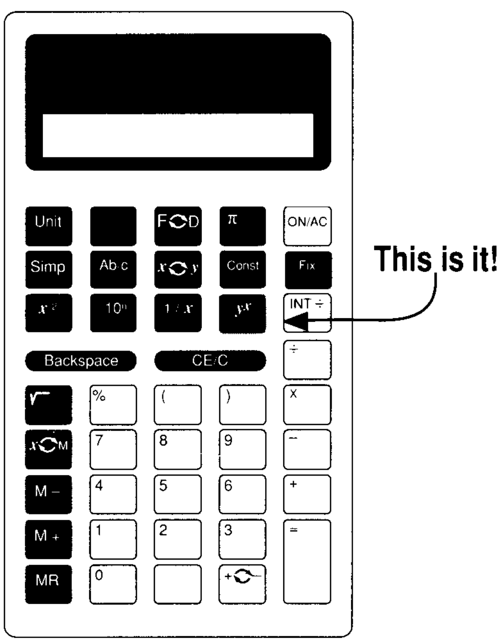

Figure 1—*Calculator with universal power key (∧, exp, Y^X, or X^y) indicated.*

For 3 seeds per cell, calculate .22 to the third power: .010648 = 1% empty cells.

Another way to look at this example is that the first hundred seeds yield 78 seedlings, the second hundred seeds yield 17 more trees, and the last hundred seeds used yield only 4 more trees. So now we are faced with the following questions:

- ! Should I plant four seeds per cell to get a rate of .22 to the fourth, or .0023 = .2%, less than 1% empty cells?
- ! Would it be worth 100 seeds to get one more tree?
- ! For that matter, was it worth 100 seeds to get 4 more trees, the difference between 2 and 3 seeds per cell?
- ! Should I drop back to 2 seeds per cell, have less thinning, and only get about 5 blanks per hundred cells?
- ! How much did this seed cost?
- ! How much seedborne disease is in this stuff?
- ! How long do I want to run this seeder?
- ! How reliable are the germination data anyway?

I don't know the answers to any of these questions. But now I hope you know how to calculate the number of expected empty cells depending on seed germination and number of seeds sown.

Short Cut or Guess and Check

1. **Enter the % germination failure.**
2. **Enter exponent (common symbols for this universal power key are ^ *(the carat symbol)* *exp,* Y^X, X^Y)**
3. **Enter how many seeds you want to sow per cell.**
4. **Enter equals (=). If this rate is close to acceptable, do it!**

If a calculator lacks the capability to raise a number to a variable power, just use repeated multiplication, for whole number amounts. For example: .22 germination failure, 3 seeds per cell.

$$.22 \times .22 \times .22 = .010648$$

Only 1% empty cells.