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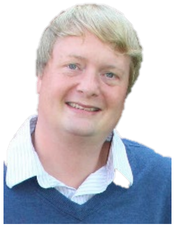

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Square foot weeks: quantify space-use efficiency for greens and herbs

The importance of space use efficiency in the greenhouse environment was impressed on me by many individuals, but especially by Dr. Lou Albright. Professor Albright was the late, great co-founder of Cornell's Controlled Environment Agriculture program. An excellent short biography of his life and work is here. Lou stressed the importance of space use efficiency in greenhouses, especially those in northern environments that are expensive to heat, light, and operate. Thus, it is important for a grower to understand and optimize their crop's space use.

An excellent embodiment of this is the Cornell CEA method for hydroponic deep water culture (DWC) head lettuce production in which a 5-6 ounce (150+ gram) head lettuce crop can be produced in 35 days from seed to harvest provided the greenhouse environment was optimized. The production protocol calls for 3 crop stages, each at different plant spacings that improve overall space use efficiency.

The seedling stage was in 1-inch propagation cubes for 11 days at which time they were transplanted to DWC rafts at an initial spacing of 9 plants per square foot. Plants were grown at this spacing for 10 days. At this point, when plant leaves are on the verge of overlapping with neighboring plants they are respaced to final rafts at 3.5 plants per square foot and grown on for their final 14 days. Dr. Chris Currey at Iowa State University also has an excellent description of this concept in his e-Gro Edible Alert e708.

So, what are square foot weeks? This is a calculation that is a measure of the total space and time it takes to grow a plant. The calculation considers the number of weeks and fraction of a square foot that a plant took at each stage (i.e. spacing regime). A more efficient crop will use less square foot weeks. Lettuce consider (pun intended) the Cornell CEA spacing regime as noted above. For each crop stage multiply the number of weeks times the fraction of a square foot the plant takes. Then we sum these up over the whole crop cycle.

Scenario 1: Cornell CEA spacing for DWC butterhead lettuce
Seedling stage: **1.5 weeks**
Plants per square foot: 144
Square feet per plant: (1 sf/144 plants) = 0.0069 sf / plnt
Square foot weeks per plant = 0.0069 (sf / plant) x 1.5 wks = 0.01035
Transplant stage 1: **1.5 weeks**
Plants per square feet: 9
Square feet per plant: (1 sf/9 plants) = 0.11 sf / plnt
Square foot weeks per plant = 0.11 (sf / plant) x 1.5 wks = 0.165
Transplant stage 2: **2 weeks**
Plants per square foot: 3.5
Square feet per plant: (1 sf/3.5 plants) = 0.286 sf / plnt
Square foot weeks per plant = 0.286 (sf / plant) x **2** wks = 0.571
Total square foot weeks per plant = 0.01 + 0.165 + 0.571 = **0.75**

Now let's compare this to a scenario where we use the same seedling stage but instead of two transplanting stages we just transplant to the final spacing. A grower might be interested in this strategy because you can save the labor of transplanting from stage 1 to stage 2.

Scenario 2: Seedling stage then transplant to final DWC spacing at 3.5 plants per square foot
Seedling stage: **1.5 weeks**
Plants per square foot: 144
Square feet per plant: (1 sf/144 plants) = 0.0069 sf / plnt
Square foot weeks per plant = 0.0069 (sf / plant) x 1.5 wks = 0.01035
Transplant stage: **3.5 weeks**
Plants per square foot: 3.5
Square feet per plant: (1 sf/3.5 plants) = 0.286 sf / plnt
Square foot weeks per plant = 0.286 (sf / plant) x **3.5** wks = 1.0
Total square foot weeks per plant = 0.01 + 1.0 = **1.01**

A neat thing we can do with square foot weeks is then calculate the weekly output from our facility. For example, let's assume every day we harvest the 35-day old plants, seed new plants, transplant some into DWC stage 1 and transplant others to DWC stage 2. Our hypothetical greenhouse has 2,400 square feet of DWC pond area (a reasonable assumption for a 3,000 square foot greenhouse. Weekly output is production area divided by square foot weeks.

Weekly output for scenario 1:
2,400 square feet / 0.75 square foot weeks per plant = **3,200 plants per week**

Weekly output for scenario 2:
2,400 square feet / 1.01 square foot weeks per plant = **2,376 plants per week**

There is more labor involved in scenario 1, but this puts you in a position to estimate if the transplanting labor is worth greater crop output, i.e. the same space giving you 824 more plants (i.e. 35% higher productivity).

Basil example

These calculations are fun! Let's look at another. Let's say you are planning to grow hydroponic basil in nutrient film technique (NFT) channels. Let's say you are looking at two different channel spacings, one in which holes are spaced 6 inches apart (gutters are also spaced 6 inches apart – center to center, resulting in each plant taking 36 square inches) and another in which holes are spaced 8 inches apart (and each plant takes 64 square inches). The production times are the same of 3 weeks at the seedling stage (1-inch propagation cubes) and 4 weeks in the NFT channel.

Scenario 3: NFT basil at 6-inch spacing
Seedling stage: **3 weeks**
Plants per square foot: 144
Square feet per plant: (1 sf/144 plants) = 0.0069 sf / plnt
Square foot weeks per plant = 0.0069 (sf / plant) x 3 wks = 0.0207
Transplant stage: **4 weeks**
Plants per square foot: 4 (i.e. plant takes up 36 square inches)
Square feet per plant: (1 sf/4 plants) = 0.25 sf / plnt
Square foot weeks per plant = 0.25 (sf / plant) x **4** wks = 1.0
Total square foot weeks per plant = 0.02 + 1.0 = **1.02**

Scenario 4: NFT basil at 8-inch spacing
Seedling stage: **3 weeks**
Plants per square foot: 144
Square feet per plant: (1 sf/144 plants) = 0.0069 sf / plnt
Square foot weeks per plant = 0.0069 (sf / plant) x 3 wks = 0.0207
Transplant stage: **4 weeks**
Plants per square foot: 2.25 (i.e. plant takes up 64 square inches)
Square feet per plant: (1 sf/2.25 plants) = 0.444 sf / plnt
Square foot weeks per plant = 0.444 (sf / plant) x **4** wks = 1.78
Total square foot weeks per plant = 0.02 + 1.78 = **1.80**

Let's assume we have a 2400 square foot NFT production system. We can now also calculate the weekly output of the two basil scenarios:

Weekly output for scenario 3 (basil at 6-inch spacing):
2,400 square feet / 1.02 square foot weeks per plant = **2,353 plants per week**

Weekly output for scenario 4 (basil at 8-inch spacing):
2,400 square feet / 1.8 square foot weeks per plant = **1,333 plants per week**

Holy cow! Assuming our basil plants never get bigger than 6 inches wide, if go with the 6-inch spacing we can produce 77% more plants per week than the 8-inch scenario. That's money in the bank!

Additional considerations for space and labor

One of the reasons I love DWC systems is because we can do this respacing and thereby have greater plant output per week. We do have to account for the labor cost of transplanting from 1 DWC raft to another. Perhaps we could prove to ourselves that in a northern greenhouse with expensive heating and lighting during the winter it's well worth our while. If we are growing in a climate where we can get away with a simpler (i.e. more cost effective) greenhouse it could be the labor cost becomes more expensive than space savings. In this case maybe we just build a larger/simpler greenhouse and just transplant to the final spacing. With automation/robotics, it may become practical to introduce several respacing steps to we have less wasted space. Then, we just need to consider if there is any transplant shock to the plant.

In traditional NFT systems the channels and their holes have a static spacing. As well, roots from one plant tend to grow into neighboring plants which may cause transplanting shock. However, one thing we can do is set up the drainpipe for our channels so that we could space our channels close together directly after transplanting and then move them further apart from each other as plants grow. At least this allows us to respace in one dimension. I also believe this is a reason we are seeing increased interest in mobile gutter systems such as Green Automation or FGM. These systems are set up to automatically move gutters through the greenhouse and respace gutters as plants grow.

Regardless of your production system and even for container plants, thinking through space use efficiency from the lens of square foot weeks calculation will help you stay a more productive grower.

References

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