Relationship between Light, Temperature and Plant Density

One of the most difficult jobs for a grower is to determine the right 24-hour temperature for his crop. How much light do the plants receive today, and what temperature should I maintain? In this article I provide more clarity into how we can play with these three parameters, in order to maintain plant vigor and maximize yield.

Joules \ Density	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5
100	16.0	16.0	15.9	15.9	15.8	15.8	15.8	15.7	15.7	15.6	15.6	15.6	15.5	15.5	15.4	15.4	15.4	15.3	15.3	15.2	15.2	15.2	15.1	15.1	15.0	15.0
200	16.5	16.4	16.4	16.3	16.3	16.2	16.1	16.1	16.0	16.0	15.9	15.9	15.9	15.8	15.8	15.7	15.6	15.6	15.5	15.5	15.4	15.3	15.3	15.2	15.2	15.2
300	16.9	16.8	16.8	16.7	16.7	16.6	16.5	16.5	16.4	16.4	16.3	16.2	16.2	16.1	16.1	16.0	15.9	15.9	15.7	15.7	15.6	15.5	15.5	15.4	15.4	15.3
400	17.3	17.2	17.2	17.1	17.1	17.0	16.9	16.9	16.8	16.7	16.7	16.6	16.5	16.4	16.4	16.3	16.2	16.1	15.9	15.9	15.8	15.7	15.7	15.6	15.5	15.5
500	17.7	17.6	17.6	17.5	17.5	17.4	17.3	17.3	17.1	17.1	17.0	16.9	16.9	16.7	16.7	16.6	16.5	16.4	16.2	16.1	16.0	15.9	15.8	15.7	15.7	15.6
600	18.1	18.0	18.0	17.9	17.9	17.8	17.7	17.7	17.6	17.5	17.4	17.4	17.3	17.2	17.1	17.0	16.9	16.8	16.7	16.4	16.3	16.1	16.1	16.0	15.9	15.8
700	18.5	18.4	18.4	18.3	18.3	18.2	18.1	18.0	17.9	17.8	17.7	17.6	17.5	17.4	17.3	17.2	17.0	16.9	16.6	16.5	16.3	16.3	16.2	16.0	16.0	15.9
800	19.0	18.9	18.9	18.7	18.7	18.6	18.5	18.4	18.2	18.2	18.1	17.9	17.9	17.7	17.6	17.5	17.3	17.2	16.9	16.7	16.5	16.4	16.4	16.2	16.1	16.1
900	19.5	19.4	19.3	19.2	19.1	19.0	18.9	18.8	18.6	18.5	18.4	18.3	18.2	18.0	17.9	17.8	17.6	17.4	17.1	16.9	16.7	16.6	16.5	16.4	16.3	16.2
1000	20.0	19.9	19.8	19.6	19.5	19.4	19.3	19.2	19.0	18.9	18.8	18.6	18.5	18.3	18.2	18.1	17.9	17.7	17.3	17.1	16.9	16.8	16.7	16.5	16.5	16.3
1100	20.5	20.4	20.3	20.0	19.9	19.8	19.7	19.6	19.3	19.2	19.1	19.0	18.9	18.6	18.5	18.4	18.1	18.0	17.5	17.4	17.1	17.0	16.9	16.7	16.6	16.5
1200	21.0	20.8	20.7	20.5	20.4	20.2	20.0	19.9	19.7	19.6	19.5	19.3	19.2	19.0	18.9	18.7	18.4	18.2	17.8	17.6	17.3	17.2	17.1	16.9	16.8	16.6
1300	21.5	21.3	21.2	20.9	20.8	20.6	20.4	20.3	20.1	20.0	19.8	19.6	19.5	19.3	19.2	19.0	18.7	18.5	18.0	17.8	17.5	17.3	17.3	17.0	16.9	16.8
1400	22.0	21.8	21.7	21.3	21.2	21.0	20.8	20.7	20.4	20.3	20.2	20.0	19.9	19.6	19.5	19.3	19.0	18.8	18.2	18.0	17.7	17.5	17.4	17.2	17.1	16.9
1500	22.5	22.3	22.1	21.8	21.6	21.4	21.2	21.1	20.8	20.7	20.5	20.3	20.2	19.9	19.8	19.6	19.3	19.0	18.4	18.2	17.9	17.7	17.6	17.4	17.3	17.1
1600	23.0	22.8	22.6	22.2	22.0	21.8	21.6	21.5	21.2	21.0	20.9	20.7	20.5	20.2	20.1	19.9	19.5	19.3	18.7	18.4	18.1	17.9	17.8	17.5	17.4	17.2
1700	23.5	23.2	22.9	22.6	22.5	22.2	22.0	21.9	21.5	21.4	21.2	21.0	20.9	20.5	20.4	20.2	19.8	19.5	18.9	18.6	18.2	18.1	18.0	17.7	17.6	17.4
1800	24.0	23.7	23.4	23.1	22.9	22.6	22.4	22.2	21.9	21.8	21.6	21.3	21.2	20.9	20.7	20.5	20.1	19.8	19.1	18.8	18.4	18.3	18.1	17.8	17.7	17.5
1900	24.5	24.2	23.8	23.5	23.3	23.0	22.8	22.6	22.3	22.1	21.9	21.7	21.5	21.2	21.0	20.8	20.4	20.1	19.3	19.1	18.6	18.4	18.3	18.0	17.9	17.7
2000	25.0	24.7	23.0	23.9	23.7	23.4	23.2	23.0	22.6	22.5	22.3	22.0	21.9	21.5	21.3	21.1	20.6	20.3	19.6	19.3	18.8	18.6	18.5	18.2	18.0	17.8

In the Netherlands, growers have largely standardized the planting density in a tomato crop. More light means a higher planting density. The Dutch climate is significantly restricted by sunlight in winter and therefore, growers start their crops at a low planting density in winter. The density is increased as light increases. But what about climates with high winter light? What planting density can be maintained at what temperature? How can the planting density be adjusted to maximize yield? What if the market demands product during times of the year when light is low?

With the table above I used my practical experience to match sunlight, density and temperature for truss and beef tomatoes. It provides a handy aid for several decisions a grower must make. The table indicates a balance between temperature, sunlight and density, in order to maintain a strong enough plant. Based on historic light levels, a determination can be made as to what planting density can be maintained. For instance, if a crop is grown through the winter, and the light levels around the shortest day averages 800 Joules, at an optimal average 24-hour temperature of 18 degrees Celsius, a planting density of 3.0 can be maintained. In some climates the summer temperature is so high that the average 24-hour temperature exceeds 22 degrees for extended periods of time. The table shows that even if the lights reaches 2,000 joules, the density should be brought back to 3.1 plants per square meter. In this way, the table helps to make an annual crop plan.

The table can also be used to ascertain what 24-hour temperature should be maintained based on how many joules the plant received during the day. For instance, if the light sum was 1,300 joules on a partly sunny day in spring, and the plant density is 3.8, the 24-hour temperature for that day should be 18.0 degrees Celsius. If the temperature was higher, the grower risks losing strength in the plant, and the head width will be reduced. Of course, the table is only a guideline, in this case for truss and beef tomatoes. For snacking and grape tomatoes, the same table can be used, but 2 degrees must be added to the temperature. Ultimately, the stem thickness will tell you if the temperature has been too high, but the table provides a useful guide.

It is also important to mention that at 24-hour temperatures of more than 19 degrees Celsius, the plant uses excess assimilates for transpiration, at the expense of yield. If, either the outside climate, or the glasshouse technology, allows the grower to maintain an average 24-hour temperature of 18-19 degrees Celsius, the highest yields will be achieved. The purple color of the temperature in the table indicates this "sweet spot", and the plant density plan should be planned in this range.

Young Plants

Young plants require less light. In warmer climates the grower can make use of this aspect by blocking out light to reduce heat in the glasshouse. In conventional greenhouses, whitewash is preferred as this keeps the heat out of the glasshouse. In semi-closed glasshouses the Par-Perfect system works better.

How much light can we shade away? The rule of thumb is that the plant needs 200 Joules plus 200 joules for every truss. Since the plant usually carries 8 trusses this means 8x200 plus 200 equals 1800 Joules as a maximum. The table below integrates the plant density into this equation.

Truss No.	Density 2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7
1	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
2	300	310	317	333	340	350	360	367	383	390	400	410	417	433	440	450	460	467	483	490	500	510	517	533	540	550
3	400	420	433	467	480	500	520	533	567	580	600	620	633	667	680	700	720	733	767	780	800	820	833	867	880	900
4	500	530	550	600	620	650	680	700	750	770	800	830	850	900	920	950	980	1000	1050	1070	1100	1130	1150	1200	1220	1250
5	600	640	667	733	760	800	840	867	933	960	1000	1040	1067	1133	1160	1200	1240	1267	1333	1360	1400	1440	1467	1533	1560	1600
6	700	750	783	867	900	950	1000	1033	1117	1150	1200	1250	1283	1367	1400	1450	1500	1533	1617	1650	1700	1750	1783	1867	1900	1950
7	800	860	900	1000	1040	1100	1160	1200	1300	1340	1400	1460	1500	1600	1640	1700	1760	1800	1900	1940	2000	2060	2100	2200	2240	2300
8	900	970	1017	1133	1180	1250	1320	1367	1483	1530	1600	1670	1717	1833	1880	1950	2020	2067	2183	2230	2300	2370	2417	2533	2580	2650

For instance, if a plant has four trusses, and the plant density is 3.0, the plant needs 750 Joules. If the light-sum for the day is 1,800 joules, the light can be reduced to 750 joules by shading away radiation, without a yield penalty.

Summary

Understanding the relationship between light, temperature and plant density is a vital part of optimizing yield. An annual crop plan must include the plant density. The tables provided in this article give an indication how the planting density, temperature and light relate to each other.

If you found this article interesting, you can read much more in my upcoming book; "How to Grow in a ModulAir Glasshouse". It is written by me and sponsored by Van Der Hoeven glasshouse builders and is full of tips on how to maximize yield in a semi-closed glasshouse. Growers will find lots of useful tips that apply to growing in general as well. If you wish to reserve an order for the limited edition of this book,

please send an email to Godfrey@glasshouse-consultancy.com. More information on my website www.glasshouse-consultancy.com

HOW TO GROW IN A MODULAIR GLASSHOUSE

My experiences

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