6. Critical Shading

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"When you can measure what you are speaking about, and express it in numbers, you know something about it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts advanced to the stage of science."

— Lord Kelvin

Kelvin was into temperature. Not satisfied with "hot", "cold", and "colder", he made measurements. He envisioned absolute zero and measured it at -273.15 degrees centigrade. Thermometry became a science. The sun's surface looks rather "hot". How hot? Answer: 5800 degrees Kelvin. Numbers are how to tell real science from charlatanry and pseudoscience.

Without any science and by a combination of accident and neglect we have grown some black walnut trees that will one day make a veneer buyer salivate. The eastern hardwood forest industry needs to know how to reliably produce similar results and establish a solid silvicultural practice for growing veneer quality black walnut consistently with minimal risk.

To say a tree species is **shade intolerant** is certainly not a number. It is "knowledge of a meager and unsatisfactory kind". All green plants are shade intolerant; it's a matter of degree. How is shade intolerance measured? I knew I would need a light meter, so I bought one for $20. That was a mistake. Anyway, it worked a little. Rather than sprinkle this document with weasel words like "approximate", "maybe", "seems", and "about", I will write like everything was accurate. It will be a better read. I know my numbers are weak, but I gag on scientific papers packed with weasel words. Kelvin wouldn't use weasel words. He wouldn't say "It seems to be about -273.15". I will leave it to real scientists to prove me wrong and do a better job with better equipment. I will be happy to be put right.

"All green plants are shade intolerant – it's a matter of degree."

Here is a simple idea. In a species monoculture with a closed canopy, lower branches wither and die. Each branch is shade intolerant just like a whole tree. So, as light passes downward through the upper leaves of the canopy, it is attenuated to a shade level that the lower branches cannot survive. Below some level, branches and their leaves are abandoned and below that point incoming light is reduced no further. A monoculture live canopy has a top and a bottom. The live height of the canopy is fixed by the light attenuation of the foliage and the shade intolerance of lower branches. The amount of shading under the canopy is self-limiting by the intolerance of each species. The light level will be the same everywhere beneath a large monoculture canopy once the trees are tall enough and the lower limbs begin to defoliate and drop.

We have two such monoculture plots on our farm: one pure black walnut and another pure eastern white pine. During mid-summer I used my $20 meter to measure the light level first out in the open, then measured again deep beneath the canopy. I got the same answer everywhere I checked under each canopy. I measured 24% of the open reading everywhere under the black walnuts and 7% under the white pines. I repeated the measurements on sunny and cloudy days and got the same percentages. How simple is that?! A single ratio easily measures intolerance light level for a species. Isn't that better than just sorting species into either a tolerant or intolerant class?

Figure 1. Eastern white pine monoculture with closed canopy and dying lower branches - general light level = 7% everywhere. We planted these trees in 1982 to kill a monoculture of multiflora rose. Multiflora rose and most weeds find 7% lighting intolerable. Autumn olive just barely survives.

Science is rightly fussy about names. Is 24% a measure of tolerance or a measure of intolerance? Once we have a measurable number, "tolerance" or "intolerance" become confusing historic names. Anyway, "Tolerance" is too gentle a word. The limiting light ratio is not about approval, it is life and death to a branch. I like the word "grave" because it has a dual meaning, but "grave" is a little too light hearted for a science. "**Critical**" is an ideal name. Hospitals use "critical" in the same situation. "Critical" can refer to **critical light ratio**, as well as the **critical crown depth**, both a level where branch dying begins.

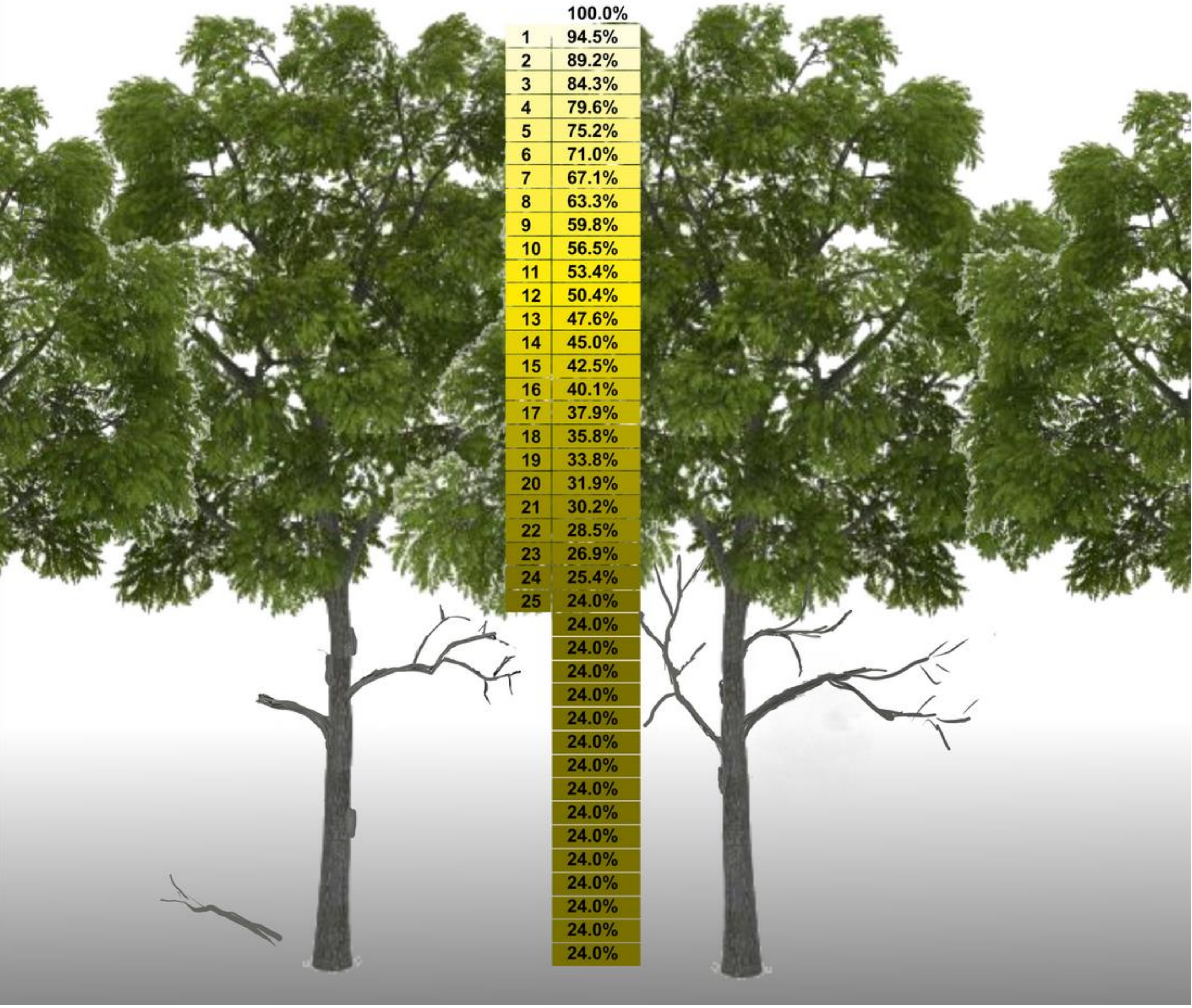

Figure 2. The light level decreases going downward through the black walnut crown foliage. A 25 foot crown of foliage reduces the light to 24%, then no further. ***diagram by W. J. Kelsey***

Canopy Light Transmittance

Another point of interest is a species' canopy density, i.e., its shade production. How much light is transmitted through a foot of canopy depth, and how much is absorbed? I estimated (excuse me Kelvin) the depth of the live canopy top to bottom. The black walnut monoculture green canopy was 25 feet deep top-to-bottom and the white pine green canopy was 20 feet. So, 25 feet of black walnut canopy reduces the light to its 24% critical level, and 20 feet of white pine canopy reduces the light ratio to white pine's 7% critical level. Combining the critical light ratio with the critical canopy depth gives the average light transmittance per foot of green canopy: 0.94 through a foot of black walnut foliage and 0.88 per foot of white pine foliage. If you would like to see the equations, check out Appendix A.

Mixed Species

By luck we also have a mixed planting of mostly white pine with dispersed black walnut. The white pines were planted on 8 x 8 foot centers in 1992 as Christmas trees. By incredible labor they were not allowed to grow more than a foot a year. By 2004 they were 12-years old and hopelessly large for Christmas trees. There were voids where we had sold trees and we made more voids by cutting out some pines. We planted 4 black walnut seeds around each white pine stump and walked away.

The black walnut seedlings grew fast and soon caught up in height. By the fall of 2018 both the black walnuts and the white pines were 48 feet tall. (This is not an estimate. I cut down some losers and measured - Kelvin would be proud.) Where black walnut was in the canopy surrounded by white pine, the black walnut green canopy thickness was only 10 feet top-to-bottom. So apparently the surrounding white pine canopy reduces the light to black walnut's critical light ratio of 24% in only 10 feet.

Figure 3. Mixed species: 14-year-old black walnut shaded by older white pines. This photo was taken late in summer when anthracnose had begun to defoliate the walnut tree, but trust me, it was leafier in mid-summer with ten feet of leafy live canopy depth. Notice the dead lower branches and that the tree is still being naturally pruned.

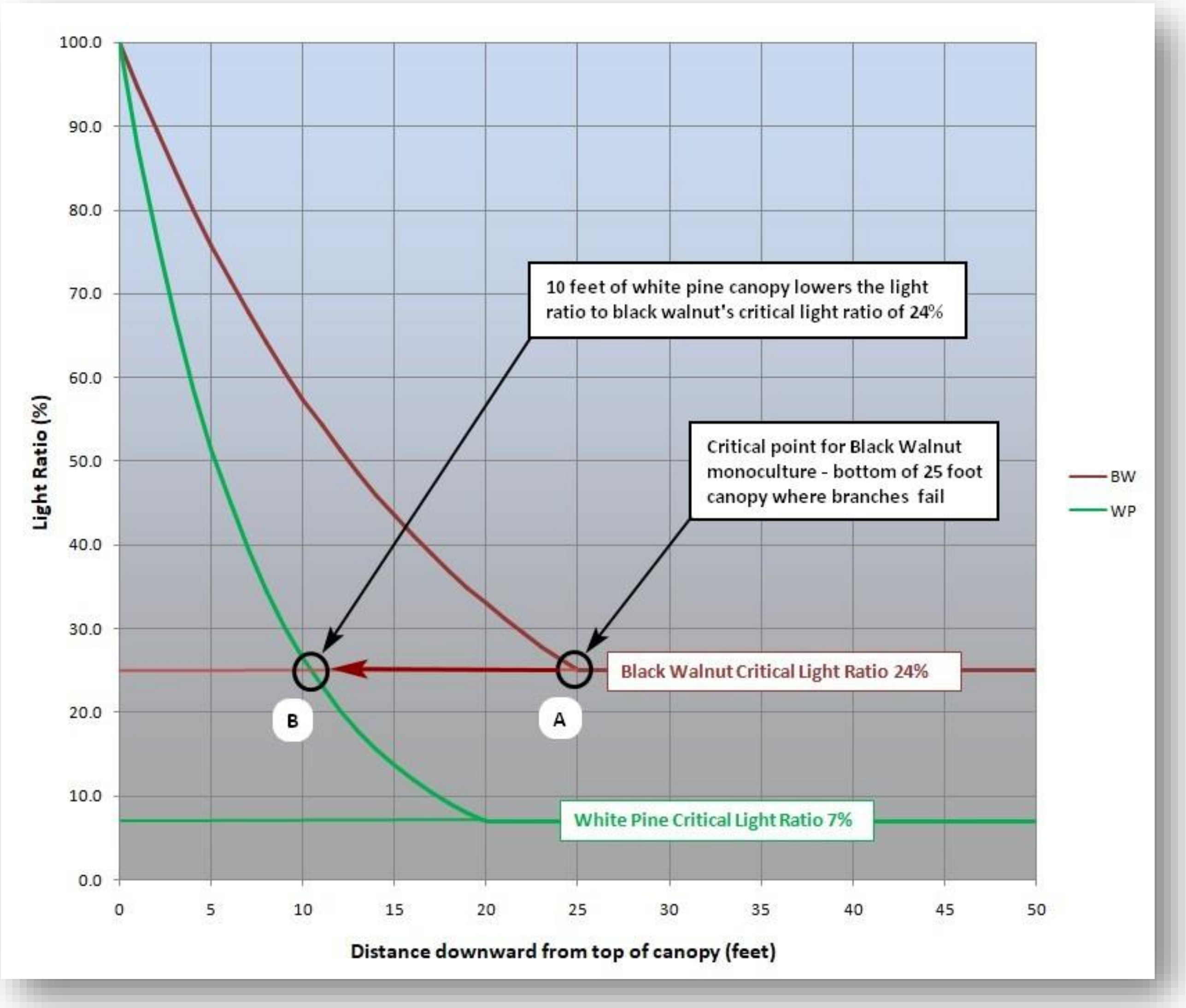

Figure 4. Light ratio descending through canopy depth for black walnut and white pine monocultures

The graph above shows the shading effect of light descending through black walnut and white pine canopies. For the issue of natural pruning, the interest is all about the underside of the canopy. For a black walnut monoculture the underside of the canopy is 25 feet from the top with a 24% light ratio (chart point "A"). Point "A" is where black walnut branch abandonment occurs. By shrewd use of white pine trainers, branch abandonment can be moved up (red arrow) to point "B", still at 24% light ratio, but only 10 feet from the top of the canopy.

By moving to point "B", black walnut branches will be abandoned much younger and smaller at 10 feet from the top. The difference between the natural abandonment of branches at 25 feet or 10 feet could not be more dramatic. In the first case (25 feet) knotty saw logs are produced. In the second (10 feet) case there is no sign the branches ever were there. Those of us with black walnut monocultures try to save the situation with manual pruning to remove branches before they would be naturally removed at 25 feet from the top – more work – poorer results.

Recap:

The critical light ratio of black walnut is 24%. 25 feet of healthy black walnut canopy attenuates the light ratio down to the 24% lethal limit. Dead branches below 25 feet cannot reduce light levels any further. Summertime light ratio measurements anywhere under a black walnut closed canopy are 24%. That is the natural limiting cut-off.

Likewise, the critical light ratio of white pine is 7%. 20 feet of healthy white pine canopy reduces the light ratio down to 7%. Lower branches cannot survive and will not reduce light any further. It is 7% everywhere in there – too dark even for most weeds.

In a mixed planting, 10 feet of white pine canopy can reduce light ratios down to the black walnut's 24% critical light ratio. The denser white pine shading causes black walnut branches to be naturally removed sooner, higher up, and at a smaller diameter.

Figure 5. The natural abandonment of branches – This black walnut tree grew in an open setting where lower branches had ample light and became large. Later the non-walnut neighbors grew tall and shaded the lower black walnut branches below their critical light ratio causing branch death. Some of the branches broke off close to the trunk, leaving numerous bumps. Other dead branches hang on, forming "widow-makers".

Veneer buyers drive past here at full speed with their eyes straight ahead.

Appendix A: Transmittance

The ambient light level is: L_0 = 100%, and the light transmittance through a foot of canopy is T, and just for laughs say 10% is absorbed and 90% gets through each foot. The transmittance then is: T = .9 per foot. So the light out the bottom of the topmost foot is $L_0 * T = 100\% * .9 = 90\%$, which is also the light going into top of the next foot down. The light coming out of the bottom of next foot down is 90% * .9 = 81% or $L_0 * T^2 = 81\%$. The light escaping below the N^{th} foot of canopy is

$L_N = L_0 * T^N$ or the light ratio is $L_N / L_0 = T^N$.

Taking the Nth root of both sides gives

$(L_N / L_0)^{(1/N)} = T^{N(1/N)}$ or $T = (L_N / L_0)^{(1/N)}$

In the critical case for black walnut the critical crown depth is N_C = 25 feet and the critical light ratio is $L_C/L_0 = .24$ Black walnut, 24% after 25 feet, transmittance is: $T_{BW} = .24^{(1/25)} = 0.9445$ per foot. For white pine, 7% after 20 feet: $T_{WP} = .07^{(1/20)} = 0.8755$ per foot.

If the goal is to reduce the light ratio to 24% within 10 feet of canopy, Then the trainer's light transmittance needs to be

$T = .24^{(1/10)} = 0.867$ per foot or less.

Note: All these numbers are originate from a $20 light meter.

Figure 8. A dispute between an unknown tree species and a sidewalk showing an extreme case of light limiting by foliage and branch death.

Appendix B. Observations:

We always want to know if our black walnut plantation will achieve veneer quality. Understanding the details of this "no intervention" natural pruning process explains the old veneer buyer's comment, "I never bought a top-quality veneer tree that didn't grow deep in a forest." The rub is that shade intolerant black walnut rarely grows deep in a forest. They need to be tricked.

Hugh Pence has a 100-acre black walnut monoculture plot which has been faithfully pruned. The bole quality is impressive, but it is still easy to see all the work that Hugh has done. I saw some beautiful flawless quality trees, the kind we want, but smaller than the majority. Hugh said "Oh, those are coppiced." – Interesting! They grew up in subdued light, and the general population acted as trainers. If the canopy was closed and the light ratio was down to 24%, they might have given up at the start. But coppice sprouts take off with stored vigor, and there is a hole in the canopy above. If the tops can get to some daylight and the lower parts are in the shading death zone – voila!

Figure 11. Bark like this on a young tree is the goal. Flawless bark tells the story that there are no big knots and there is no decay inside. I was absent for many years. The existence of trees like this was a pleasant surprise in 2018.