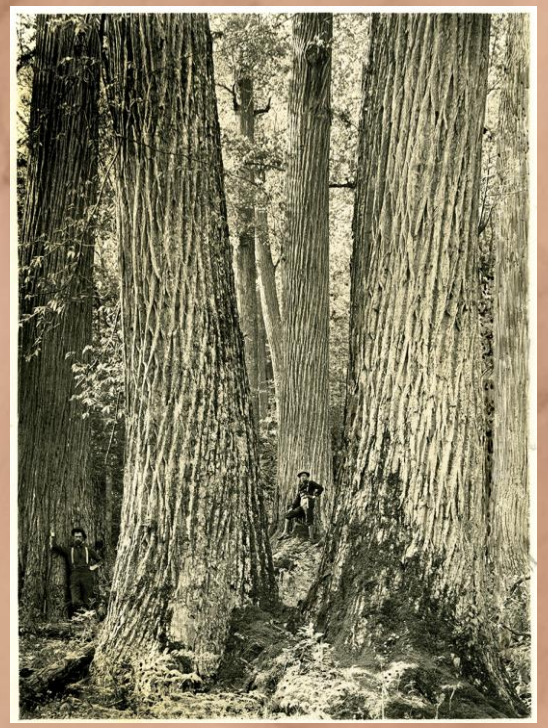
CHESTNUT CHAT

WOOD QUALITY IN HYBRID CHESTNUTS

CHARLES D. RAY, PH.D.

THE PENNSYLVANIA STATE UNIVERSITY

9/17/2021



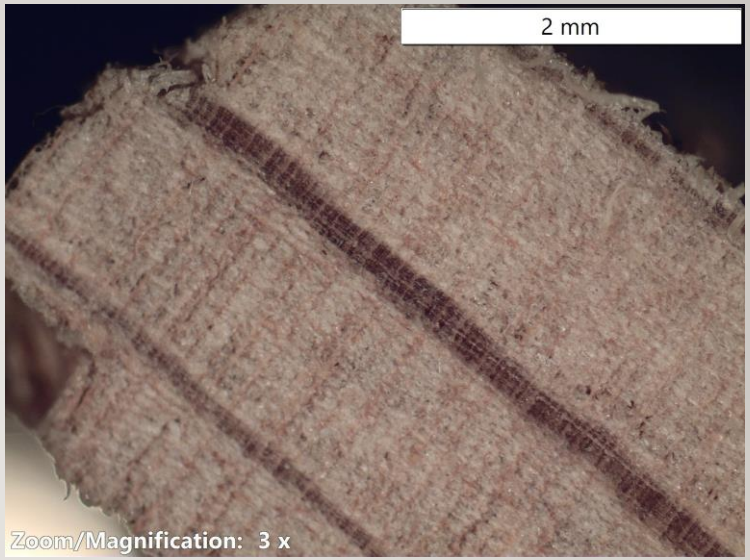
THE AMERICAN CHESTNUT FOUNDATION®

WOOD DICHOTOMIES TO BE CLEAR ABOUT

- Hardwood/Softwood
- Heartwood/Sapwood
- Earlywood (Springwood)/Latewood (Summerwood)
- Juvenile wood/Mature wood
- Green wood/Dry wood

Source: Researchgate.net (Liang Mei)

SOFTWOOD
Baldcypress



HARDWOOD/SOFTWOOD

Hardwoods: Angiosperms (Deciduous trees)

Softwoods: Gymnosperms (Coniferous trees)

No real relation to the "hardness" or "softness" of the wood.

http://gowood.blogspot.com search for hardwood softwood

HARDWOOD
Sumac

HEARTWOOD/SAPWOOD

Heartwood: Central portion of stem no longer conducting water or serving food to the tree

Sapwood: Outer "living" portion of the stem where water conduction and food storage occurs.

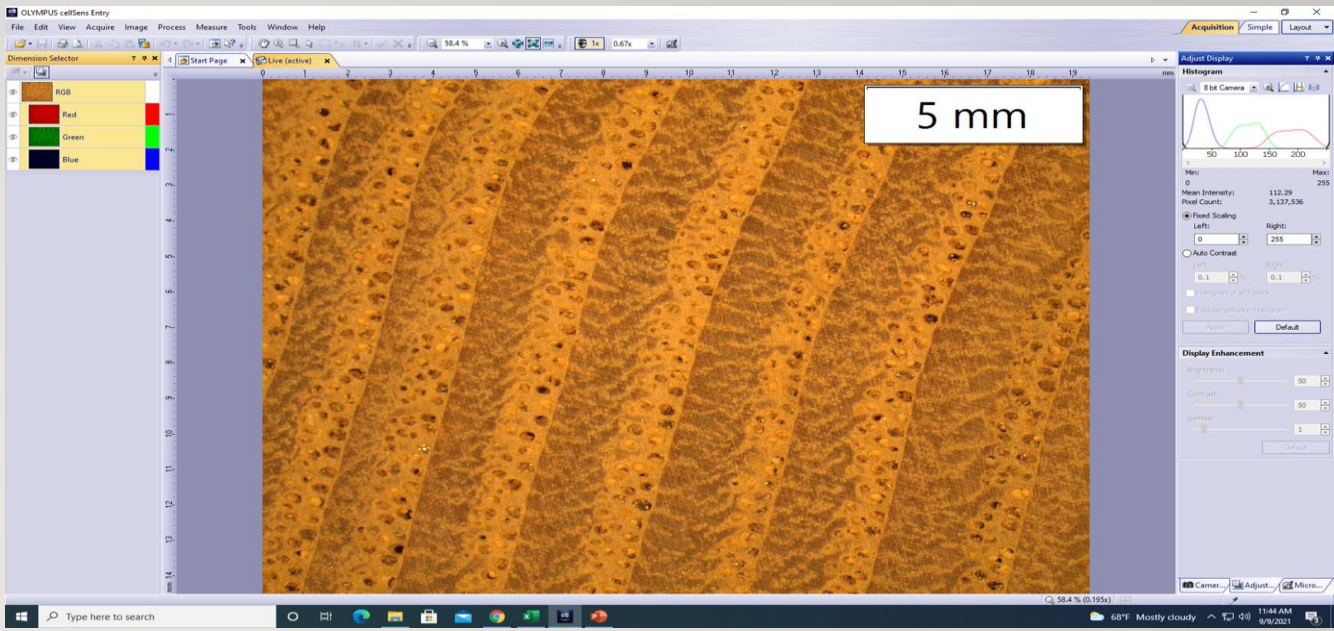
Relative size of heartwood and sapwood varies according to growing conditions.

Sumac showing gradual transition of sapwood to heartwood

Hemlock showing distinct transition of heartwood to sapwood

EARLYWOOD/LATEWOOD

- Earlywood is formed from the time the sap begins rising in the late winter until roughly the summer solstice, when days begin to shorten. New cell generation responds to lengthening days and plentiful water. In "ring-porous" hardwoods (such as chestnut and oak) the first cells produced each year are called "pores", which are large open vessel cells that allow large volumes of water to flow at the beginning of annual growth.
- Latewood is formed during the later part of the growing cycle when less sap flow is occurring, days are shortening, and tree growth is primarily in the form of thickening latewood cells rather than porous vessel cell production. The transition between earlywood and latewood can be distinct or gradual.



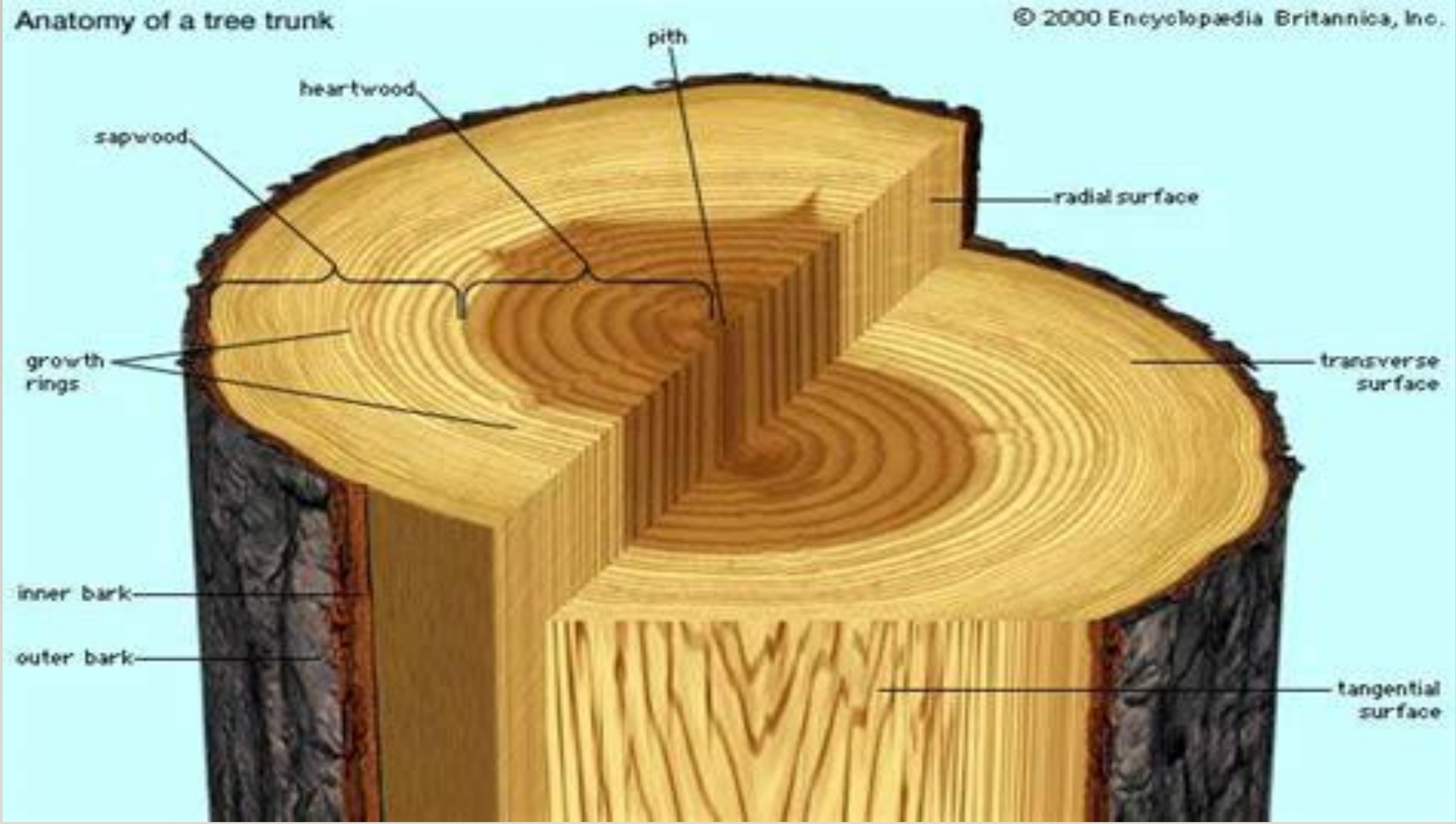
JUVENILE/MATURE WOOD

- **Juvenile Chestnut**
- Higher growth rate (wider rings) usual to trees in their first 8-12 years of life
- More variability in growth ring shape
- Greater microfibril angles due to environmental adaptation
- Lighter in color due to higher percentage of earlywood
- Lower density(?)

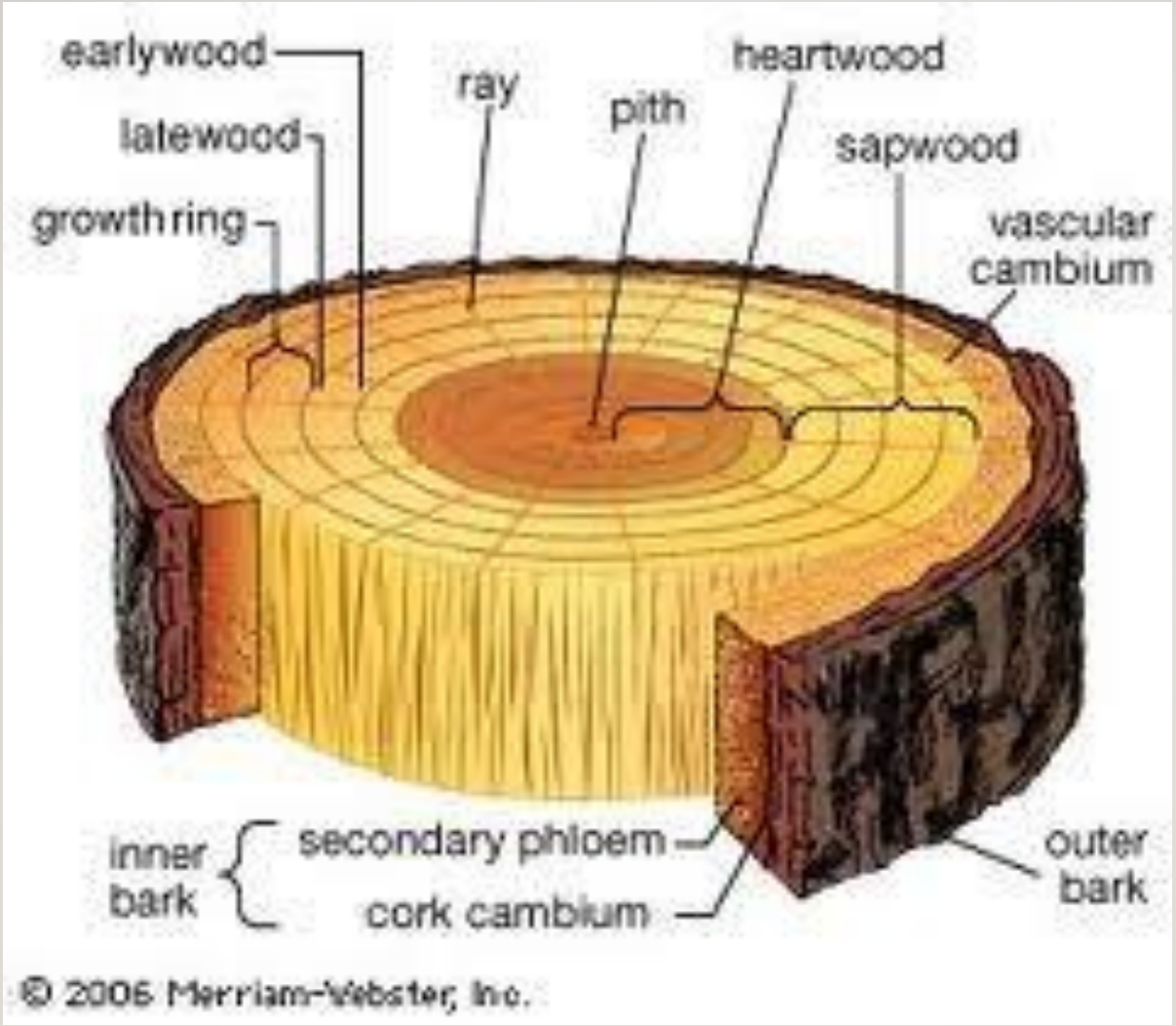
- **Mature White Ash**
- Lower growth rate (narrower rings) usual to "mature" trees
- Growth rings much more concentric and uniform
- Microfibril angles less pronounced and more uniform
- Darker in color due to higher percentage of latewood
- Higher density?

GREEN WOOD / DRY WOOD

- Green wood typically has been harvested in the last year and has a moisture content higher than 20%. It is going through a natural process of drying down to "equilibrium moisture content" (EMC) which is from 10-16% MC in different parts of North America. Green wood is so called because many species exhibit a greenish hue when at higher moisture content. Chinese chestnut, for example, appears very green when freshly cut, as does sycamore, striped maple, and yellow poplar.
- Dry wood is wood that is at or near EMC (below 20%) either through natural air-drying or mechanical kiln-drying. Natural air-drying can be sped up by minimizing moisture exposure in a drying shed, an industrial pre-drier, or a climate-controlled room. Dried wood typically changes color from slightly to a lot depending on the species and the cut of wood.



Source: Brittanica.com



Source: Merriam-Webster.com

CHARACTERISTICS OF PLANTATION CHESTNUTS

- Specimens from culled trees – significant impact from blight cankers
- Mostly, if not all, "juvenile" wood
- "Saplings" – mostly sapwood, high moisture content, "green"
- Thin bark
- Attractive to insect pests in most of tree's lifetime, resulting in…
- Annual deformative impact on wood development

CHARACTERISTICS OF MATURE FOREST CHESTNUTS

- Steady growth patterns in majority of the tree's lifespan
- Thick bark – resistant to pests
- Mostly "mature", not "juvenile" wood
- Mostly heartwood…lower moisture content

GENESIS OF A RESEARCH PROJECT

Chestnut wood - Protected View - Saved to this PC

Search

Ray Sr., Charles David

File Home Insert Design Layout References Mailings Review View Help

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The Appearance of Wood from Backcrossed American Chestnut Trees

By Gary P. Carver

At the TACF 2008 annual meeting in Chattanooga, Tennessee, Maryland chapter members distributed souvenir 25th anniversary coasters to the attendees. We made them from cookies cut from B3 trees rogued from our ThorpeWood orchard, the first backcross orchard in Maryland. I was struck by how unattractive the wood looked.

I've worked with many kinds of woods over many years to make furniture and sculpture. Carving is my specialty and for that I mainly use flexible-shaft carving tools and power gauges. I do not paint my carvings because I want them to show the natural beauty of the woods, especially rescued old woods like American chestnut from barn beams. To me, it is mainly the beauty of the wood, especially its natural color and grain patterns, that makes a carving attractive. I think American chestnut wood is the most beautiful domestic wood.

Since my experience with the anniversary coasters, I have been thinking about the visual attractiveness of the wood from trees in our breeding program. Since we want the wood from the restored American chestnut tree to be commercially valuable due to the tree's fast growth and the wood's high strength-to-weight ratio, rot resistance, and other useful physical qualities, surely, we also want it to have straight grain and be as aesthetically pleasing as pure American chestnut wood.

But, are we, in selecting for blight resistance in our backcrossed trees (because we must), also inadvertently selecting for Chinese wood-like characteristics? I consider Chinese chestnut wood as unattractive compared to American chestnut wood. To me, he wood from the ThorpeWood B3s looks Chinese.

I thought about what we could do to monitor the wood qualities in our breeding program. I kept coming up with the joke that we should cut selected trees to examine the wood. "Oops, that was a good one—too bad we cut it down!

In the last few years, our chapter has rogued our breeding orchards to give the best trees space to mature and to prepare for open pollination of the selected trees. I collected sections of logs from some of the rogued trees. This report is a summary of what I found by preparing and photographing samples of the wood from Americans, Chinese, one F1, B2s, B3s, and B4s from our orchards; B3F2s from Meadowview; and one of my B3F3s that died from blight. All the samples I collected from our orchards and all the samples of B3F2s that I received from Meadowview are shown in the figures.

Sample preparation

I cut each stem section to an approximate one-foot length. I cut a one-inch-thick cookie from each one. Then I made a ripping cut near the center. I sanded one side of the cookie and the flat surface of the larger of the two stem sections of each tree sample with better than 100-grit sandpaper. The cookies exposed the end grain and the ripped stem section exposed the side, or "face," grain. See Figure 1.

Appearance of Chestnut Wood

To evaluate the density, hardness, strength, and other physical and mechanical properties of wood requires preparing specialized samples. Whereas appearance, especially coloration and "figure," the markings on side- or face-grain surfaces of wood, is a characteristic that is easily observed and typically visually distinctive among different kinds of wood.

Compared to other deciduous trees (commercially known as "hardwoods"), American chestnut wood is of medium density and hardness. The heartwood is light brown, often with a reddish or cocoa tinge. Since it is a ring-porous wood, the "grain," i.e., the visible growth ring structure, is prominent. The earlywood (spring growth) has large pores. The latewood (summer growth) has small pores that are not easily visible without magnification. Therefore, to the unaided eye, the latewood appears to have no pores.

In chestnut, the rays, bands of tissue that are radial and cross the annual rings, are very narrow and are difficult to see even with magnification. The result is that American chestnut wood has prominent grain and is "clean" looking, that is, there are hardly any figure and/or markings in the wood between the layers of pores. See Figures 2 and 3.

Chinese chestnut wood, by comparison, has a light greenish or olive-brown color. It has less prominent grain and has irregular, random markings in its latewood. See Figure 4.

Comparisons of the different breeding-tree categories

To compare the samples, I sorted them into breeding generations and set them on a white paper with a faint one-inch grid spacing. I took photos with a digital camera. The cropped and brightened photos in this article are otherwise unchanged; I made no other adjustments. The samples were lit with a row of incandescent bulbs and the built-in flash of the camera. This was the closest I could get to having the photos show the color I could see with my naked eyes. But the coloration is still not perfect; even in daylight, photos did not look like the color I could see by looking at the wood. Every photo I show was taken under the same conditions.

The comparisons are complicated by the different diameters of the samples and, therefore, the different ratios of sapwood to heartwood. However, there are general trends that are discernable in the appearance of the wood, both within each tree generatio

Since the different generations of breeding trees have var
expectation is that the F1 wood may have some apparent
generations may tend more and more toward American c

That is approximately what I observed, as can be seen in F
to see the differences by looking at the samples directly).
samples (the B3s and B3F2s) do not look like pure Americ
"busy" appearance with streaks of darker and lighter colo
tendency toward greenish (Chinese) tints. There is wide v
samples. Some of them look more like American wood th

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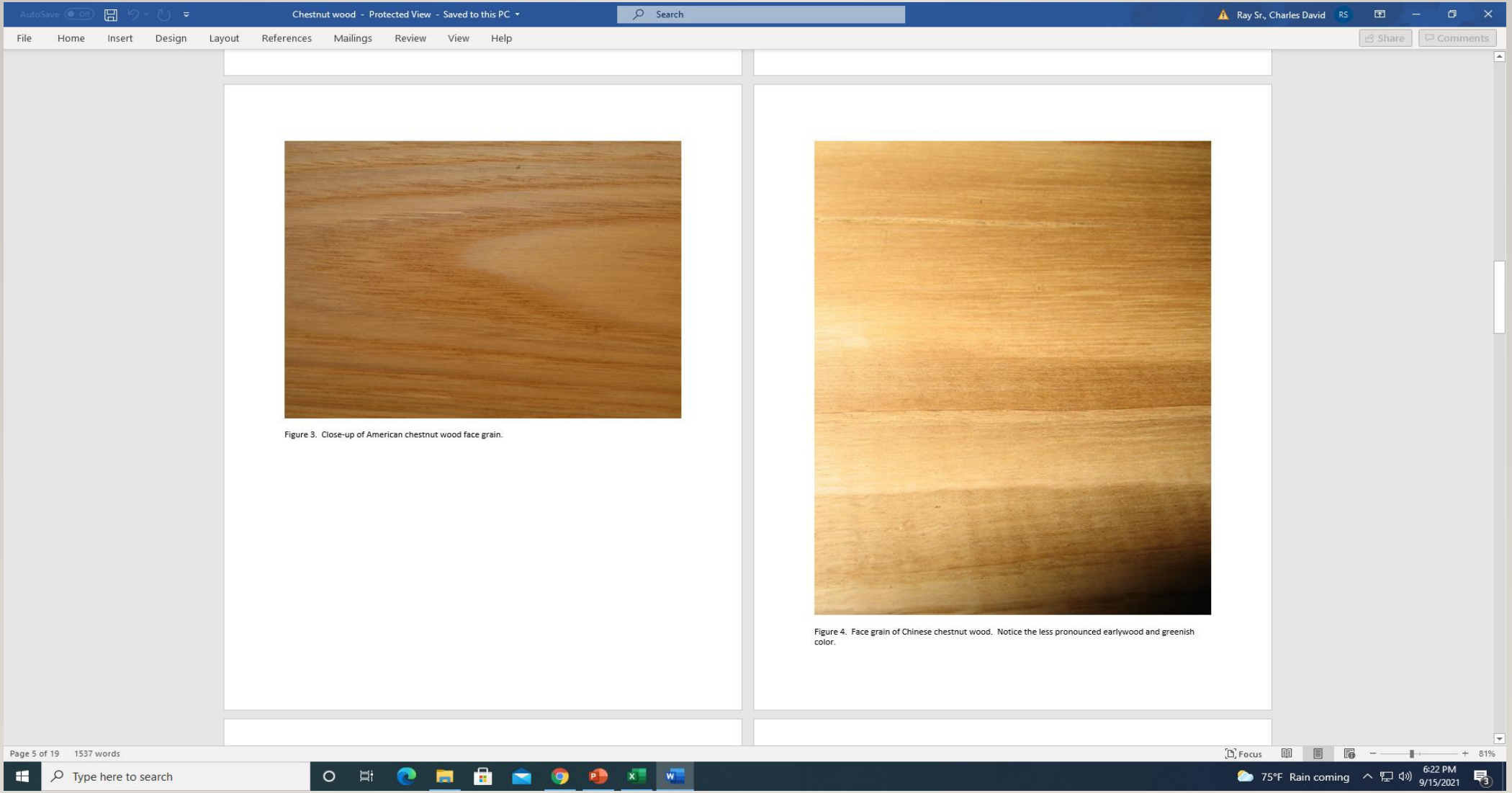
GENESIS OF A RESEARCH PROJECT



The lab set-up

- Computer, Olympus SZ6 microscope with camera, light source, and scale
- Schott 150 watt tungsten halogen light source with solid state rheostat
- Light level, specimen position, light sources, and microscope lens in fixed positions
- Slight differences in specimen height corrected with microscope focus to maintain a constant focal distance

Step 1. Develop Color Index for Use in Quantifying Color Differentials

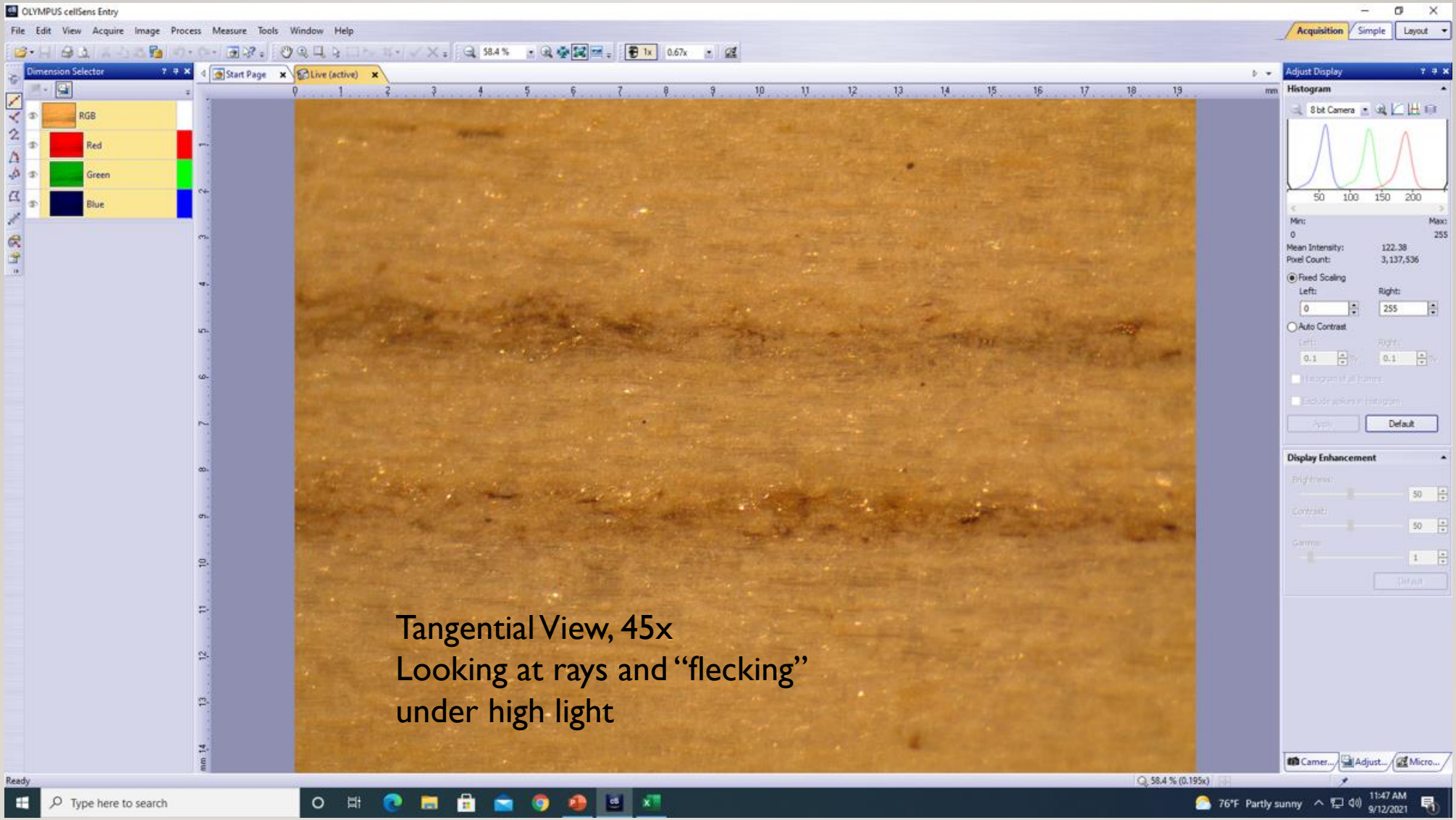

DICK 152
AM
MOND 298 B2
THPW-2
B3
WSSC 112 B4


DICK 152
AM


DICK 152
AM
MOND 298 B2
THPW-2
B3
WSSC 112 B4
DICK 117 CH

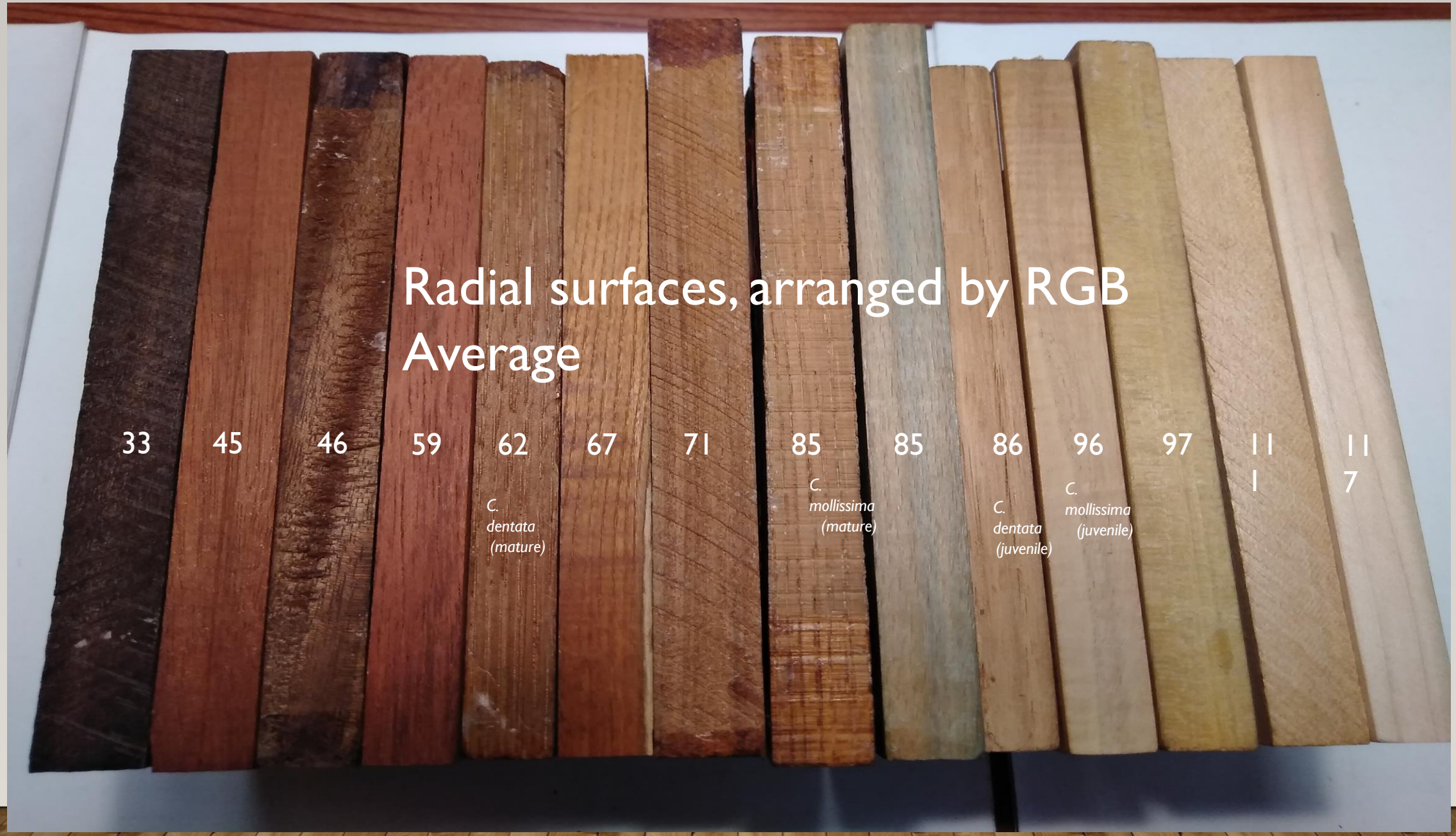

DICK 152

Using the Computer Software to analyze color



WHAT EARLY DATA TELL US…

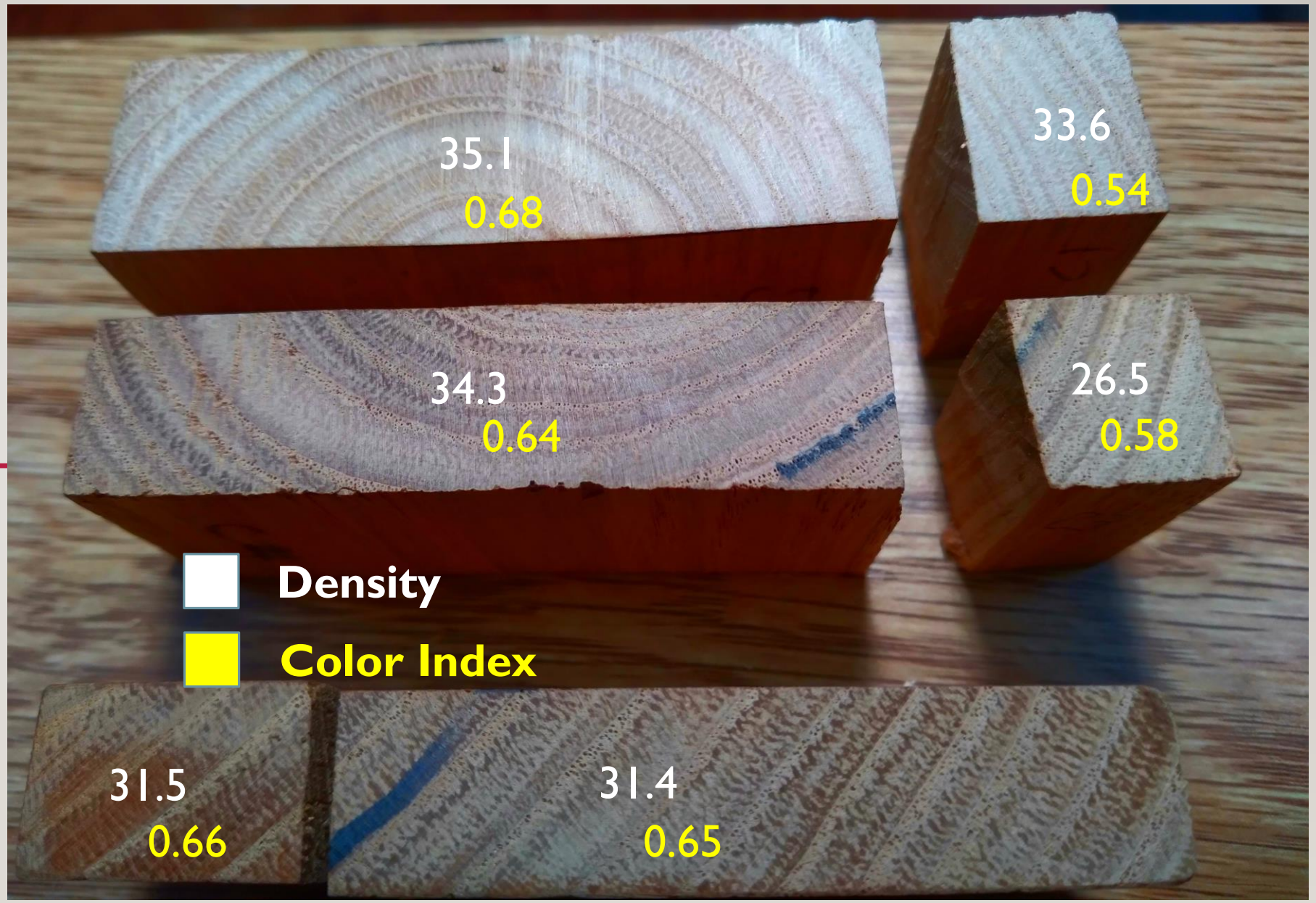
- Chestnut color differentiable from other species


Radial surfaces, arranged by RGB Average
33
45
46
59
62
C. dentata (mature)
67
71
85
C. mollissima (mature)
85
86
C. dentata (juvenile)
96
C. mollissima (juvenile)
97
111
117


Radial surfaces, arranged by calculated Color Index
1.49
1.37
1.24
1.22
1.18
1.16
C. dentata (mature)
1.10
1.02
C. mollissima (mature)
1.02
C. dentata (juvenile)
0.94
C. mollissima (juvenile)
0.93
0.89
0.84
0.76

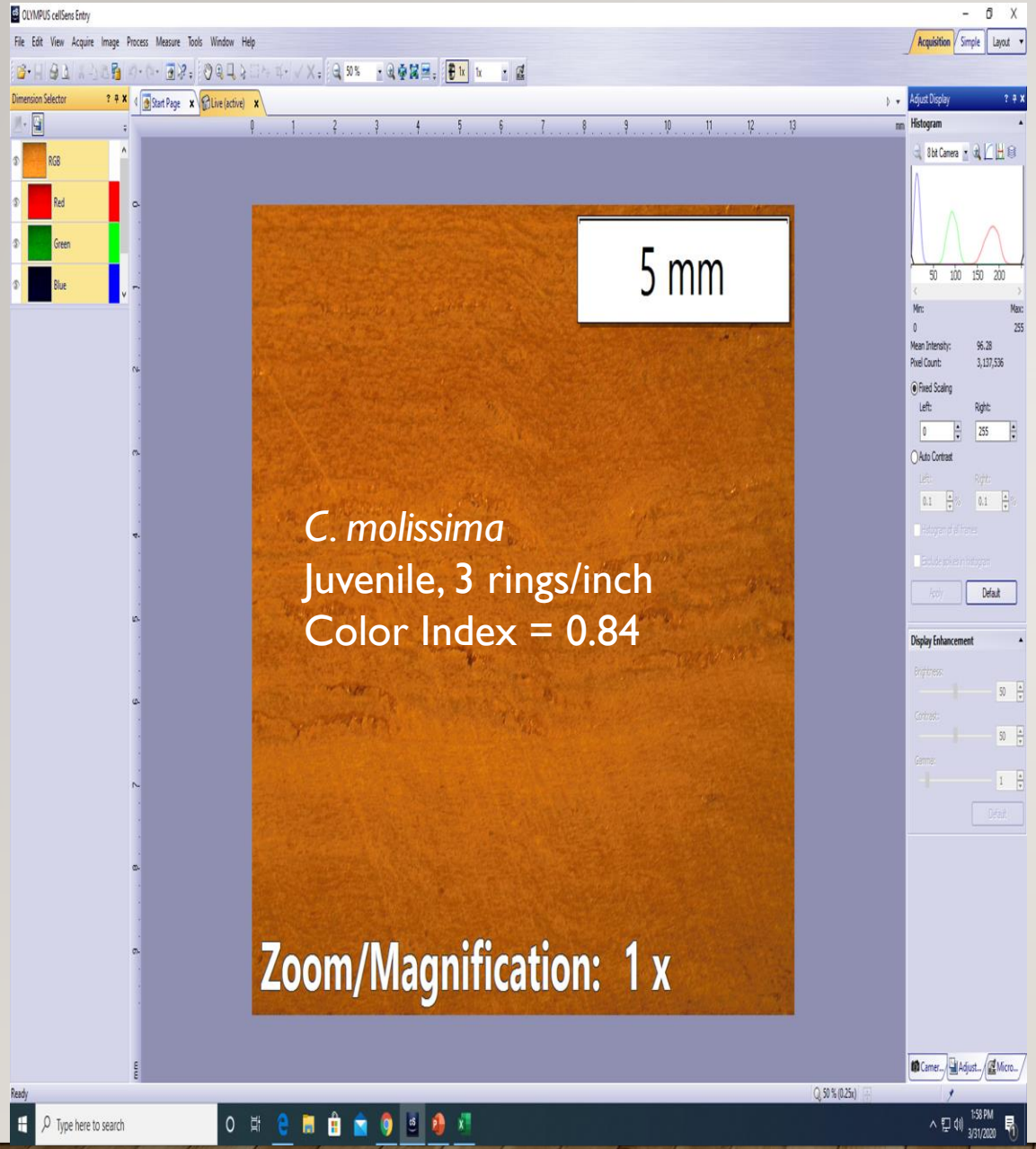
C. SATIVA ANALYSIS

- Three different specimens in Penn State xylarium
- First determined density of three standard specimens (3x6x0.5)
  - 34.2 lbs/cuft
  - 33.7 lbs/cuft
  - 31.9 lbs/cuft
- Split into Juvenile/Mature Wood and reduced to macroscopy size. Then re-determined density of six and performed macroscopy
- Density and color data confirmed juvenile wood differential in first two specimens, but also showed that all wood in Specimen 3 (new 5&6) was mature wood



WHAT EARLY DATA TELL US…

- Chestnut color differentiable from other species
- Chestnut color differentiable based on juvenile/mature wood

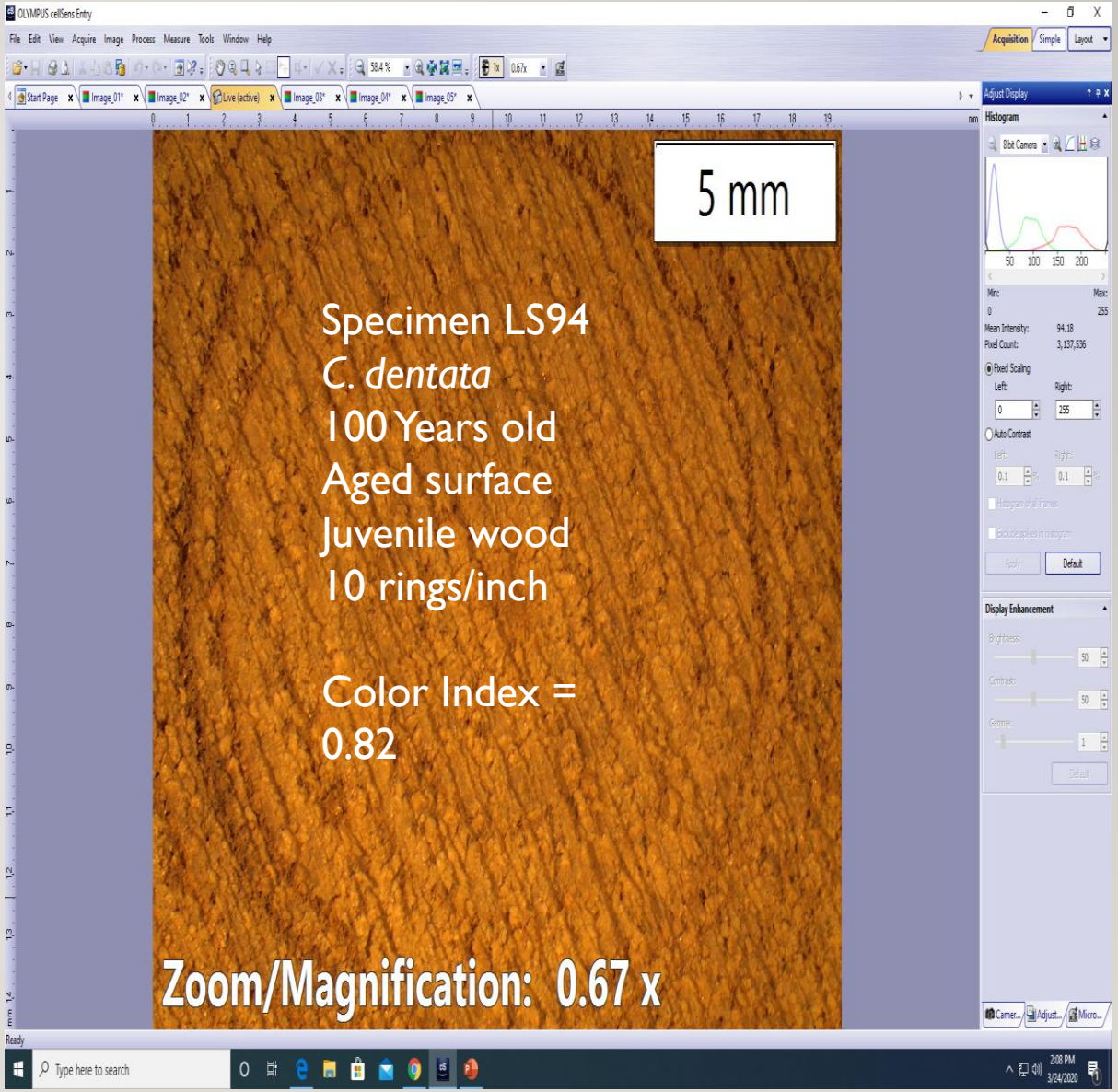

5 mm
C. molissima
Juvenile, 3 rings/inch
Color Index = 0.84
Zoom/Magnification: 1 x


5 mm
C. dentata
Mature, 5 rings/inch
Color Index = 0.90
Zoom/Magnification: 1 x

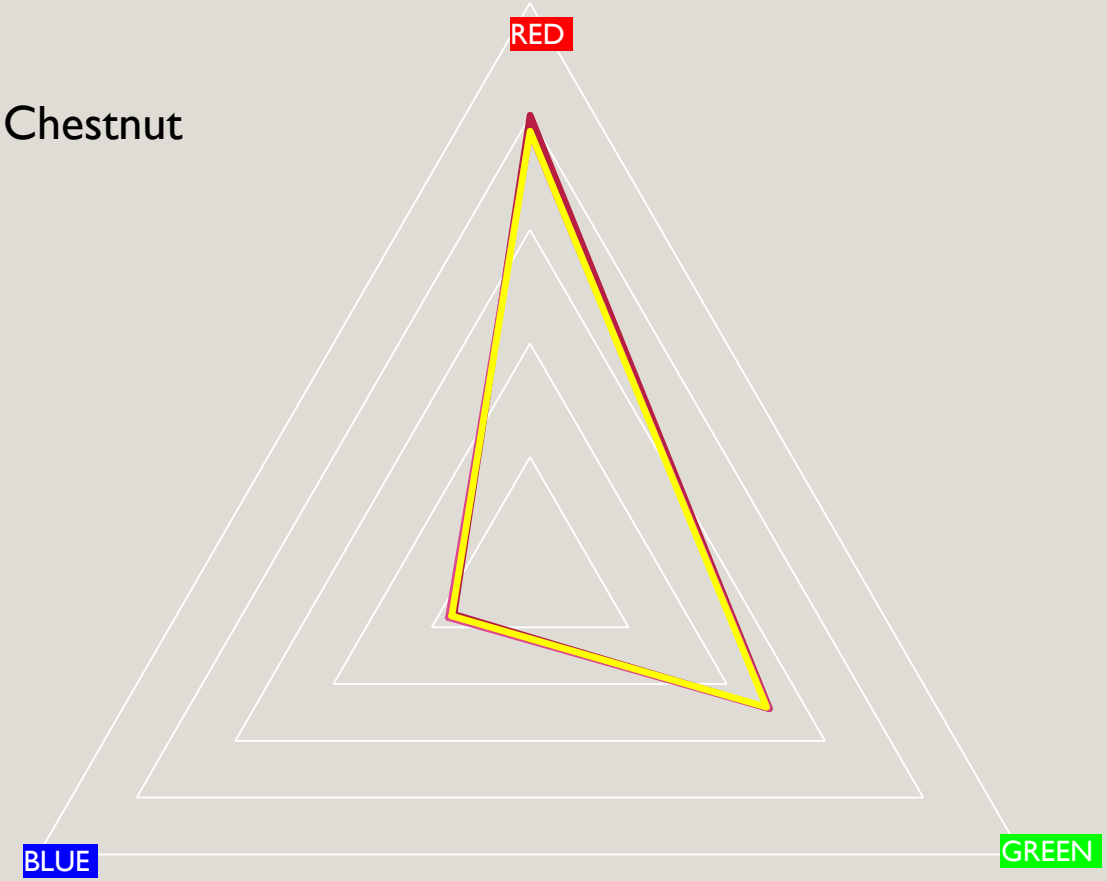
WHAT EARLY DATA TELL US…

- Chestnut color differentiable from other species
- Chestnut color differentiable based on juvenile/mature wood
- Chestnut color not differentiable by species within juvenile/mature wood classification

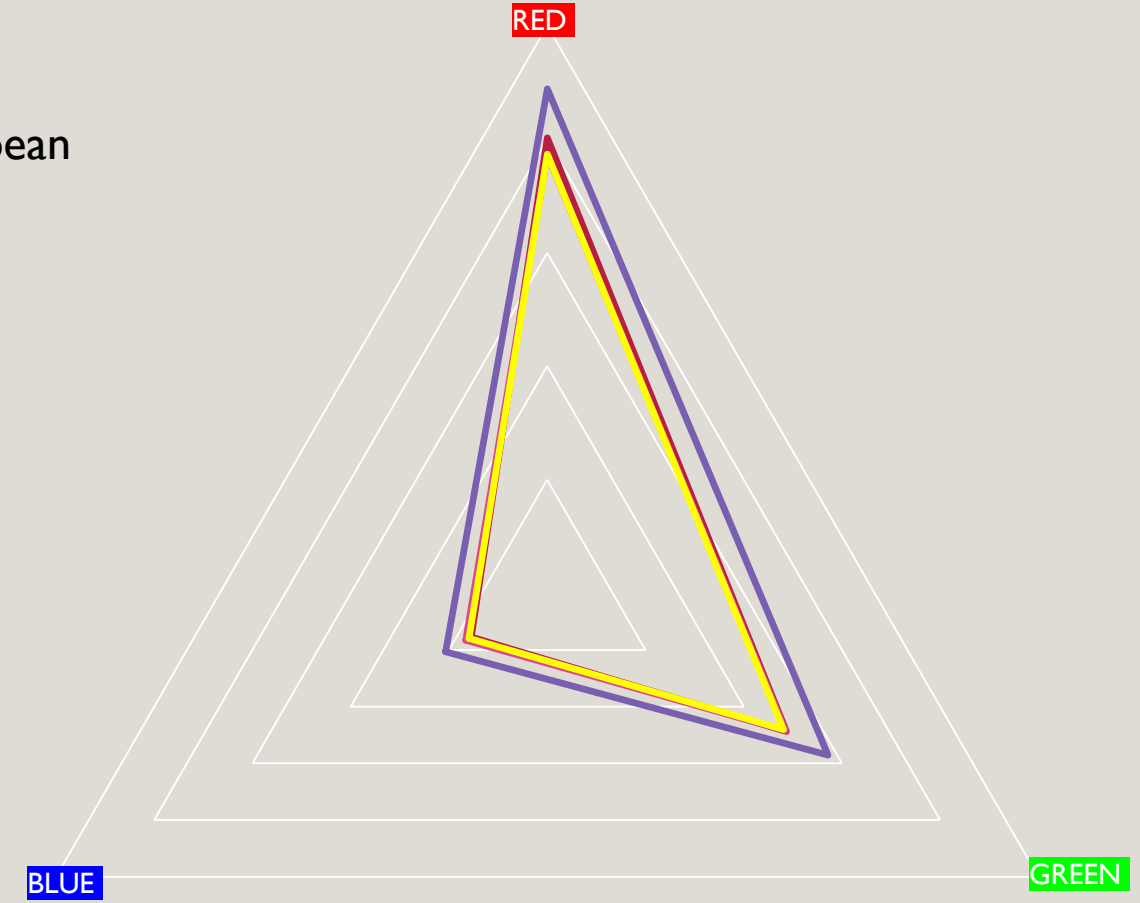

5 mm
Specimen D4
B3F2
6 weeks
Fresh cut
Juvenile wood
4 rings/inch
Color Index =
0.80
Zoom/Magnification: 0.67 x


5 mm
Specimen LS94
C. dentata
100 Years old
Aged surface
Juvenile wood
10 rings/inch
Color Index =
0.82
Zoom/Magnification: 0.67 x

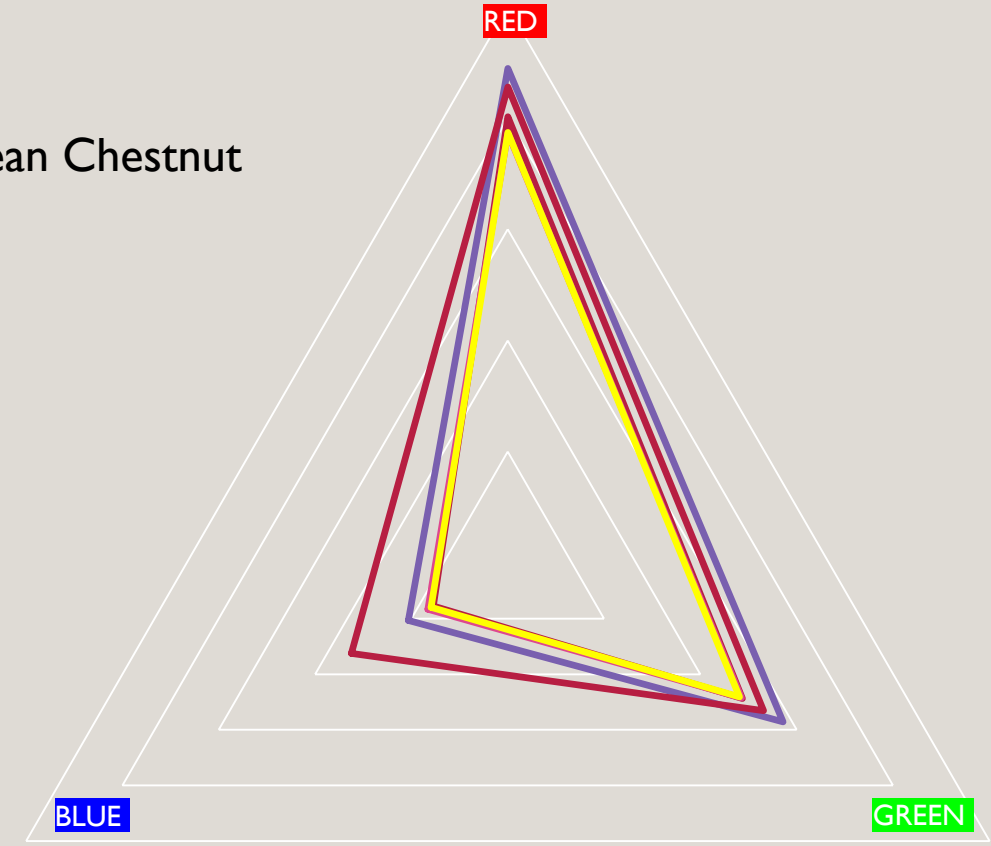
RGB Color Scales
American, Chinese, European Chestnut



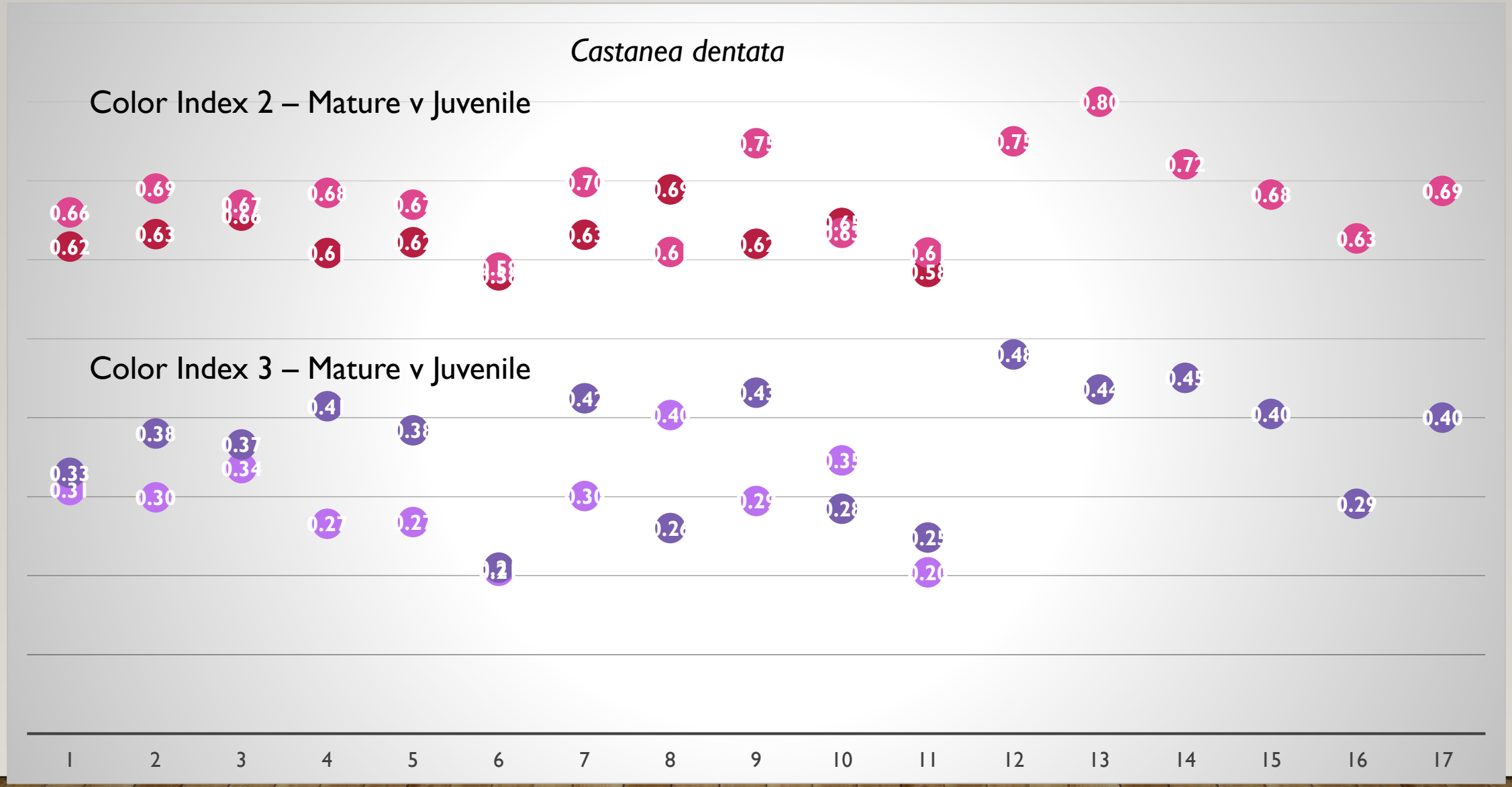
RGB Color Scales
American, Chinese, European
Chestnut
+ Hybrids



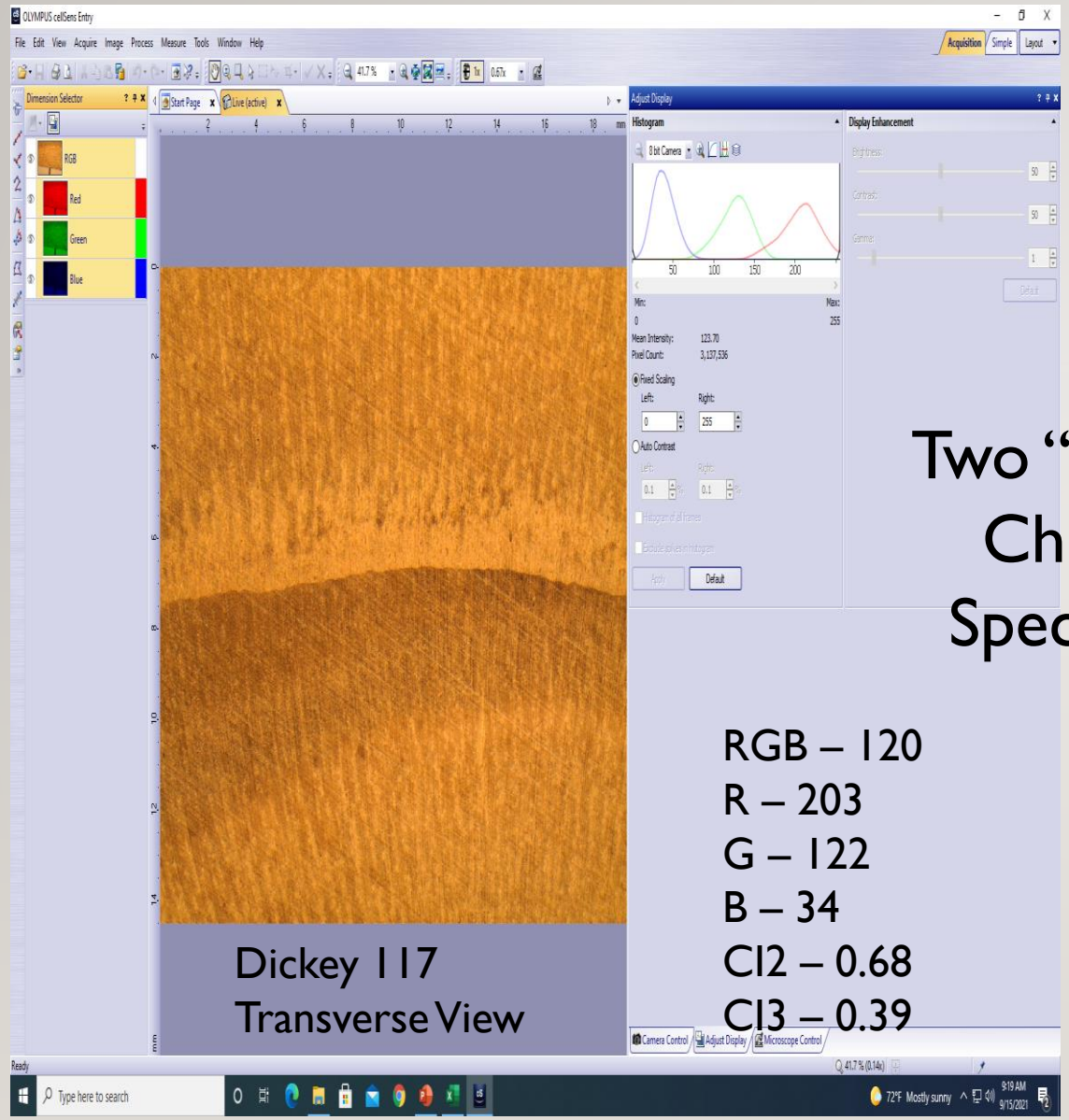
RGB Color Scales
American, Chinese, European Chestnut
+ Hybrids
+ American Juvenile



Color Index Improvement to Increase Differentiation within Species

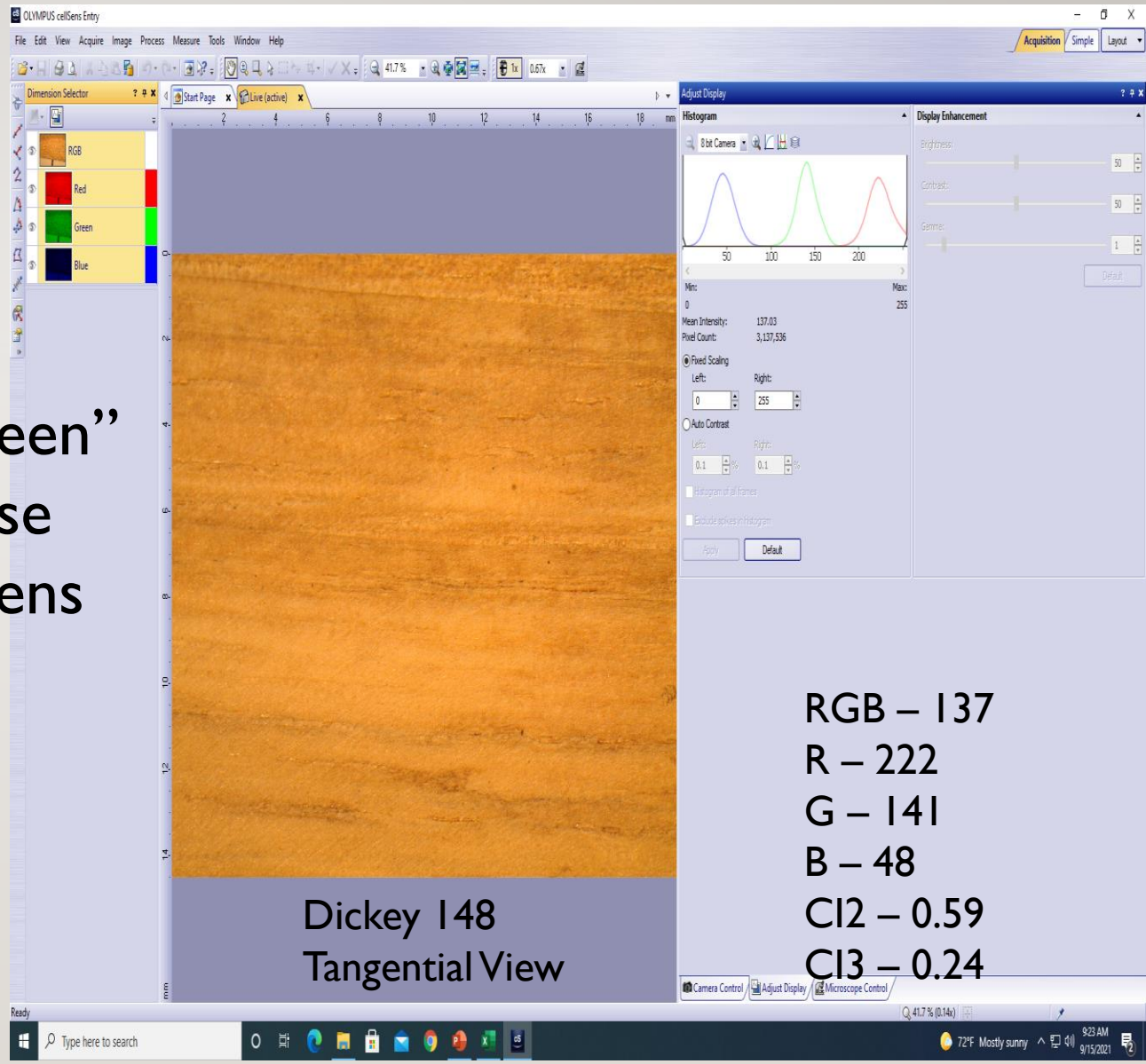


Two "Green" Chinese Specimens



Dickey 117
Transverse View

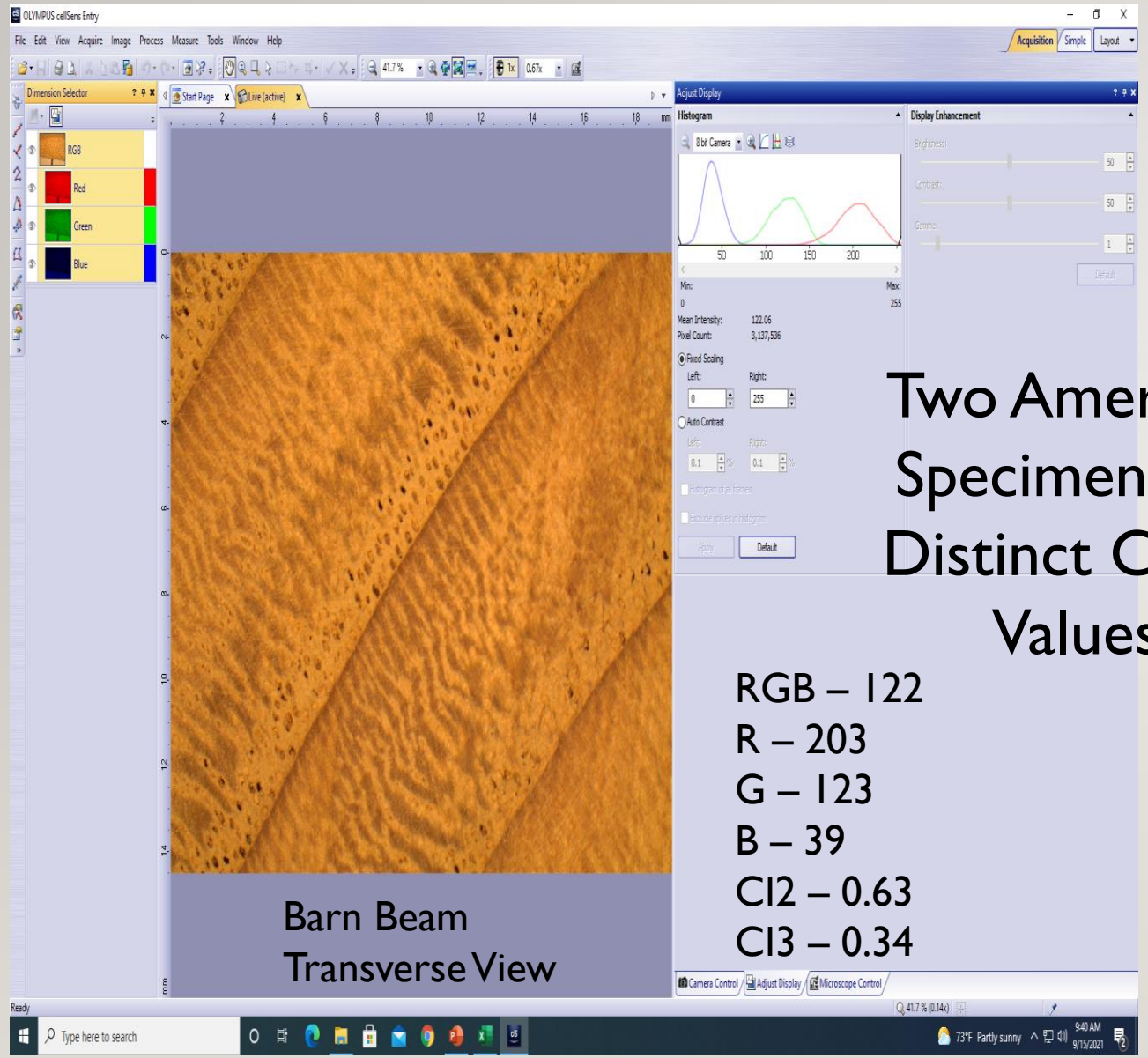
RGB – 120
R – 203
G – 122
B – 34
CI2 – 0.68
CI3 – 0.39



Dickey 148
Tangential View

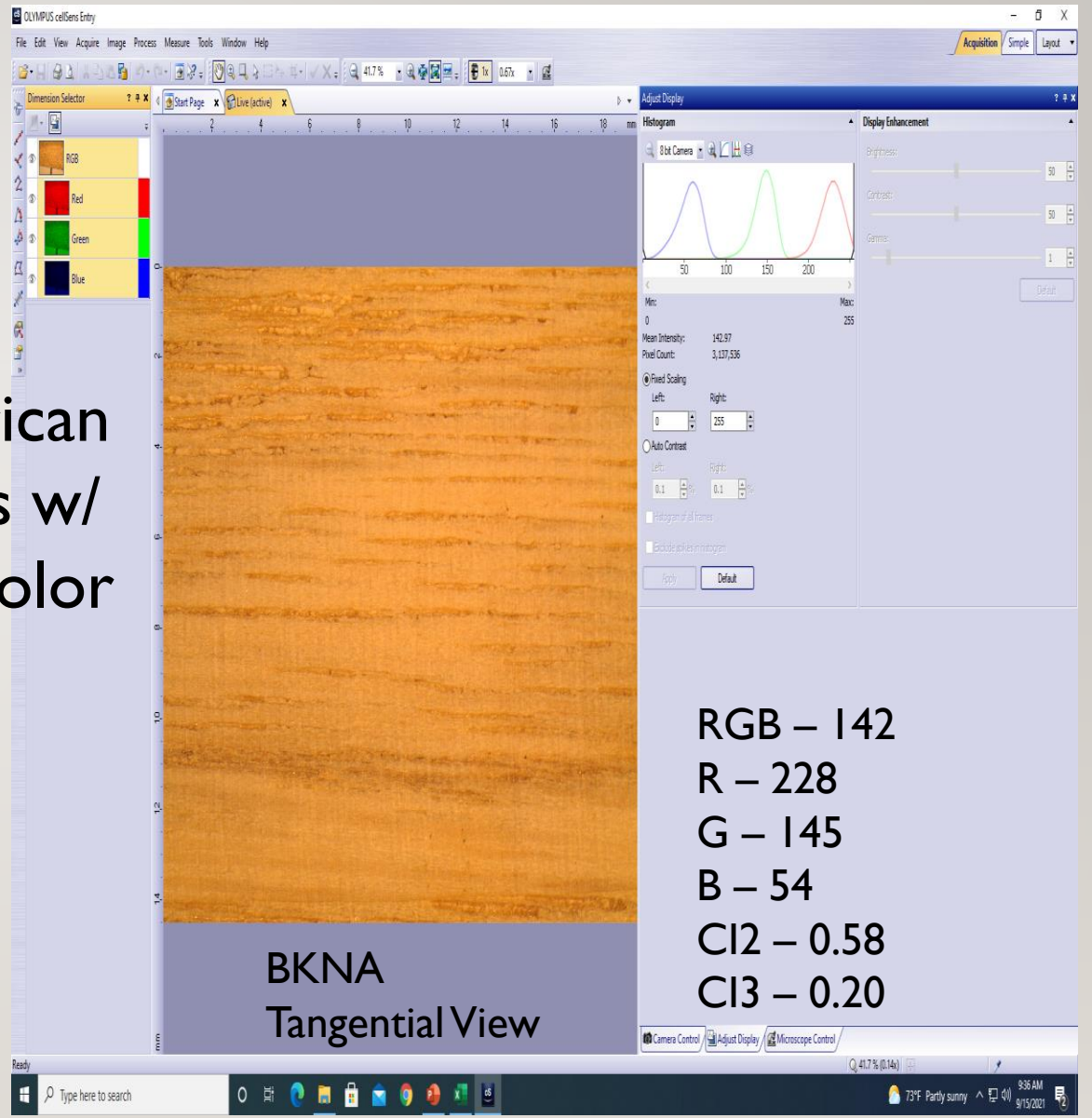
RGB – 137
R – 222
G – 141
B – 48
CI2 – 0.59
CI3 – 0.24

Two American Specimens w/ Distinct Color Values



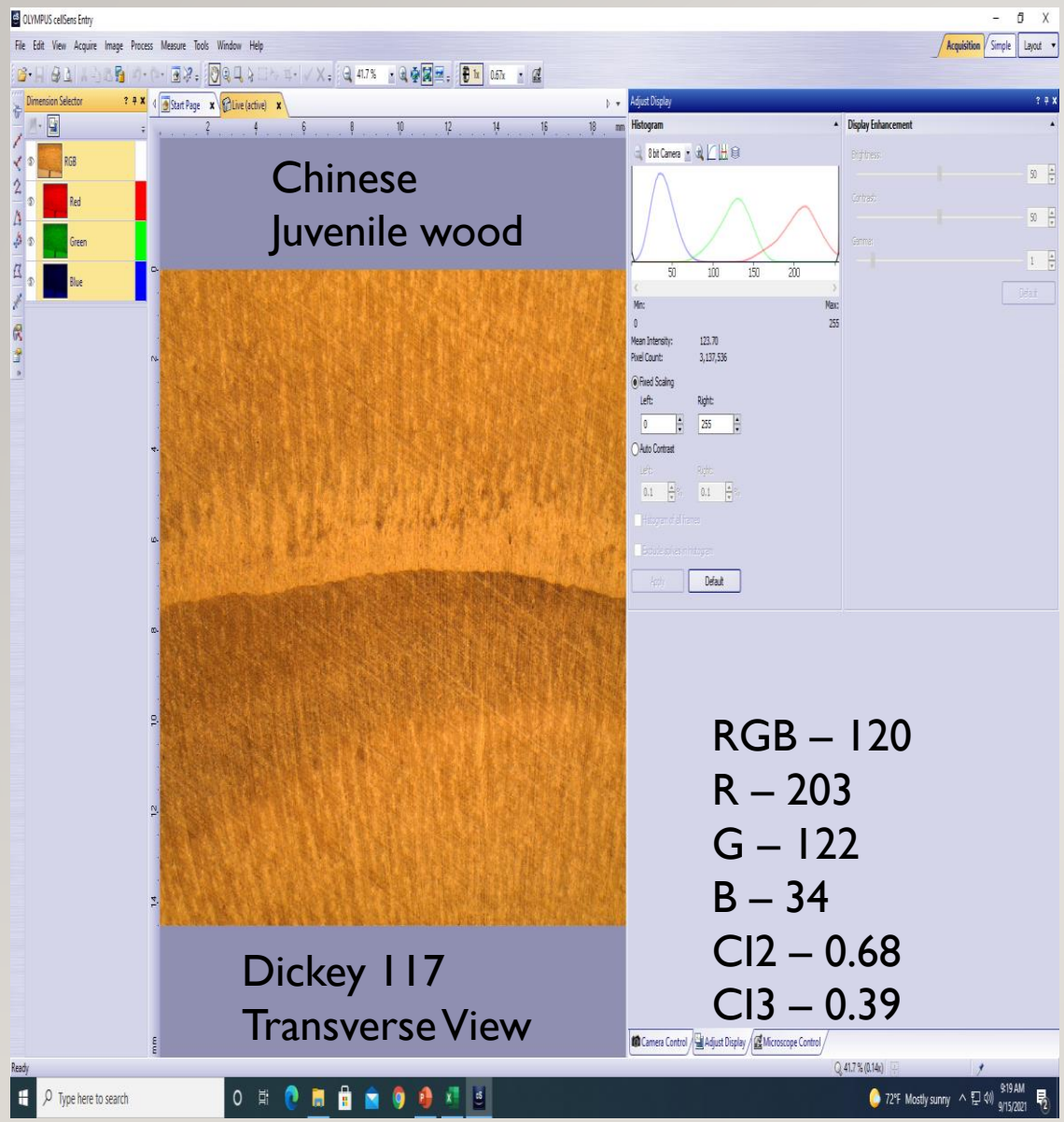
Barn Beam
Transverse View

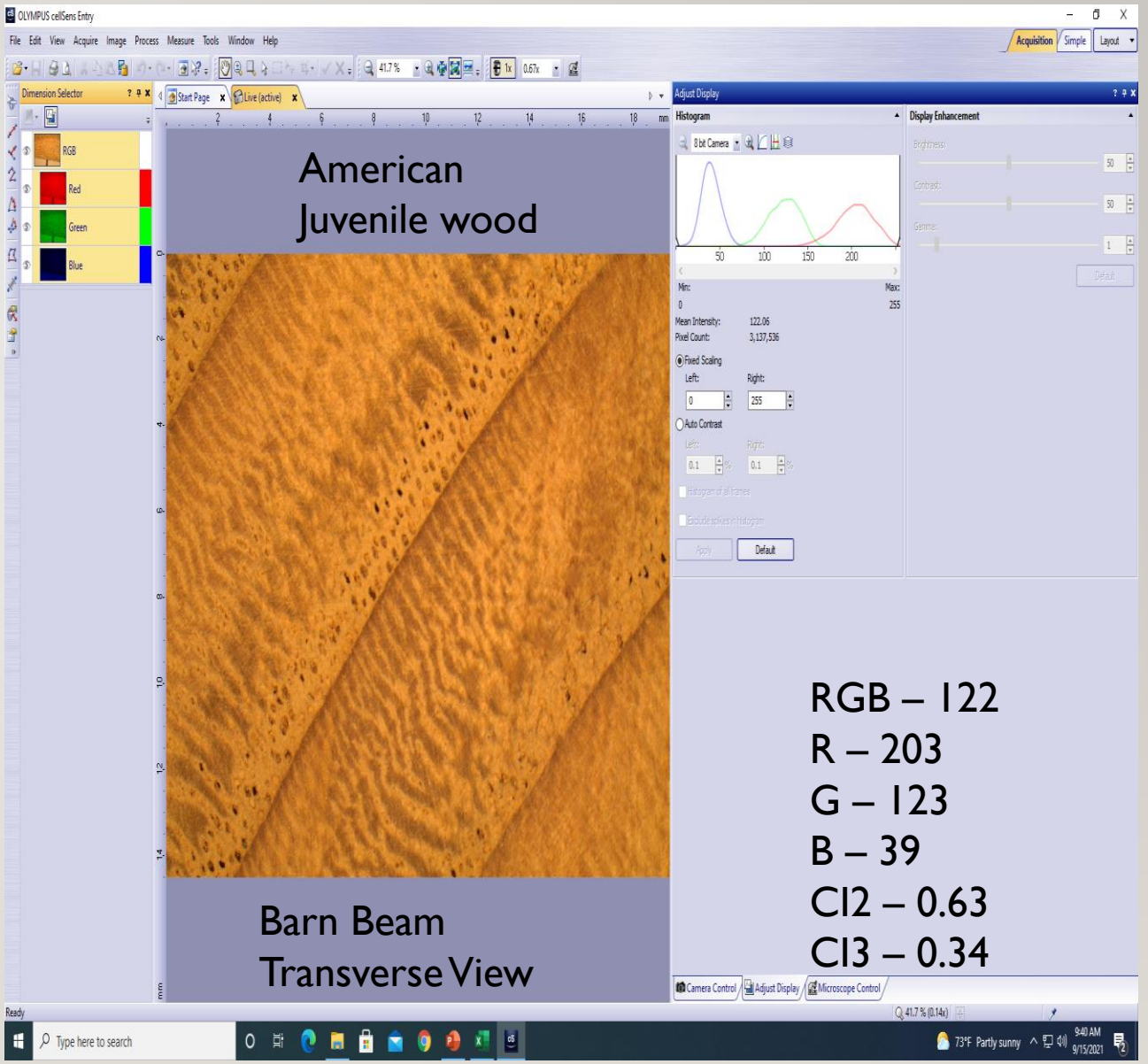
RGB – 122
R – 203
G – 123
B – 39
CI2 – 0.63
CI3 – 0.34

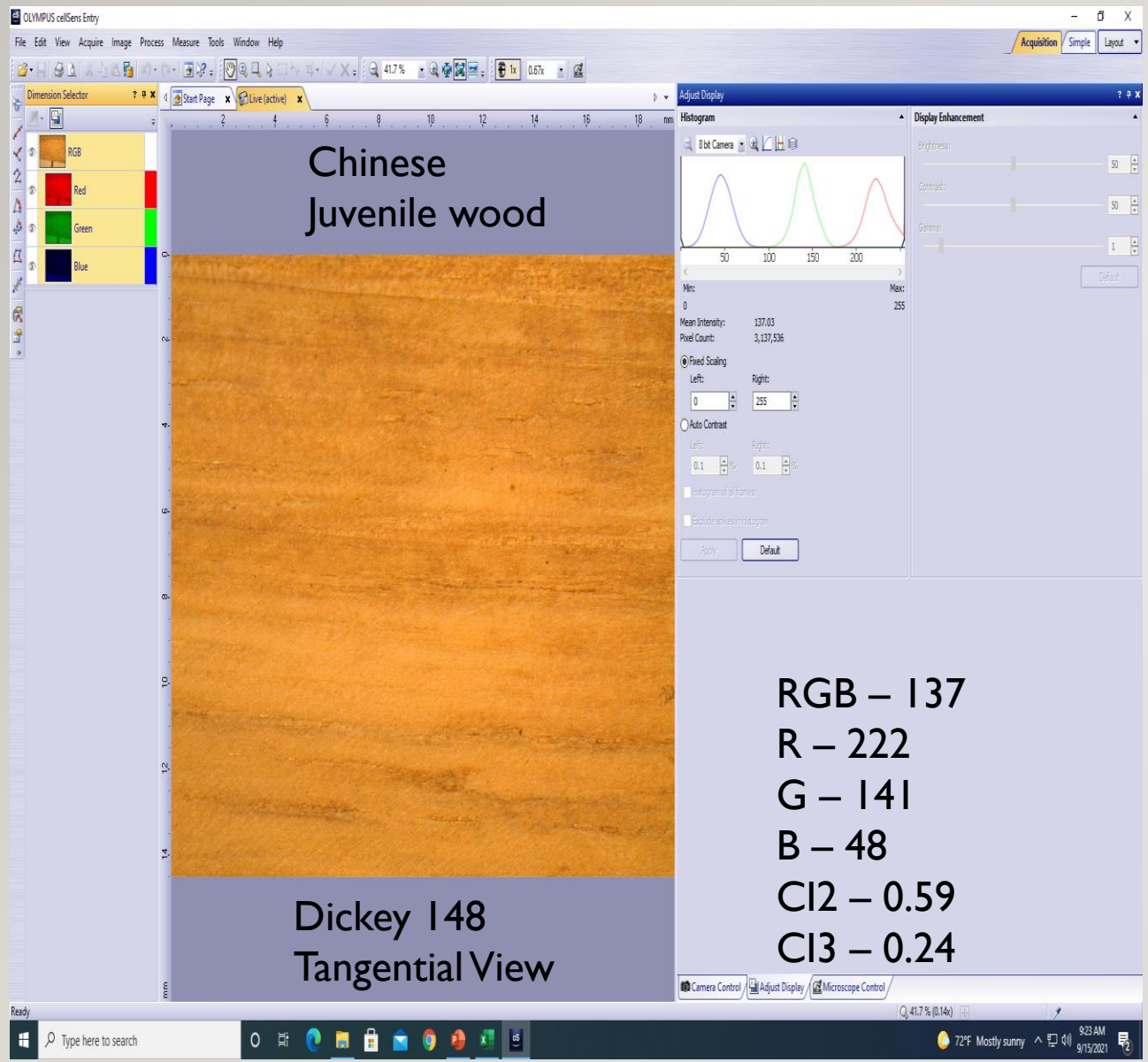


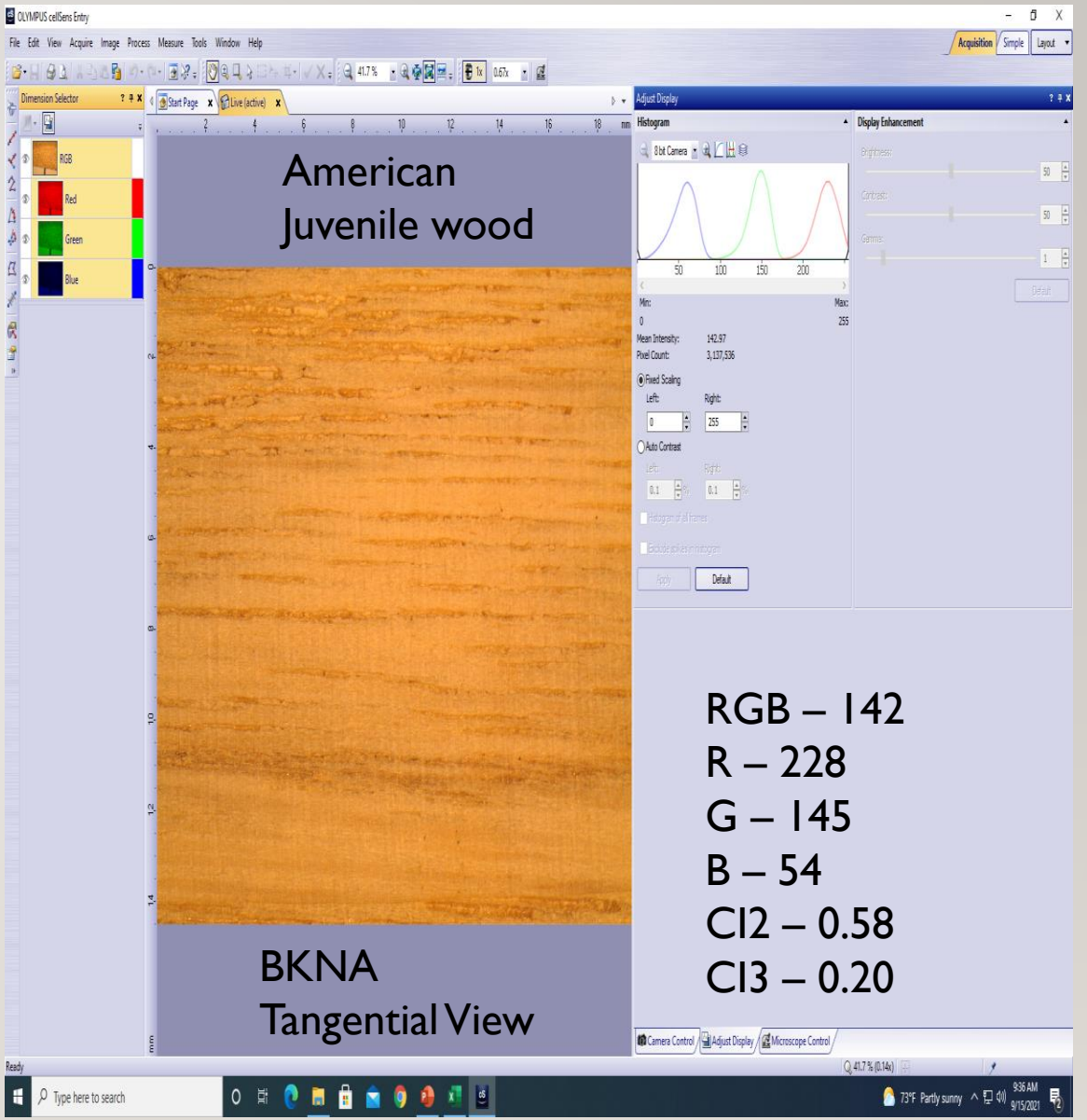
BKNA
Tangential View

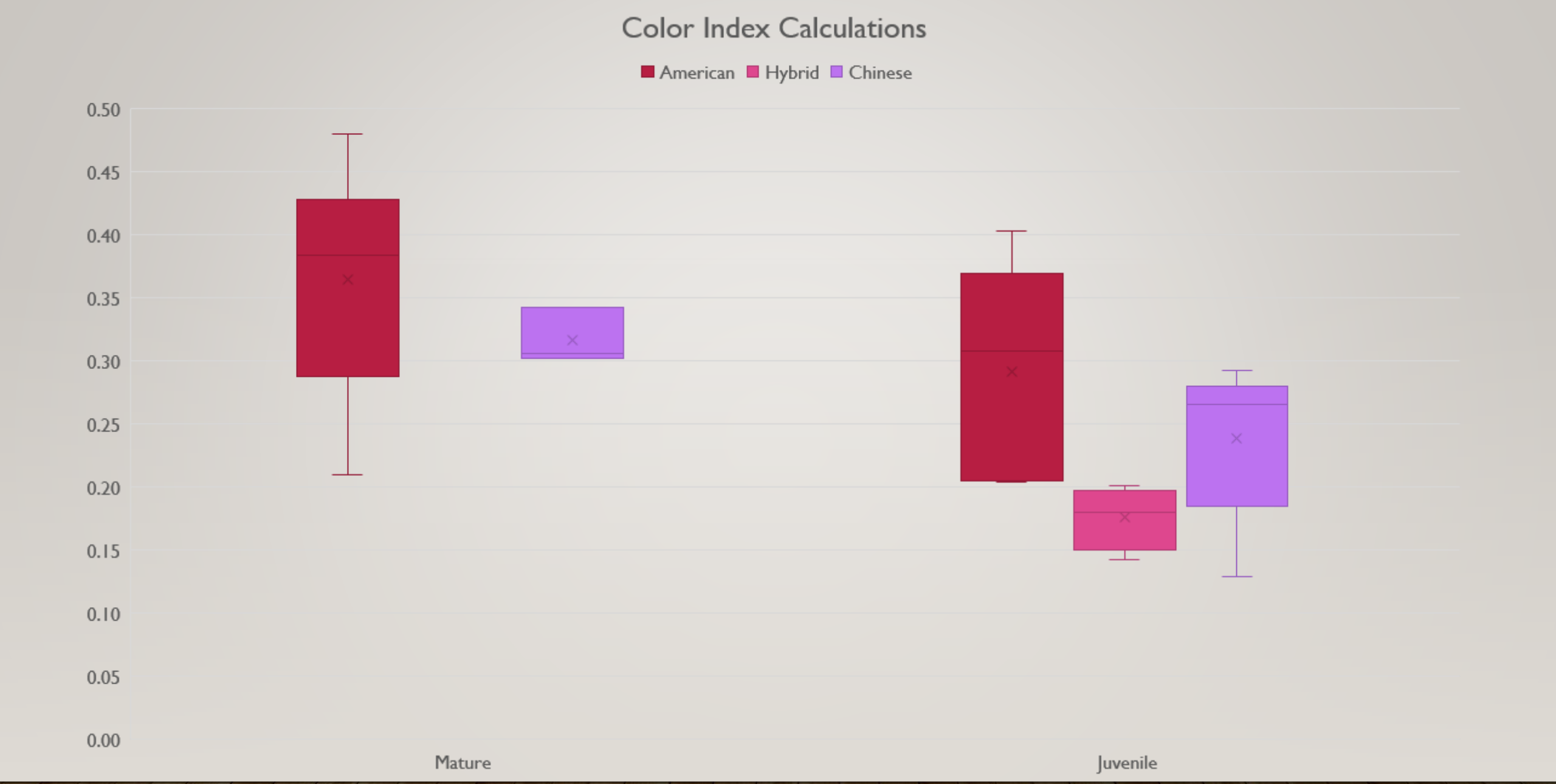
RGB – 142
R – 228
G – 145
B – 54
CI2 – 0.58
CI3 – 0.20


Chinese
Juvenile wood
Dickey 117
Transverse View
RGB – 120
R – 203
G – 122
B – 34
CI2 – 0.68
CI3 – 0.39


American
Juvenile wood
Barn Beam
Transverse View
RGB – 122
R – 203
G – 123
B – 39
CI2 – 0.63
CI3 – 0.34

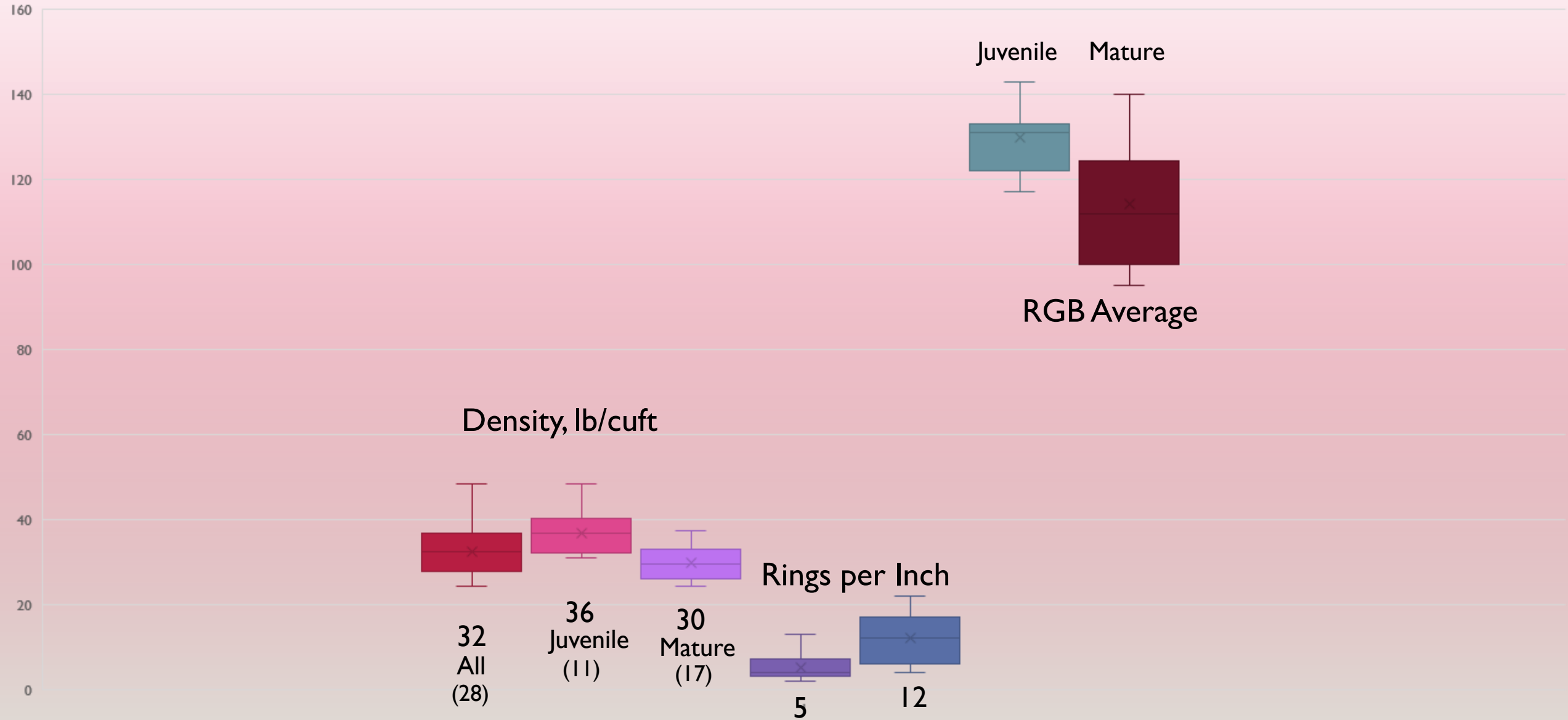

Chinese
Juvenile wood
Dickey 148
Tangential View
RGB – 137
R – 222
G – 141
B – 48
CI2 – 0.59
CI3 – 0.24


American
Juvenile wood
BKNA
Tangential View
RGB – 142
R – 228
G – 145
B – 54
CI2 – 0.58
CI3 – 0.20

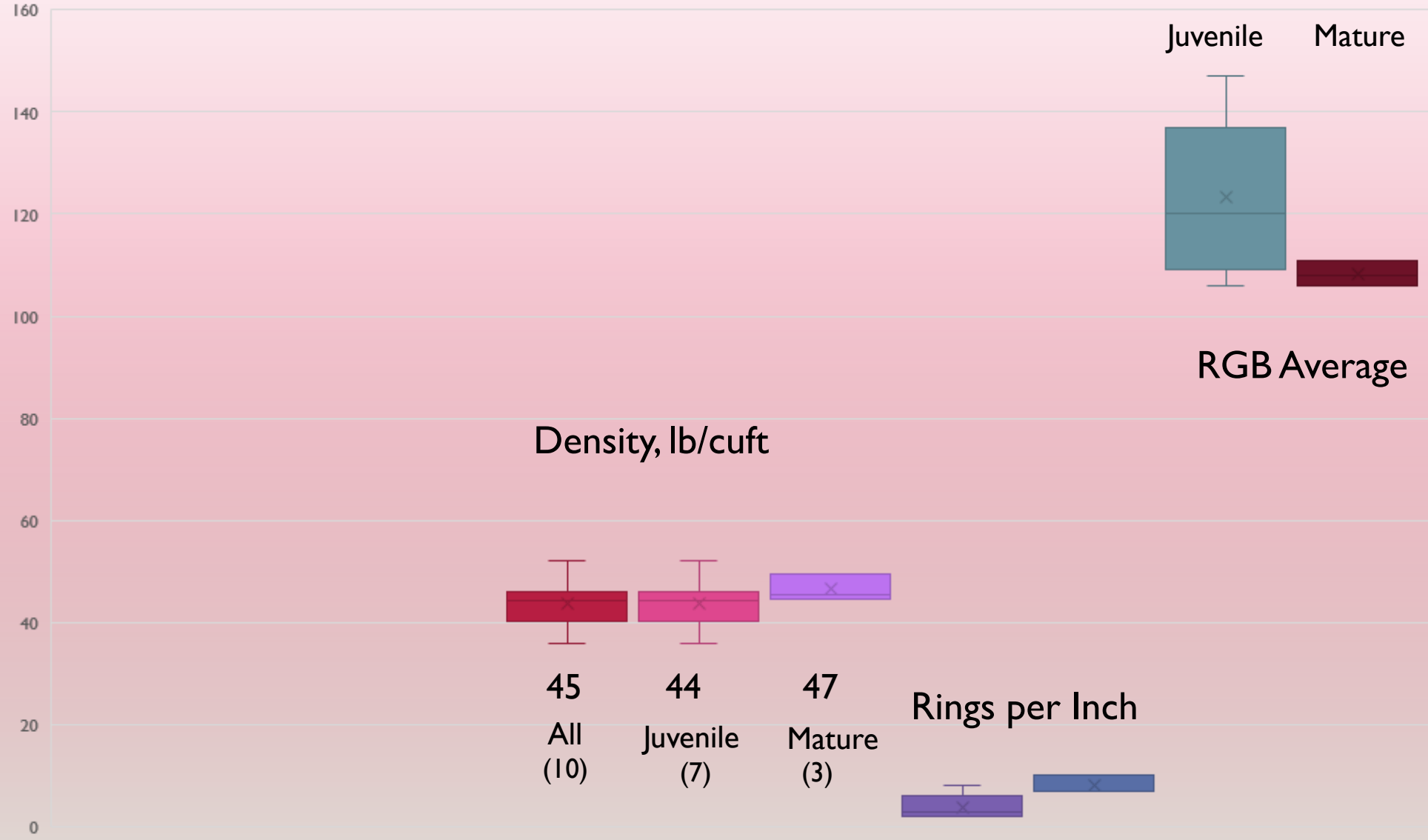

Color Index Calculations
American
Hybrid
Chinese
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Mature
Juvenile

Step 2. Investigate Role of Wood Density in Color Variation

C. dentata, Juvenile vs. Mature Wood Comparison



C. mollissima, Juvenile vs. Mature Wood Comparison



RGB Average

Density, lb/cuft

45
All
(10)

44
Juvenile
(7)

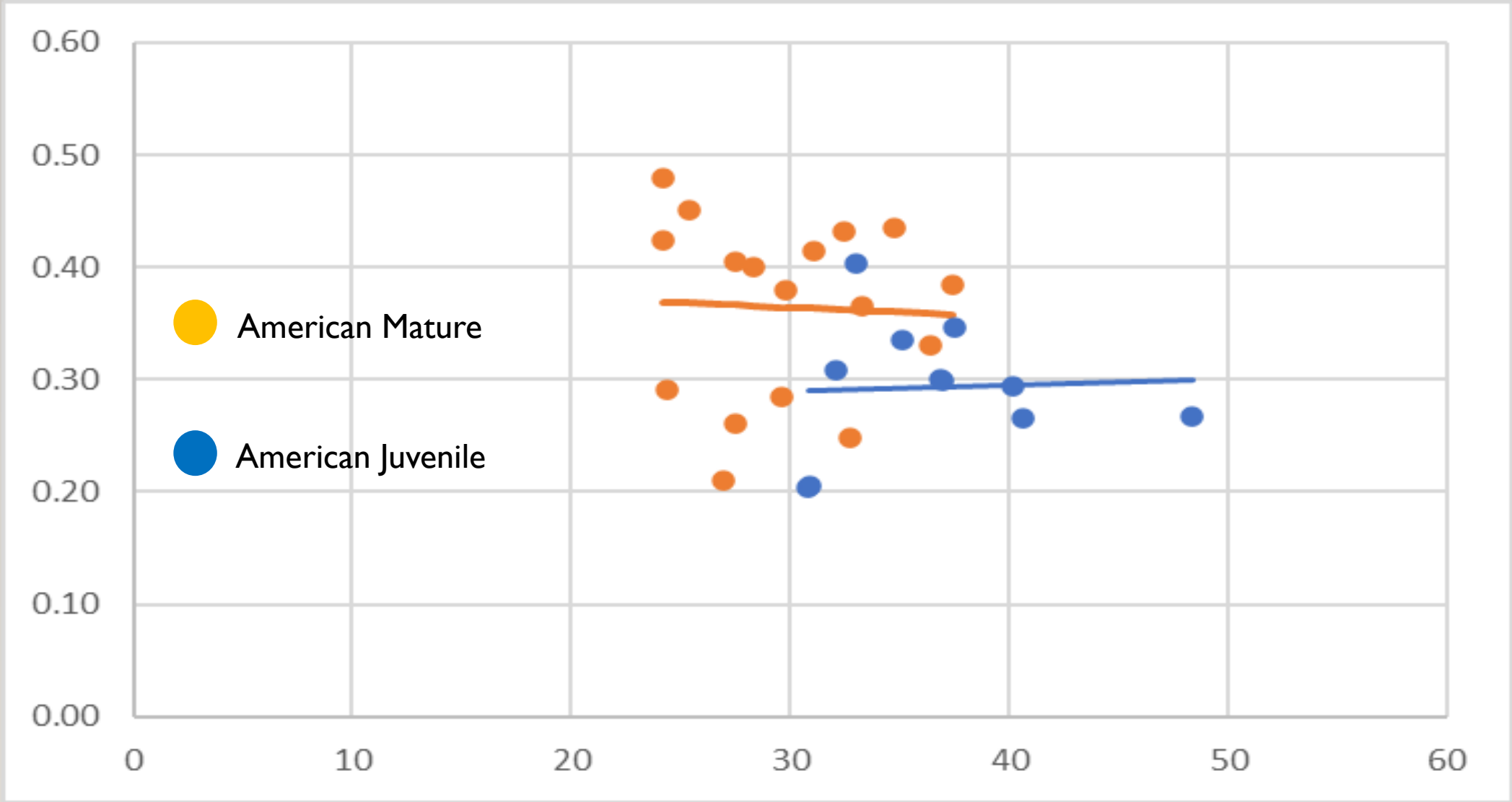
47
Mature
(3)

Rings per Inch

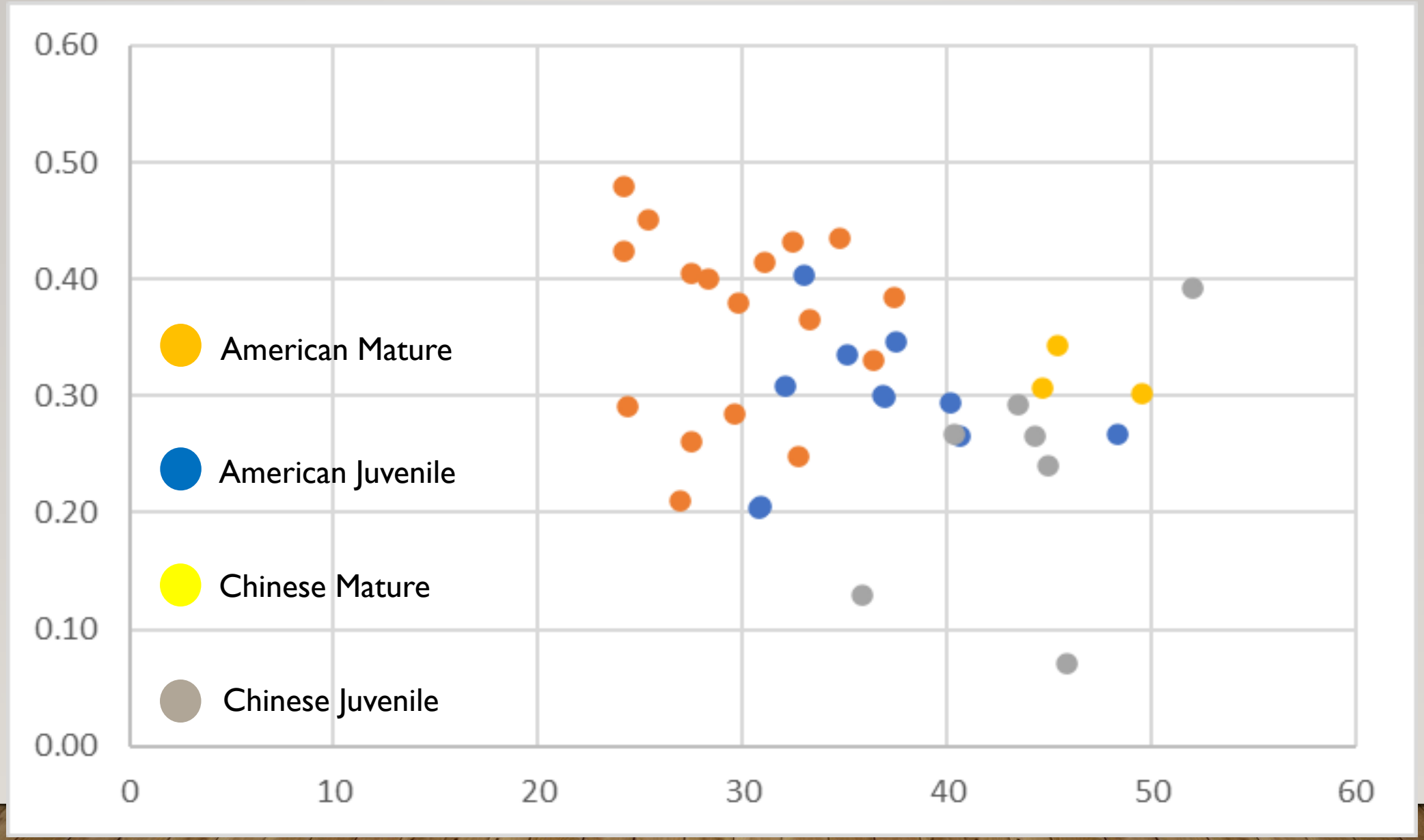
4
Juvenile

8
Mature

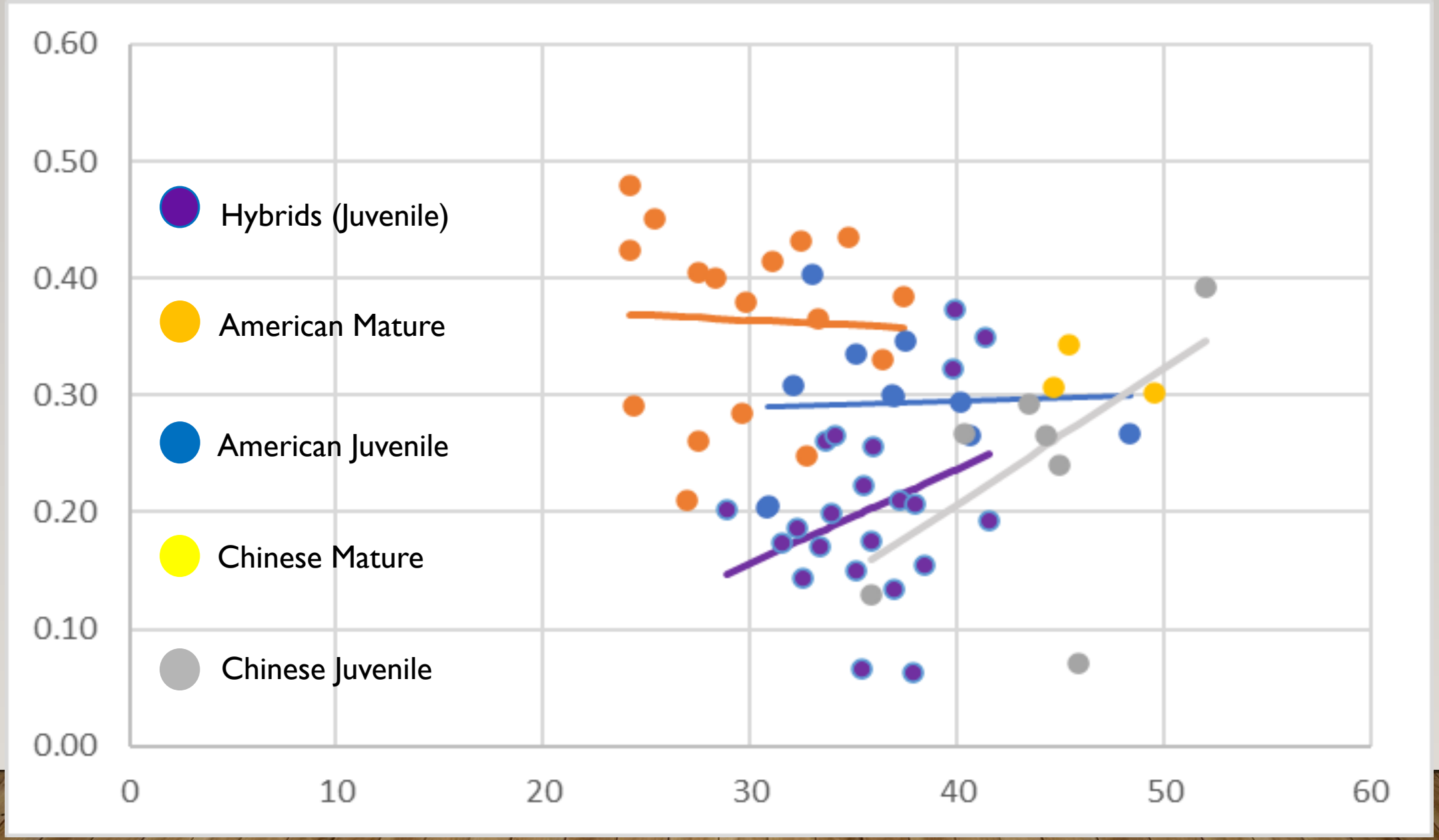
Chestnut Wood – Color Index v. Density



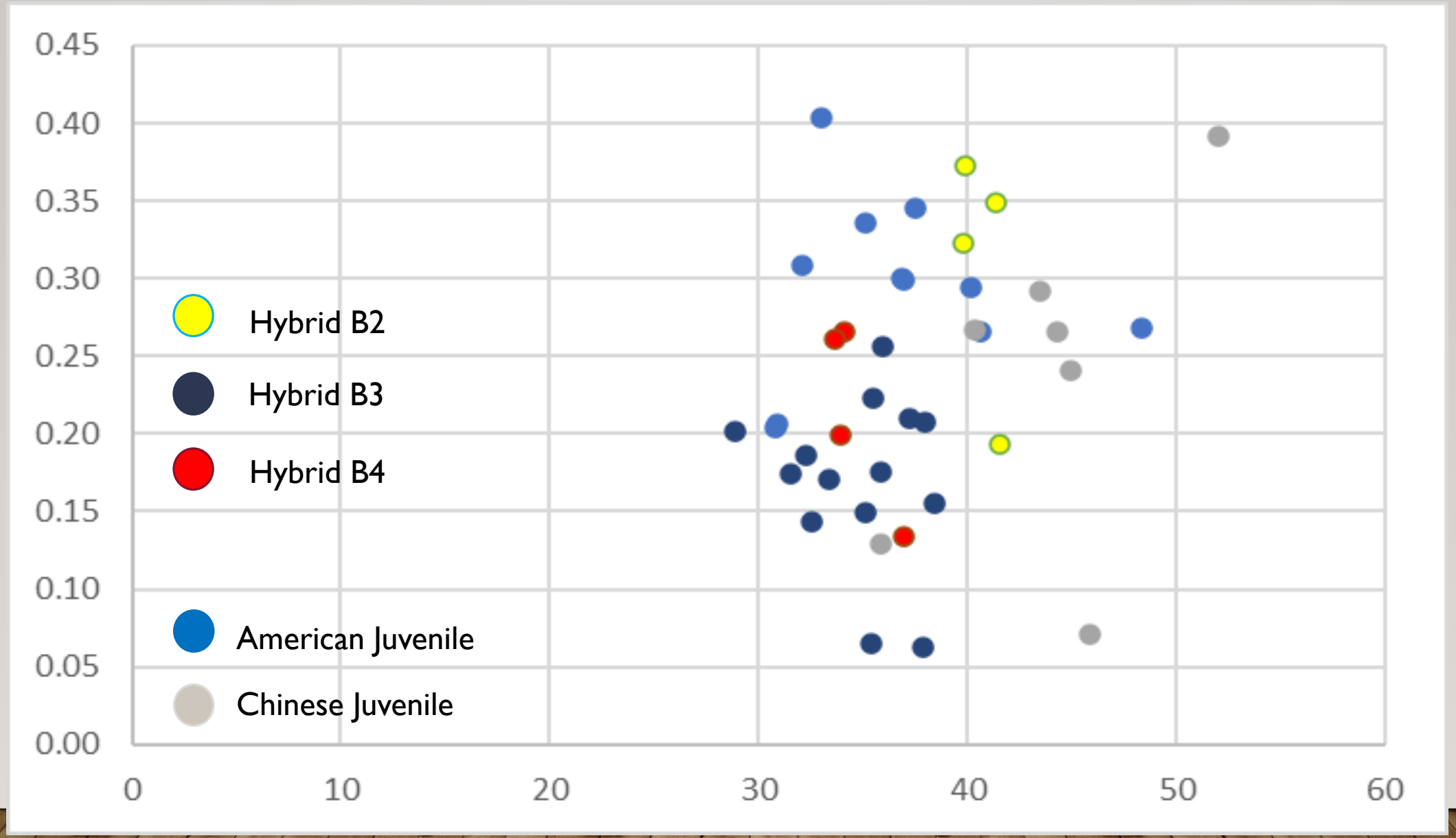
Chestnut Wood – Color Index v. Density



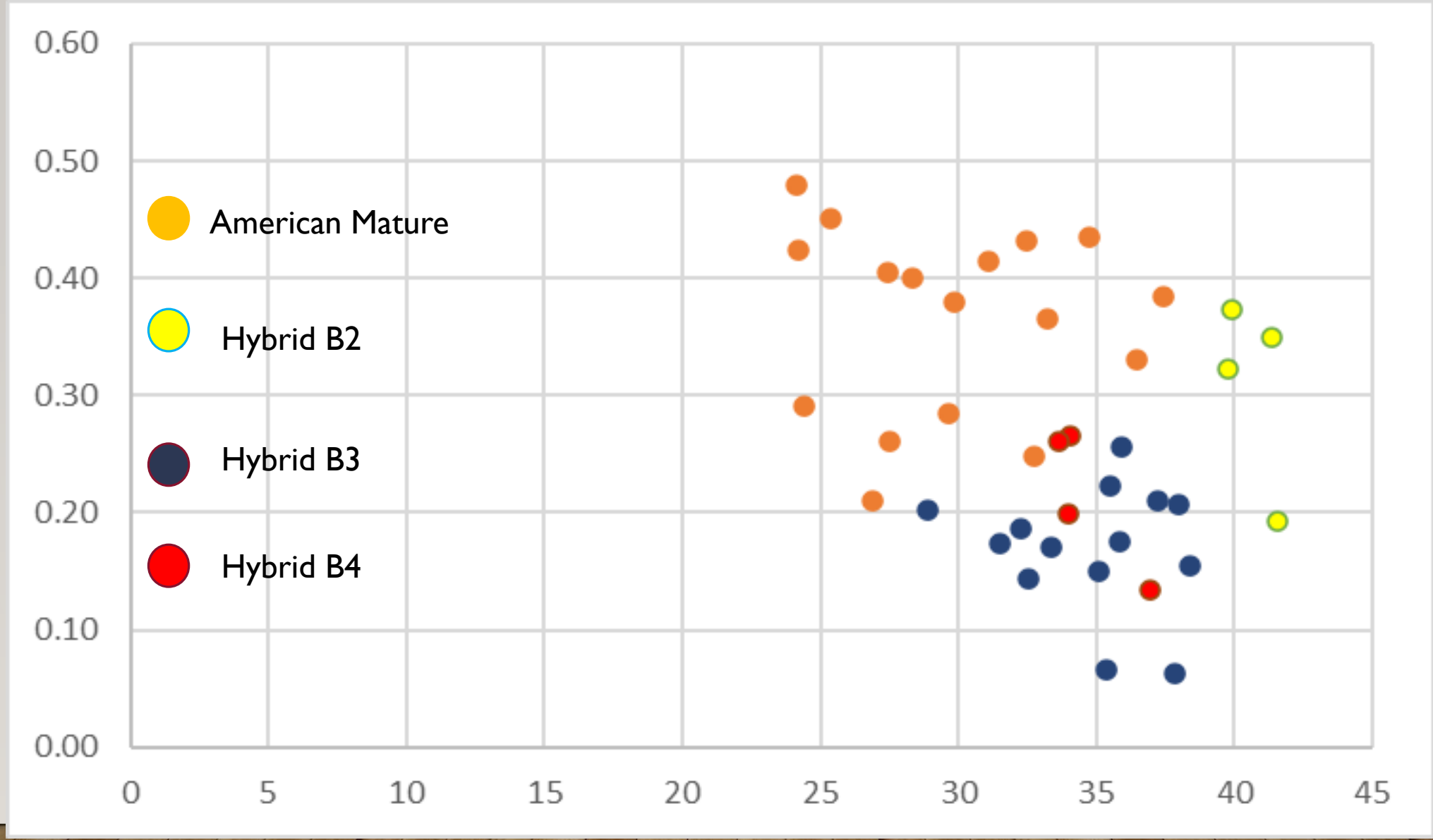
Chestnut Wood – Color Index v. Density



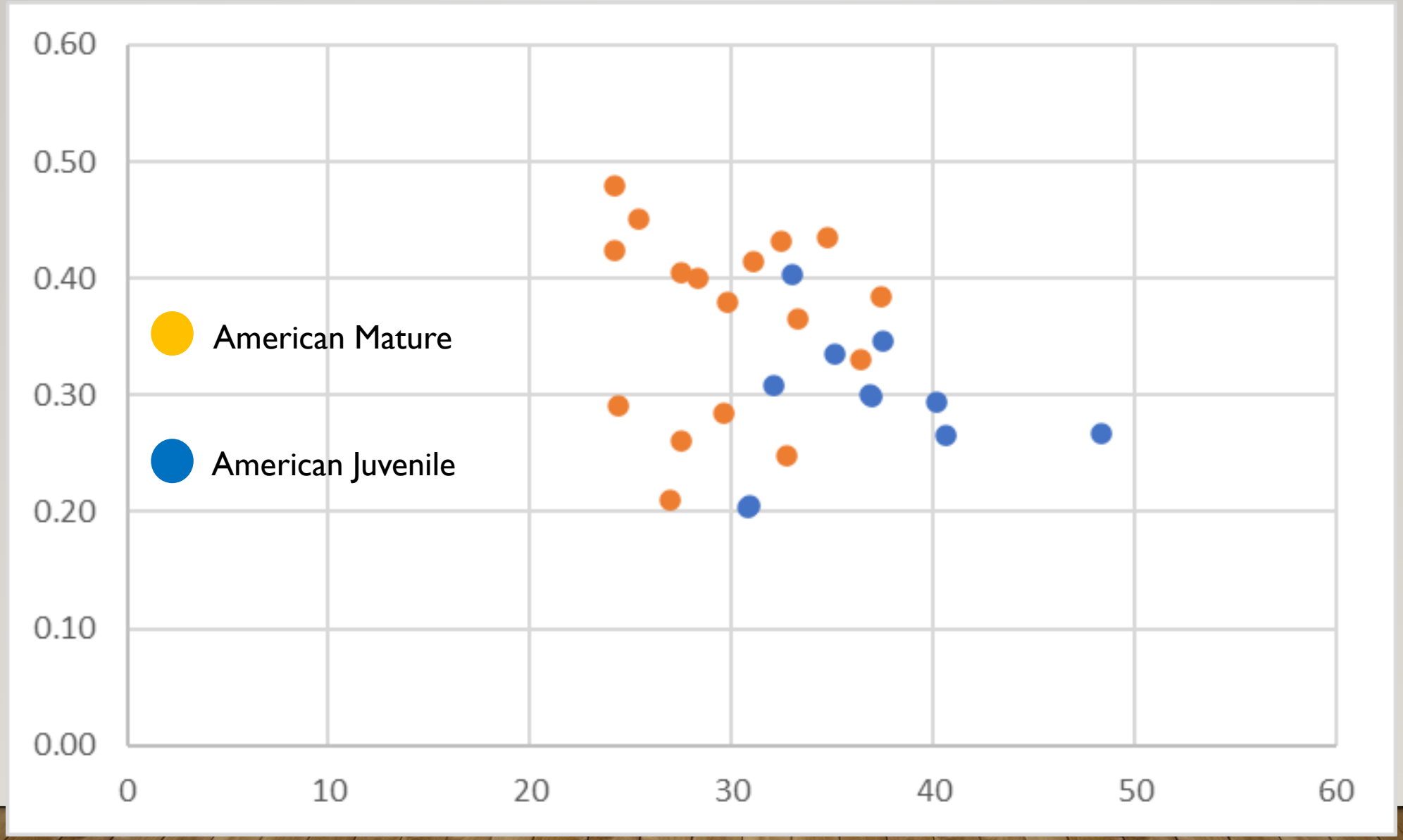
Chestnut Wood – Color Index v. Density



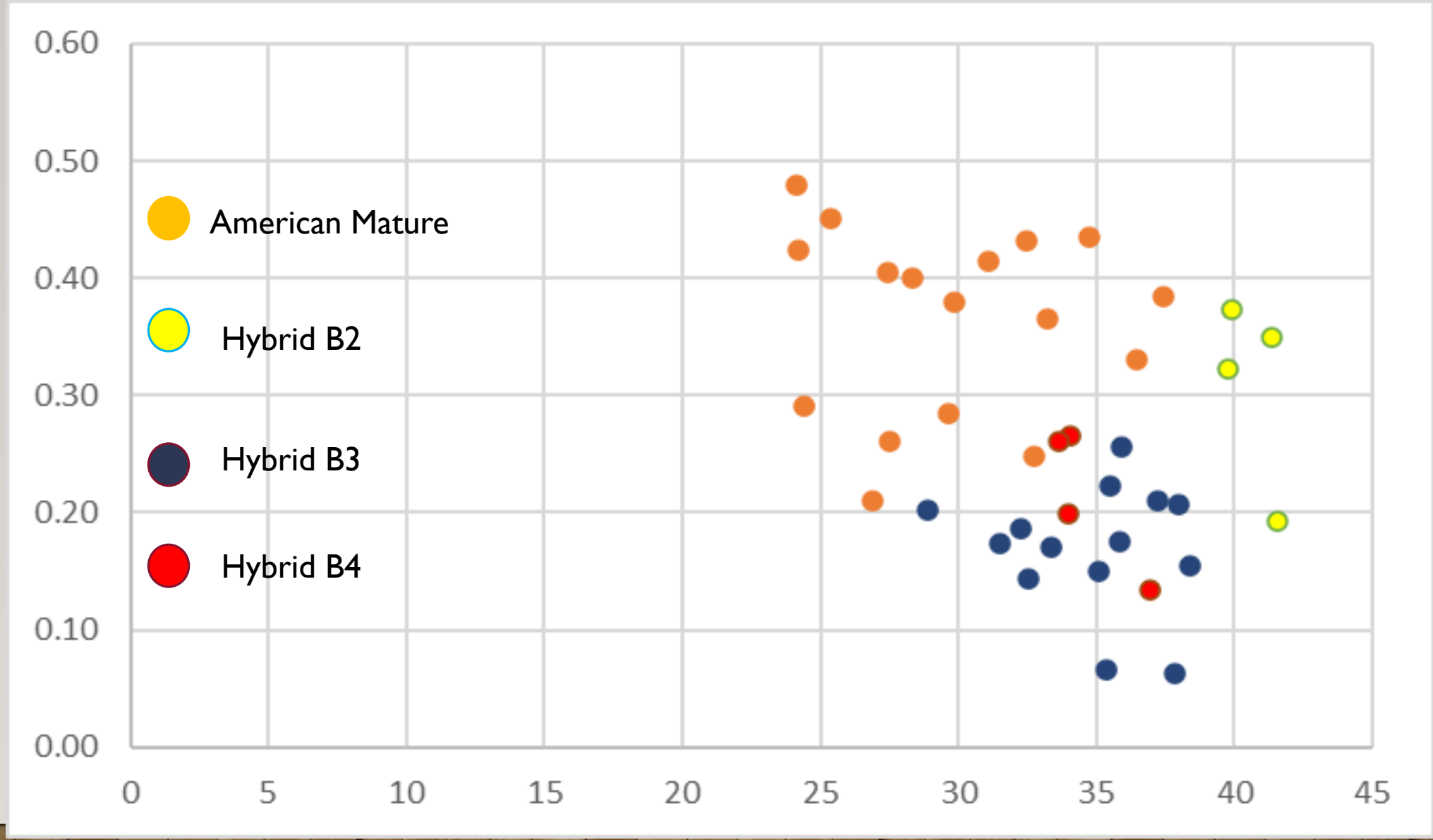
Chestnut Wood – Color Index v. Density



Chestnut Wood – Color Index v. Density



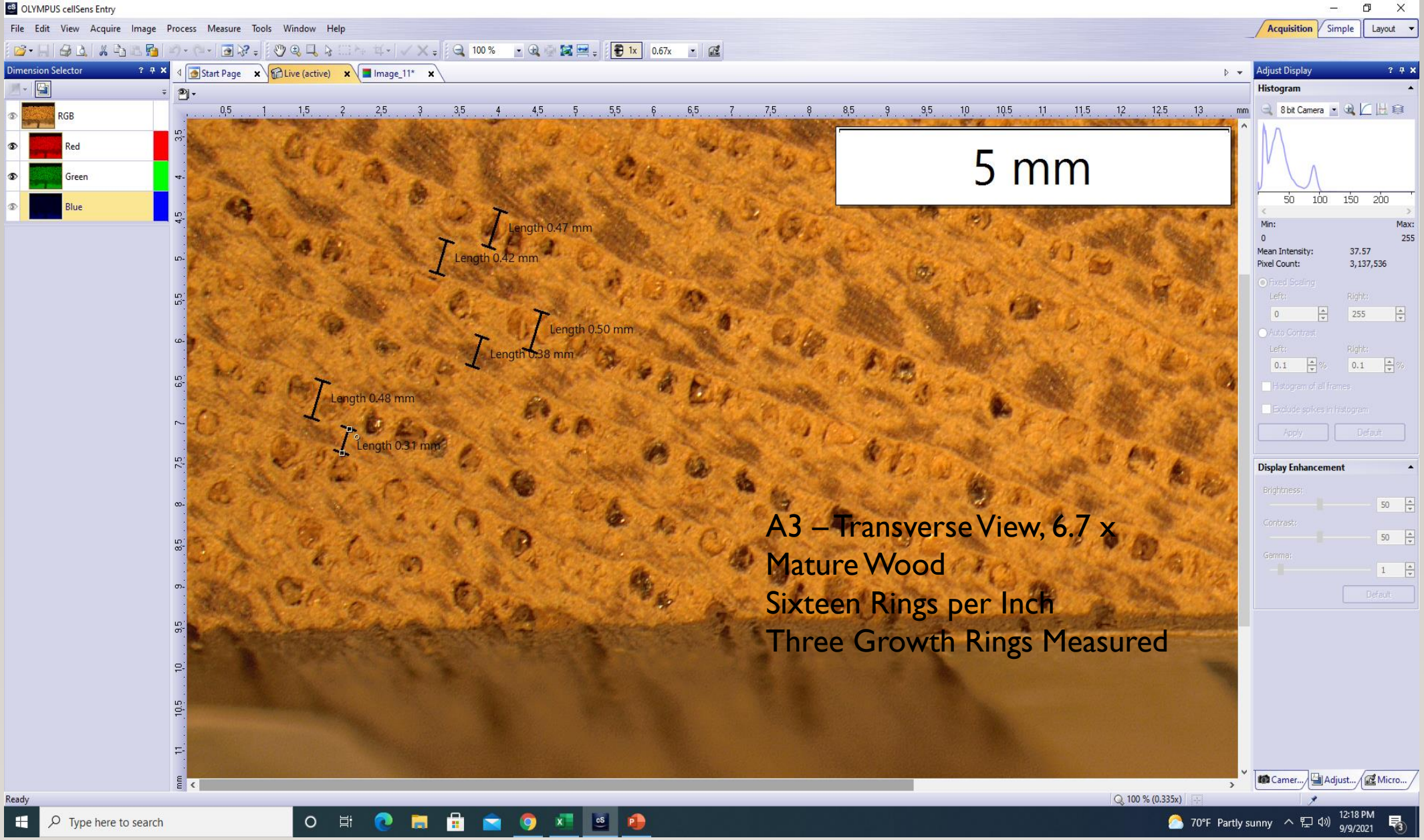
Chestnut Wood – Color Index v. Density

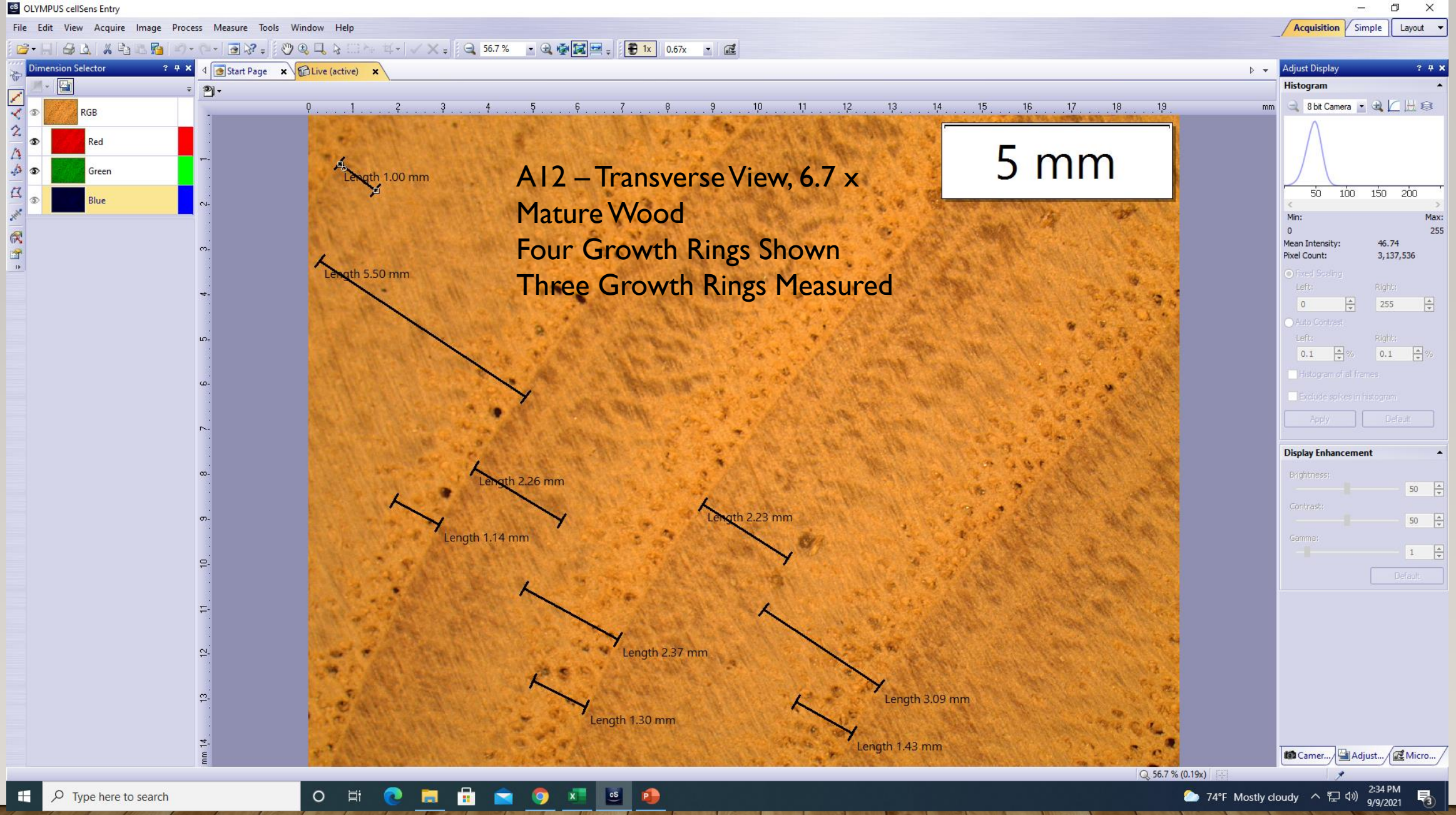


So, if density is not the principal reason for entire specimen color variation, what causes this color variation?

Are the cells themselves a different color, or are the cell "patterns" the cause of the difference?

Step 3. Investigate Role of Cell Type, Size, and Variability in Color Variation


OLYMPUS cellSens Entry
File Edit View Acquire Image Process Measure Tools Window Help
Acquisition Simple Layout
Dimension Selector
RGB
Red
Green
Blue
Start Page
Live (active)
Image_11*
Adjust Display
Histogram
8 bit Camera
Min: Max:
0 255
Mean Intensity: 37.57
Pixel Count: 3,137,536
Display Enhancement
Brightness:
Contrast:
Gamma:
5 mm
Length 0.47 mm
Length 0.42 mm
Length 0.50 mm
Length 0.38 mm
Length 0.48 mm
Length 0.31 mm
A3 – Transverse View, 6.7 x
Mature Wood
Sixteen Rings per Inch
Three Growth Rings Measured
Ready
100 % (0.335x)
Type here to search
70°F Partly sunny
12:18 PM
9/9/2021

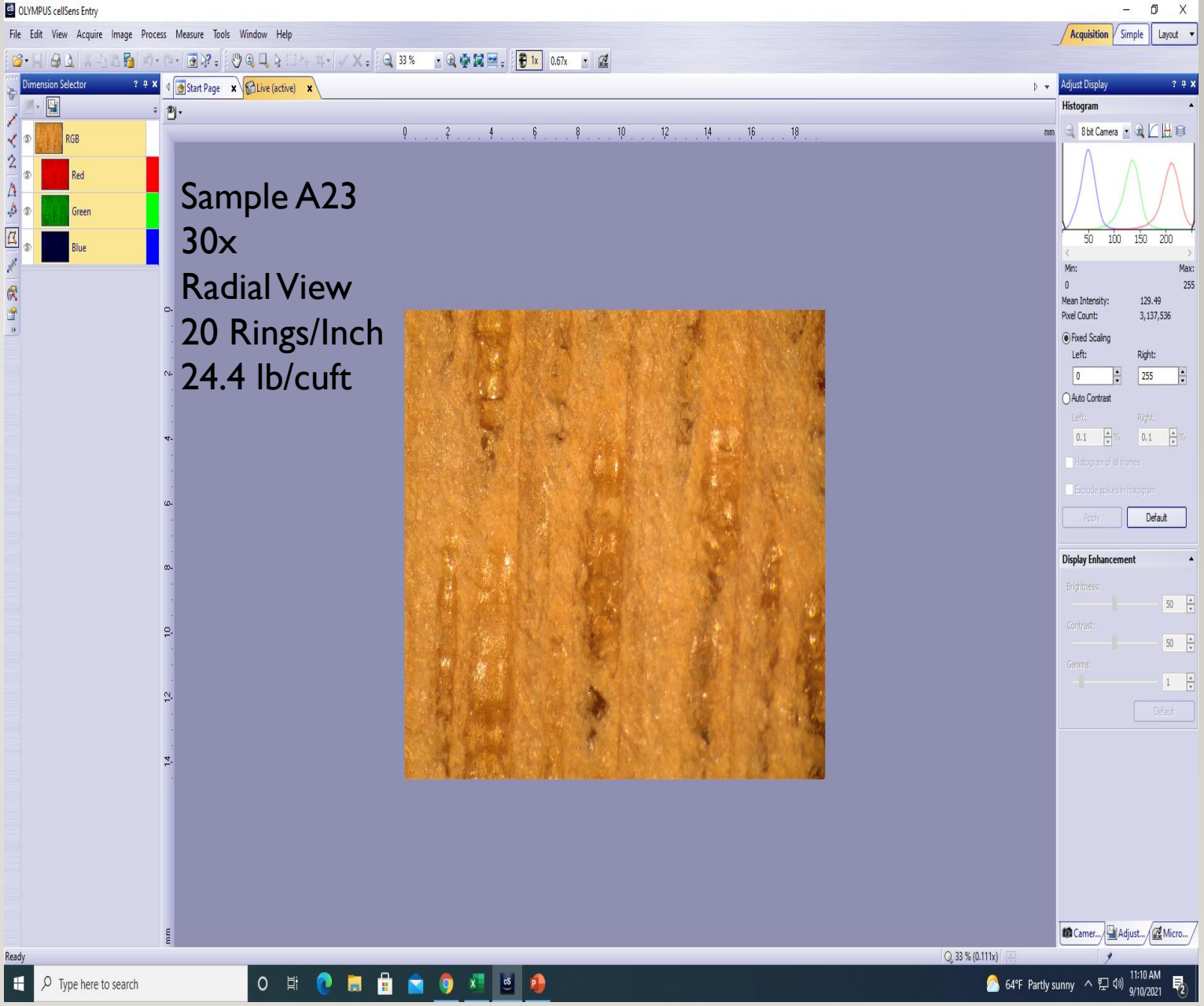

OLYMPUS cellSens Entry
File Edit View Acquire Image Process Measure Tools Window Help
Acquisition Simple Layout
Dimension Selector
RGB
Red
Green
Blue
Start Page
Live (active)
Adjust Display
Histogram
8 bit Camera
Min: 0
Max: 255
Mean Intensity: 46.74
Pixel Count: 3,137,536
Display Enhancement
Brightness:
Contrast:
Gamma:
5 mm
A12 – Transverse View, 6.7 x
Mature Wood
Four Growth Rings Shown
Three Growth Rings Measured
Length 1.00 mm
Length 5.50 mm
Length 2.26 mm
Length 1.14 mm
Length 2.23 mm
Length 2.37 mm
Length 1.30 mm
Length 3.09 mm
Length 1.43 mm
56.7 % (0.19x)
Type here to search
74°F Mostly cloudy
2:34 PM
9/9/2021

Sample A23
6.7x
Radial View
20 Rings/Inch
24.4 lb/cuft

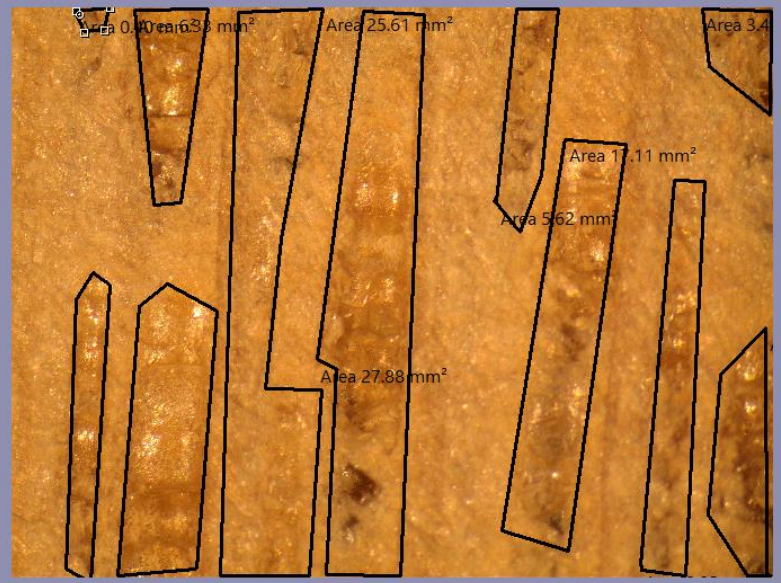
Tyloses

“Vessel occlusion through tyloses or gums is a natural phenomenon occurring with aging and heartwood formation, and in sapwood in response to vessel embolism. These types of vessel occlusion play a crucial role to limit the spread of pathogens and wood decay organisms, also as part of compartmentalization after wounding. In the sapwood, they can be considered to be an effective stress response.”

- De Micco, et al. June 2016
IAWA journal / International Association of Wood Anatomists **37(2016):186-205**



Sample A23
30x
Radial View
20 Rings/Inch
24.4 lbs/cuft
44% Pore Area



AutoSave Off | TACF Data edited | Search | Ray Sr., Charles David

File Home Insert Page Layout Formulas Data Review View Help | Share | Comments

SIGN IN TO OFFICE It looks like your stored credentials are out of date. Please sign in as cdr14@psu.edu so we can verify your subscription. Sign In

AP24 =AD24/AM24

	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1	View	RGB Mean	R Mean	G Mean	R-G	B Mean	R-B	Index2	P1	P2	P3	Rav	EW1	EW2	EW3	EWAv	LW1	LW2	LW3	LWAv	GR	EW/LW	P/LW	P/GR			
20	Trans	131	211	135	76	49	162	0.58	0.33	0.44	0.46	0.41	1.32	1.05	1.08	1.15	0.47	0.43	0.53	0.476667	1.626667	2.4	0.9	0.3			
21	Tan	111	191	111	80	30	161	0.72	7.48			7.48	10.62			10.62	6.54			6.54	17.16	1.6	1.1	0.4			
22	Rad	126	215	129	86	35	180	0.68	3.67	1.79		2.73	4.81	2.72		3.765	2.28	1.48		1.88	5.645	2.0	1.5	0.5			
23	Trans	133	221	137	84	44	177	0.63	0.86	0.097		0.4785	8.78	4.62		6.7	3.33	2.09		2.71	9.41	2.5	0.2	0.1			
24	Rad	134	221	137	84	45	176	0.63	0.41	0.69	0.6	0.566667	0.86	0.69	0.64	0.73	0.64	0.34	0.64	0.54	1.27	1.4	1.0	0.4			
25					0		0	#DIV/0!				#DIV/0!				#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			

PreliminaryStudy | Full Study | Sheet1 | American | Chinese | B2 | B3 | B4

Ready

Dimension Selector

RGB
Red
Green
Blue

Start Page | Live (active)

Length 0.64 mm
Length 0.64 mm
Length 0.60 mm
Length 0.64 mm
Length 0.86 mm
Length 0.41 mm
Length 0.34 mm
Length 0.69 mm
Length 0.69 mm

Adjust Display

Histogram

8 bit Camera

50 100 150 200

Min: 0 Max: 255
Mean Intensity: 44.89
Pixel Count: 3,137,536

Fixed Scaling Left: 0 Right: 255
Auto Contrast Left: 0.1 % Right: 0.1 %
Histogram of all frames
Exclude spikes in histogram
Apply Default

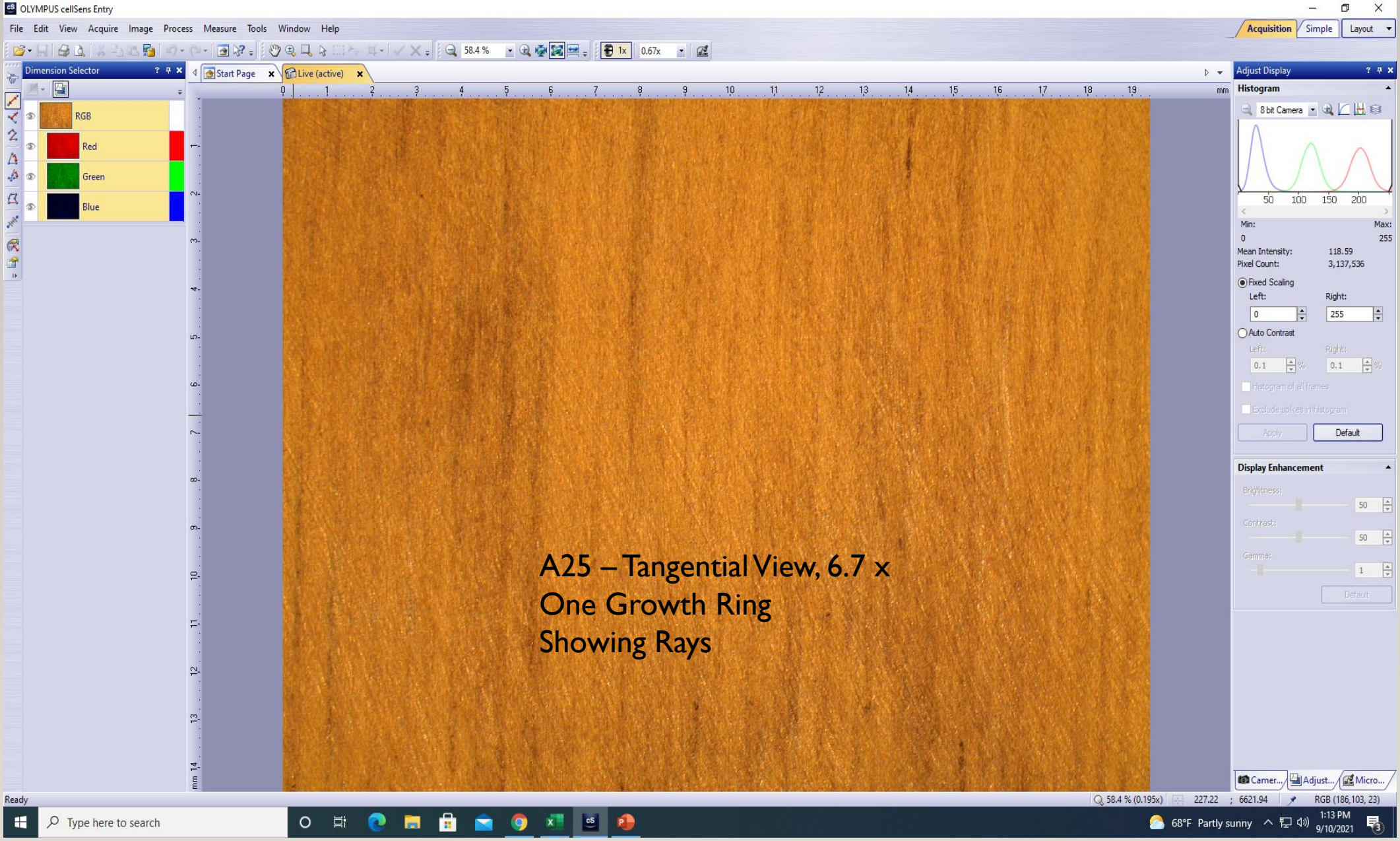
Display Enhancement

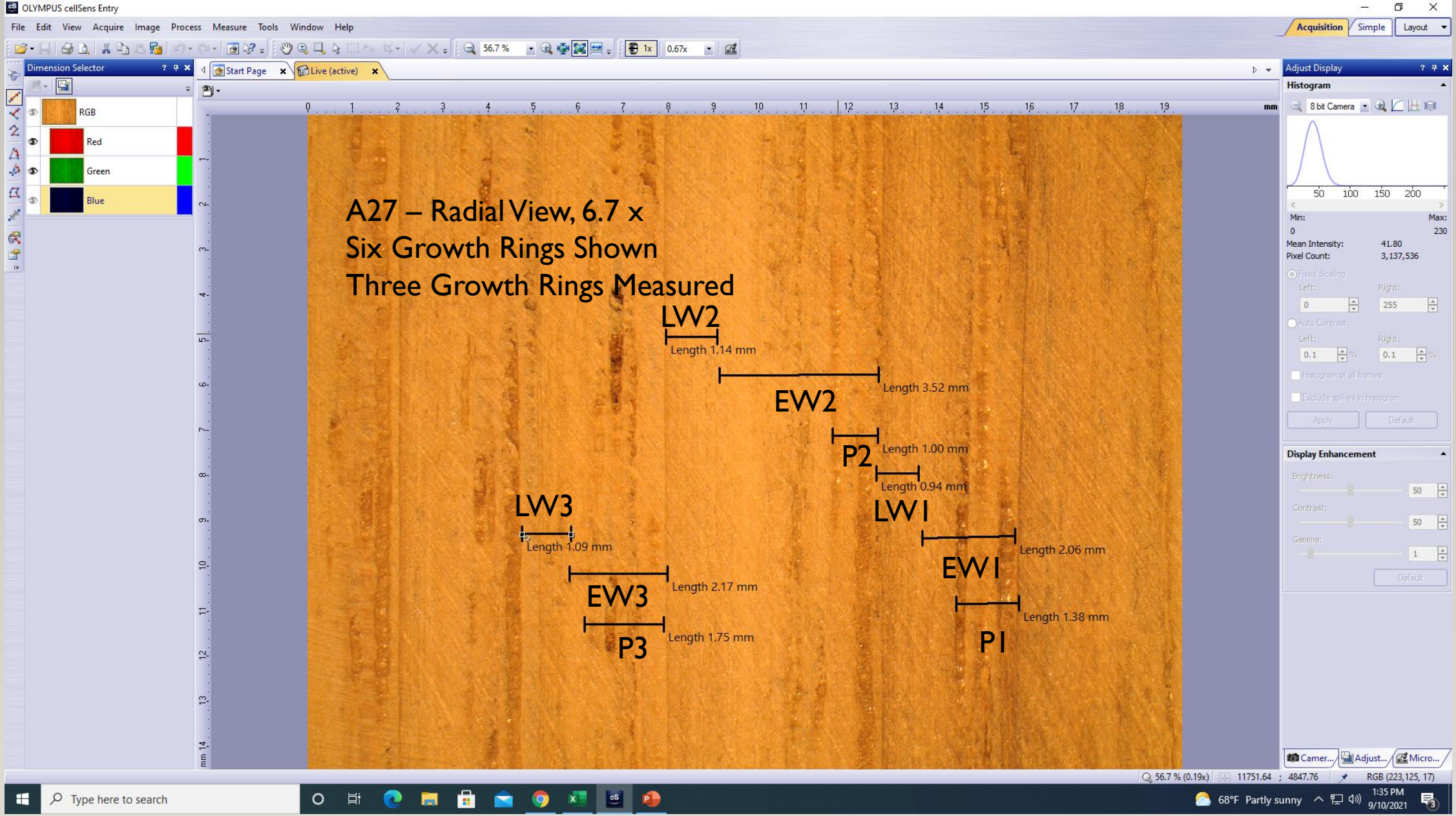
Camer... Adjust... Micro...

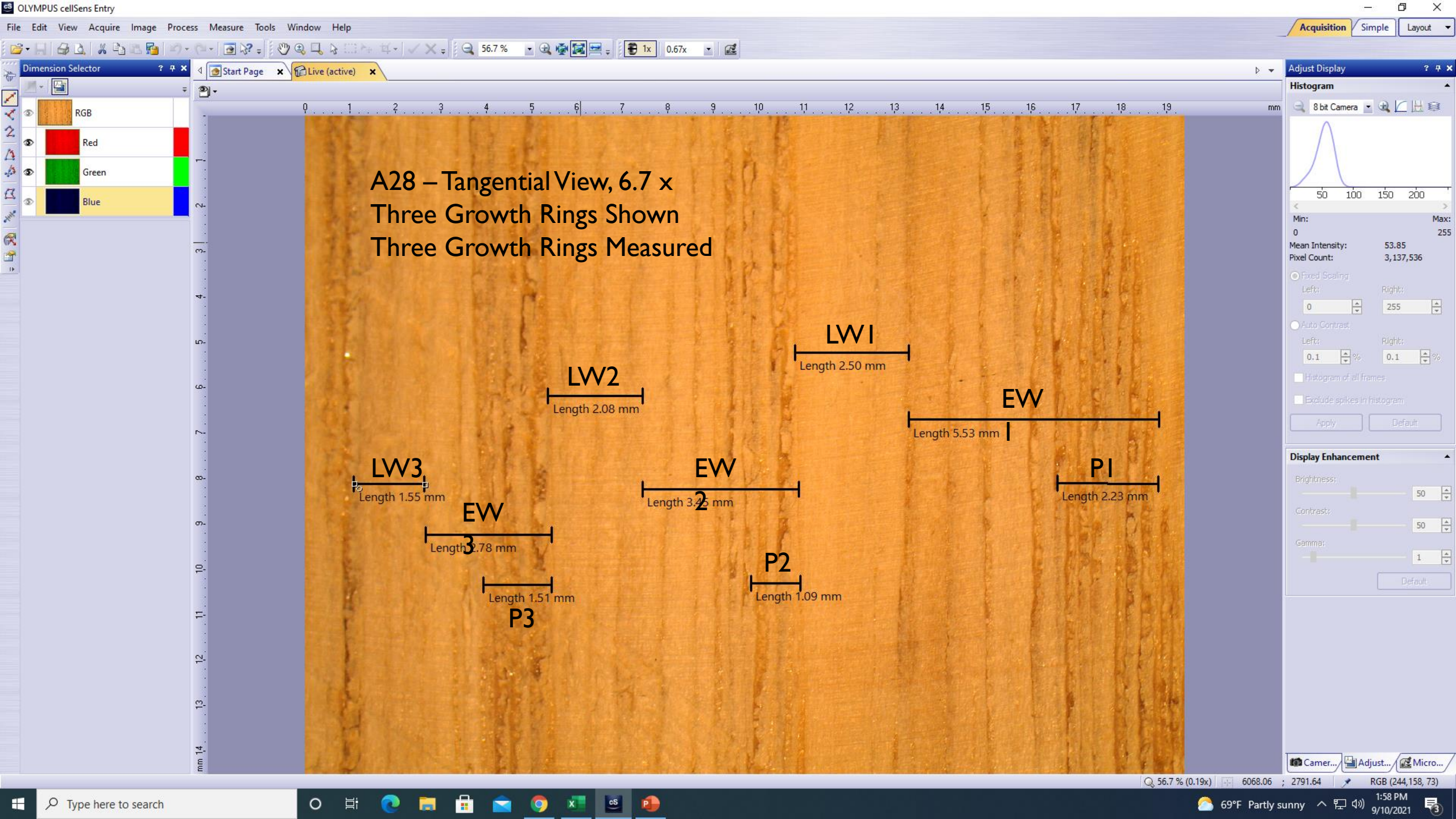
Ready 33 % (0.111x)

Type here to search

64°F Partly sunny 11:27 AM 9/10/2021

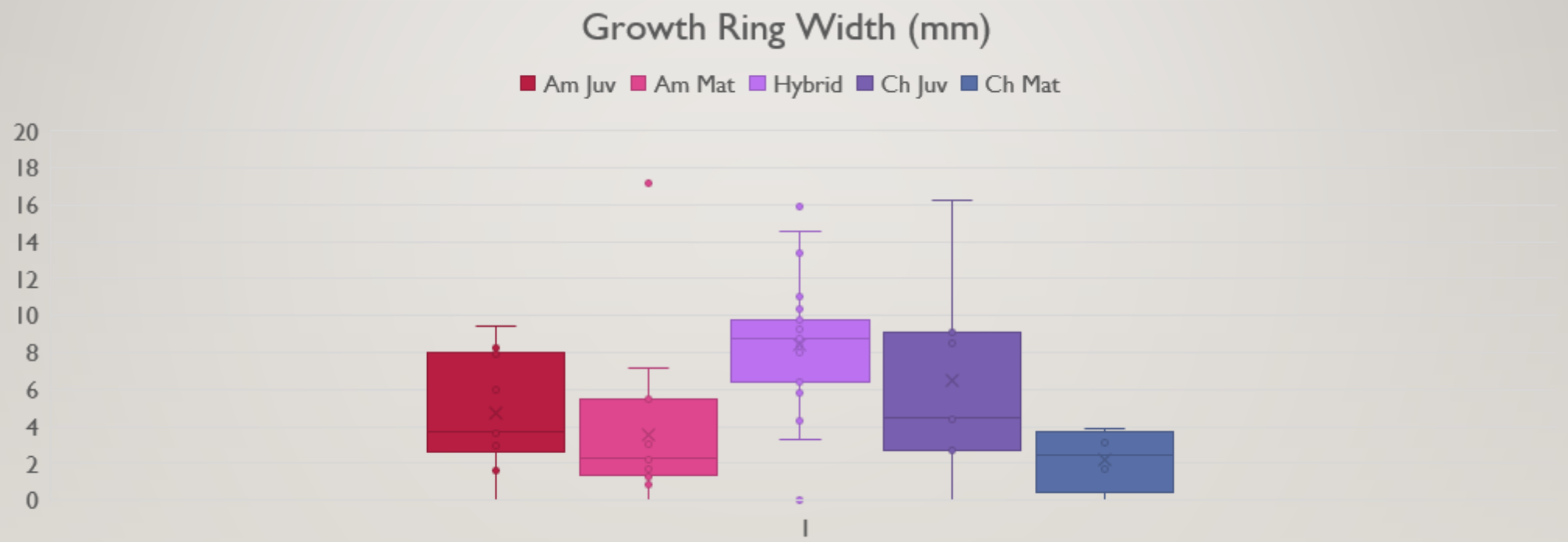

OLYMPUS cellSens Entry
File Edit View Acquire Image Process Measure Tools Window Help
Acquisition Simple Layout
Dimension Selector
RGB
Red
Green
Blue
Start Page
Live (active)
Adjust Display
Histogram
8 bit Camera
Min: Max:
0 255
Mean Intensity: 118.59
Pixel Count: 3,137,536
Fixed Scaling
Left: Right:
Auto Contrast
Histogram of all frames
Exclude spikes in histogram
Apply Default
Display Enhancement
Brightness:
Contrast:
Gamma:
Default
A25 – Tangential View, 6.7 x
One Growth Ring
Showing Rays
Ready
58.4 % (0.195x) 227.22 ; 6621.94 RGB (186,103, 23)
Type here to search
68°F Partly sunny
1:13 PM
9/10/2021


OLYMPUS cellSens Entry
File Edit View Acquire Image Process Measure Tools Window Help
Acquisition Simple Layout
Dimension Selector
RGB
Red
Green
Blue
Start Page
Live (active)
A27 – Radial View, 6.7 x
Six Growth Rings Shown
Three Growth Rings Measured
LW2
Length 1.14 mm
EW2
Length 3.52 mm
P2
Length 1.00 mm
LW1
Length 0.94 mm
LW3
Length 1.09 mm
EW1
Length 2.06 mm
EW3
Length 2.17 mm
P1
Length 1.38 mm
P3
Length 1.75 mm
Adjust Display
Histogram
8 bit Camera
Min: 0
Max: 230
Mean Intensity: 41.80
Pixel Count: 3,137,536
Display Enhancement
Brightness:
Contrast:
Gamma:
Type here to search
68°F Partly sunny
1:35 PM
9/10/2021

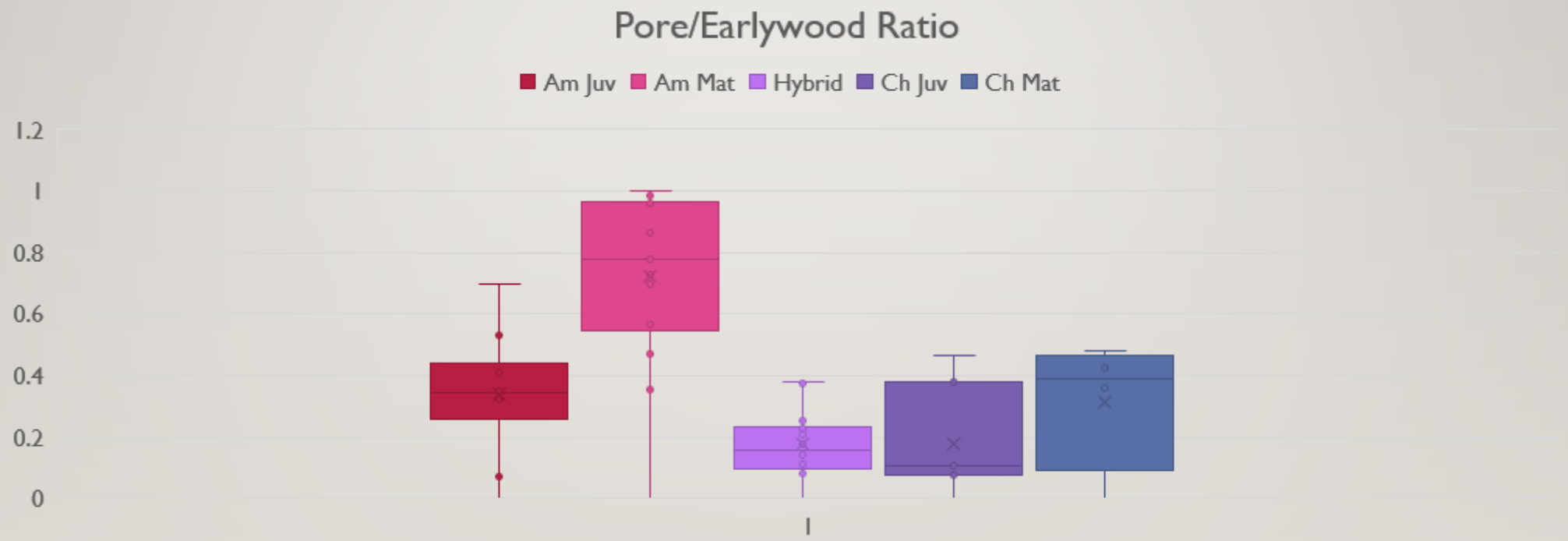

OLYMPUS cellSens Entry
File Edit View Acquire Image Process Measure Tools Window Help
Acquisition Simple Layout
Dimension Selector
RGB
Red
Green
Blue
Start Page
Live (active)
Adjust Display
Histogram
8 bit Camera
50 100 150 200
Min: 0
Max: 255
Mean Intensity: 53.85
Pixel Count: 3,137,536
Fixed Scaling
Left: 0
Right: 255
Auto Contrast
Left: 0.1 %
Right: 0.1 %
Histogram of all frames
Exclude spikes in histogram
Apply
Default
Display Enhancement
Brightness: 50
Contrast: 50
Gamma: 1
Default
A28 – Tangential View, 6.7 x
Three Growth Rings Shown
Three Growth Rings Measured
LW1
Length 2.50 mm
LW2
Length 2.08 mm
EW
Length 5.53 mm
LW3
Length 1.55 mm
EW
2
Length 3.42 mm
P1
Length 2.23 mm
EW
3
Length 2.78 mm
P2
Length 1.09 mm
Length 1.51 mm
P3
56.7 % (0.19x)
6068.06 ; 2791.64
RGB (244,158, 73)
Type here to search
69°F Partly sunny
1:58 PM
9/10/2021

RESULTS

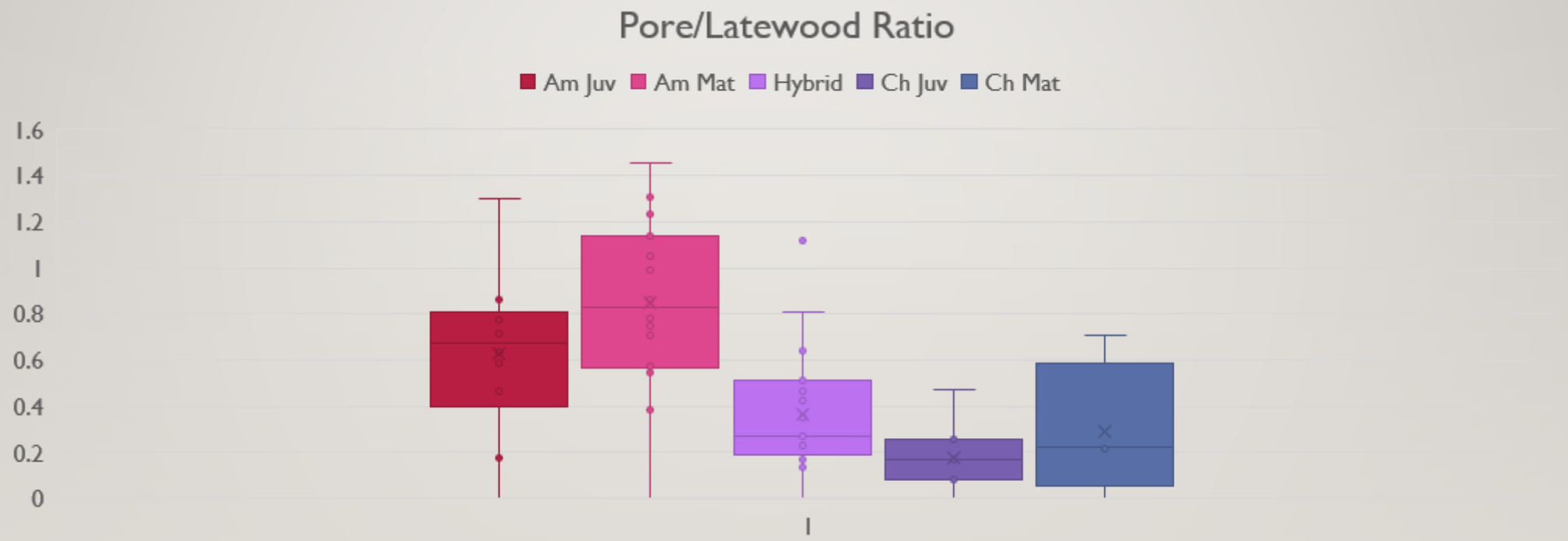
CHESTNUT WOOD GROWTH RING PROPERTIES



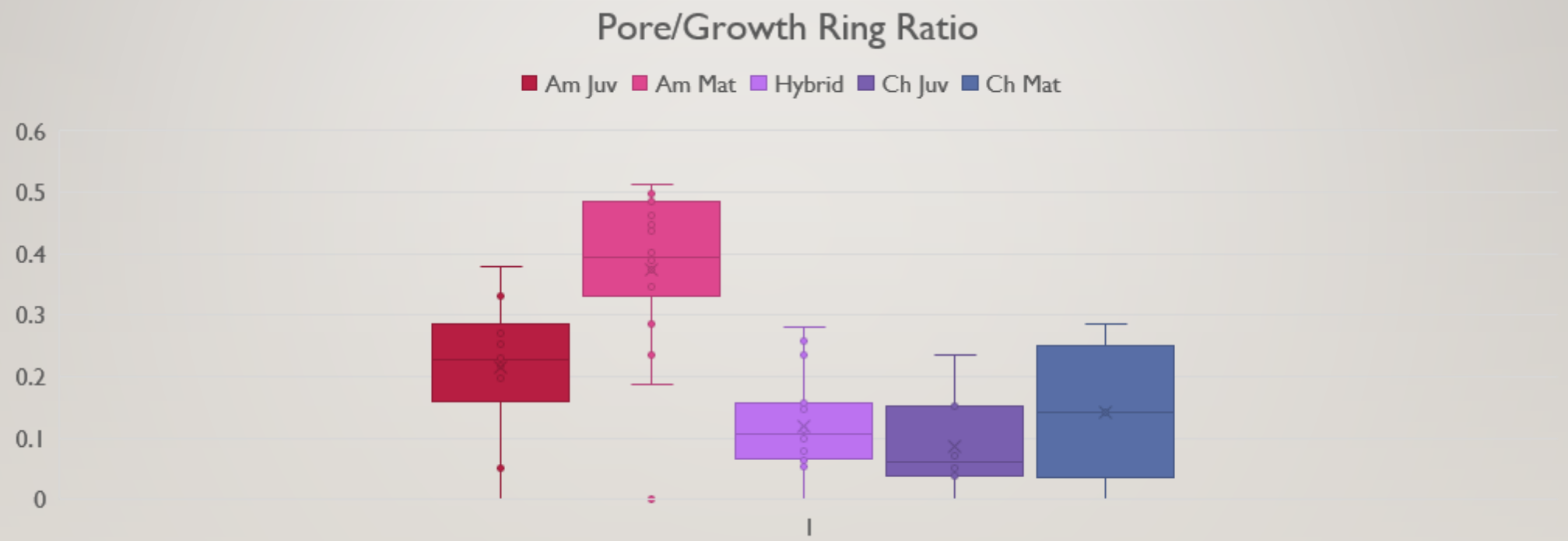
CHESTNUT WOOD GROWTH RING PROPERTIES



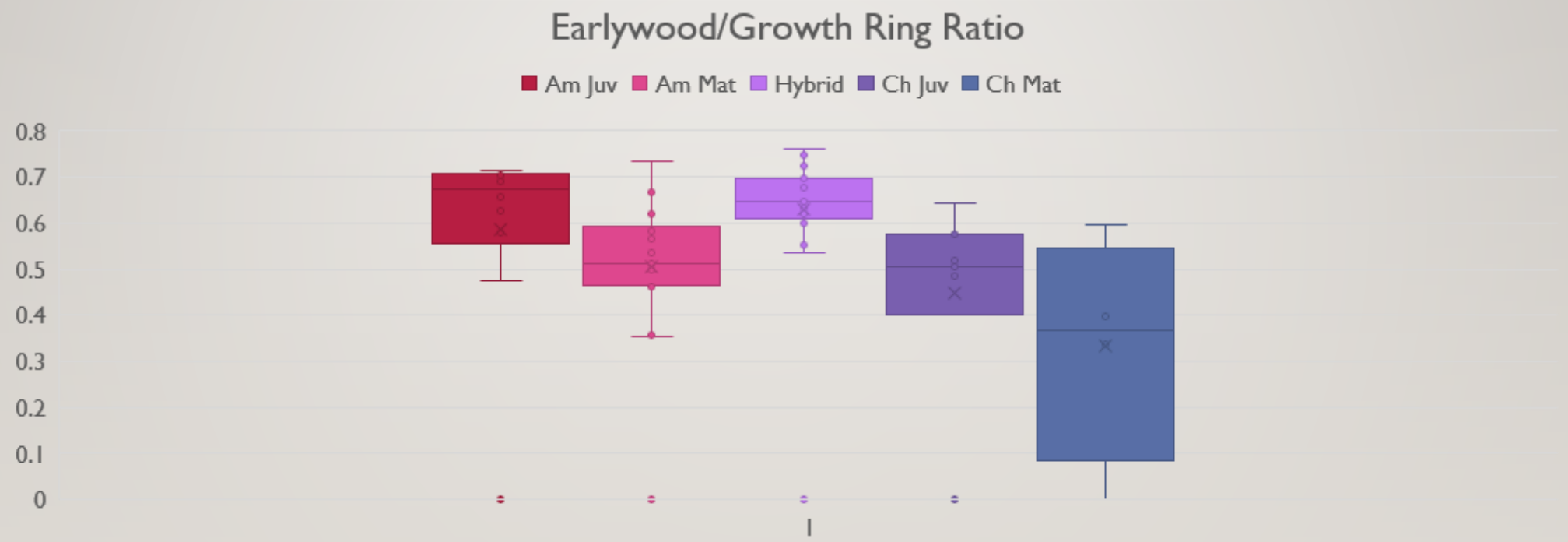
CHESTNUT WOOD GROWTH RING PROPERTIES



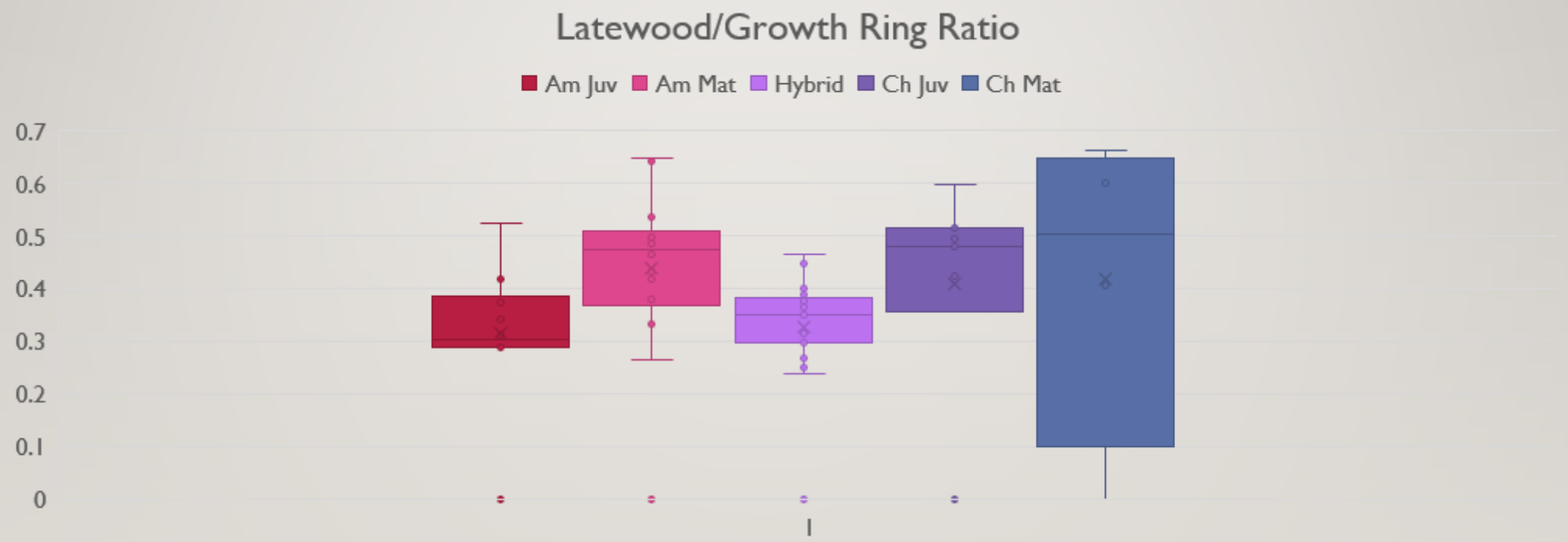
CHESTNUT WOOD GROWTH RING PROPERTIES



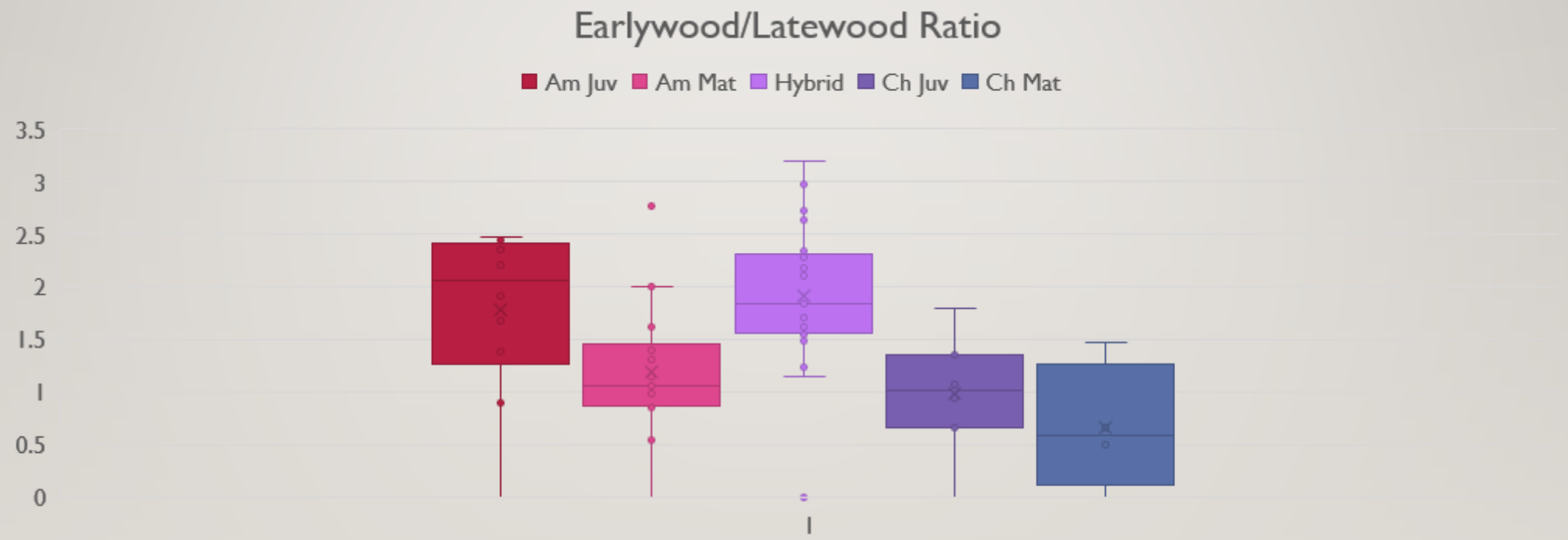
CHESTNUT WOOD GROWTH RING PROPERTIES



CHESTNUT WOOD GROWTH RING PROPERTIES



CHESTNUT WOOD GROWTH RING PROPERTIES



SUMMARY OF GROWTH RING MEASUREMENTS

- Hybrid growth rings tend to be wider than either American or Chinese juvenile growth rings
- Hybrid pore width relative to earlywood is more like Chinese juvenile wood than American juvenile wood, but hybrid pore width relative to latewood and to the entire growth ring is transitionary between Chinese and American
- In three ratios not related to pore width (Earlywood to Growth Ring, Latewood to Growth Ring, and Earlywood to Latewood) Hybrids almost precisely match American ratios and are distinctly different from Chinese ratios.

CONCLUSIONS

1. COLOR METRICS

- RGB averages show no difference between *C. dentata*, *C. mollissima*, and *C. sativa,* but that Hybrid specimens are lighter with the same color profile. American juvenile wood is closer to the RGB profile of the Hybrid specimens, except in the blue spectrum.
- Color Index examination, which is more discriminating than the RGB profile, does not definitively show a color distinction between American wood (juvenile or mature) and Chinese mature wood, but does show a difference between Chinese juvenile wood and American wood.
- Color Index examination also confirms that hybrid (all juvenile wood) specimen colors are distinct from American wood, both mature and juvenile, and Chinese mature wood. It also suggests a slight difference from Chinese juvenile wood.

2. DENSITY METRICS

- Chinese wood is 36% more dense than American wood. Chinese juvenile wood is 20% more dense than American juvenile wood, and Chinese mature wood does not seem to exhibit the significantly lighter mature wood like American. More sampling needed.
- Hybrid specimens were 10% more dense than all American specimens but were almost precisely the same density as American juvenile wood. Density profile of Hybrid chestnuts is much more similar to American chestnut than Chinese chestnut.
- Correlation plots suggest there is no correlation between color and density.
- The same correlation plots show that Hybrid specimens occupy the same color/density profile as American juvenile wood and have a distinctly different color/density profile than Chinese chestnut wood.

3. CELL GROWTH METRICS

- American chestnut mature wood goes against convention and is less dense than its juvenile wood, due to the pore ring size being nearly equal to the latewood size. It would be interesting to investigate this phenomenon in other ring-porous hardwoods.
- Hybrid specimens exhibit the same approximate growth ring size as American and Chinese juvenile wood and are distinctly different from American and Chinese mature wood specimens.
- Hybrid pores exhibit similar characteristics to Chinese wood in all ratios and are distinctly different from American pore ring dimensions.
- However, in three ratios not related to pore ring width (Earlywood to Growth Ring, Latewood to Growth Ring, and Earlywood to Latewood) Hybrids almost precisely match American ratios and are distinctly different from Chinese ratios.

IMPLICATIONS OF THE RESEARCH

- Color variability in the data suggest Hybrid wood is more nearly Chinese colored, but this is due to the color metrics only looking at juvenile Hybrid wood. Stand parameters of Hybrid plantations mirror more closely Chinese chestnut stands and growth form, promoting wider crowns to stem and more fluid and food transportation during earlywood generation, resulting in pore ring and earlywood size similar to Chinese trees.
- However, annual ring data suggest that as Hybrids evolve from juvenile wood to mature wood, and crowns close and thin, the wood will more closely resemble American chestnut wood and will be distinctly different from Chinese. Final form of the tree will determine the ultimate wood quality; the taller and more tubular, the more the wood will resemble *C. dentata*.
- The color/density profiles suggest that that the F3 generation of Hybrids in fact moved wood parameters closer, and perhaps indistinguishable from native *C. dentata,* and were a significant improvement over F2 wood characteristics. The small number of F4's in the study seem to suggest a slight improvement over the F3, but so slight as to probably not be noticeable or statistically significant.


The
End