Tree Vitality:

shining a light on tree health

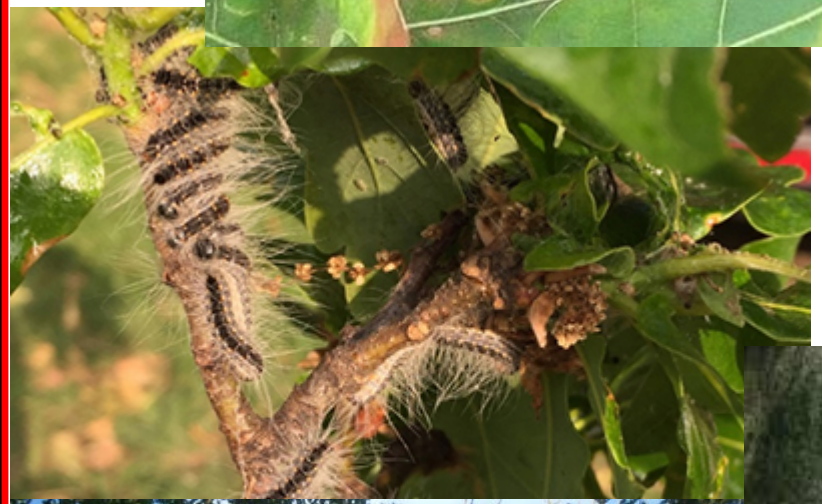
Jon Banks – jbanks@Bartlett.com

Aim

- Intro to tree health and vitality
- Tree health evaluation methods: past present and future
- An Introduction to chlorophyll fluorescence and Arborcheck®
- FAQ & Case study

What is Tree Health?

(but remember)



Stress cascade:

stomatal closing ≥ ABA accumulation >

water potential > **photosynthesis** >

cell **growth** (turgor) > wall/protein synthesis >

chlorophyll formation > **nitrate** reductase ≥ ROS accumulation >

respiration > accumulation of proline and sugars > **cell leakage** > necrosis > death.

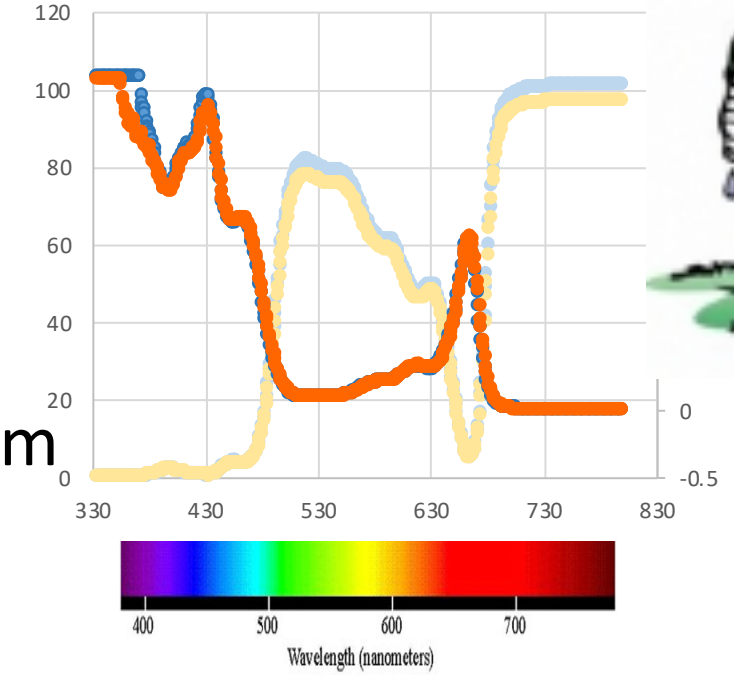
Measuring Stress
Some “Historic”/current methods

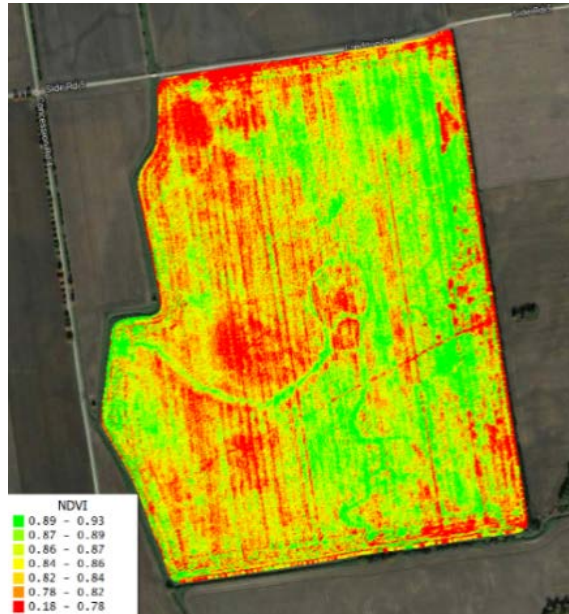
- Extension growth
- Root Growth Potential
- Visual index (tree/foliage morphology & condition, yellowing)
- Stem/root/leaf electrolyte leakage

Photos : Goodman et al (2017)

More “Current”/advanced Methods

- Foliage temperature
- NDVI (NIR /+&-Red)
  normalized difference vegetation index
- Chlorophyll content 650/940nm
- Stomatal Conductance
- Water Potential
- IRGA
  infrared gas analyser





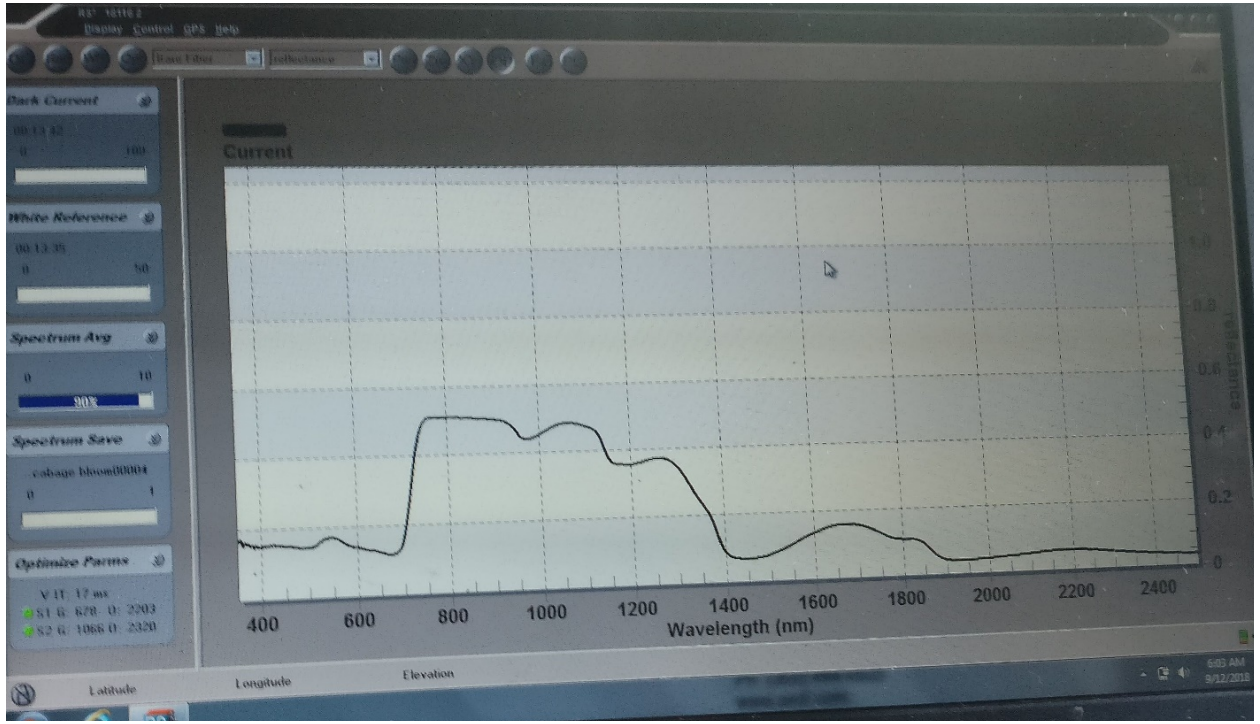
New Methods

- IRGA ~£40-50K
- Hyperspectral “imaging” ~£70K
- Chlorophyll fluorescence ~£1-2K
  - PhotosynQ (as seen online) ~£1K

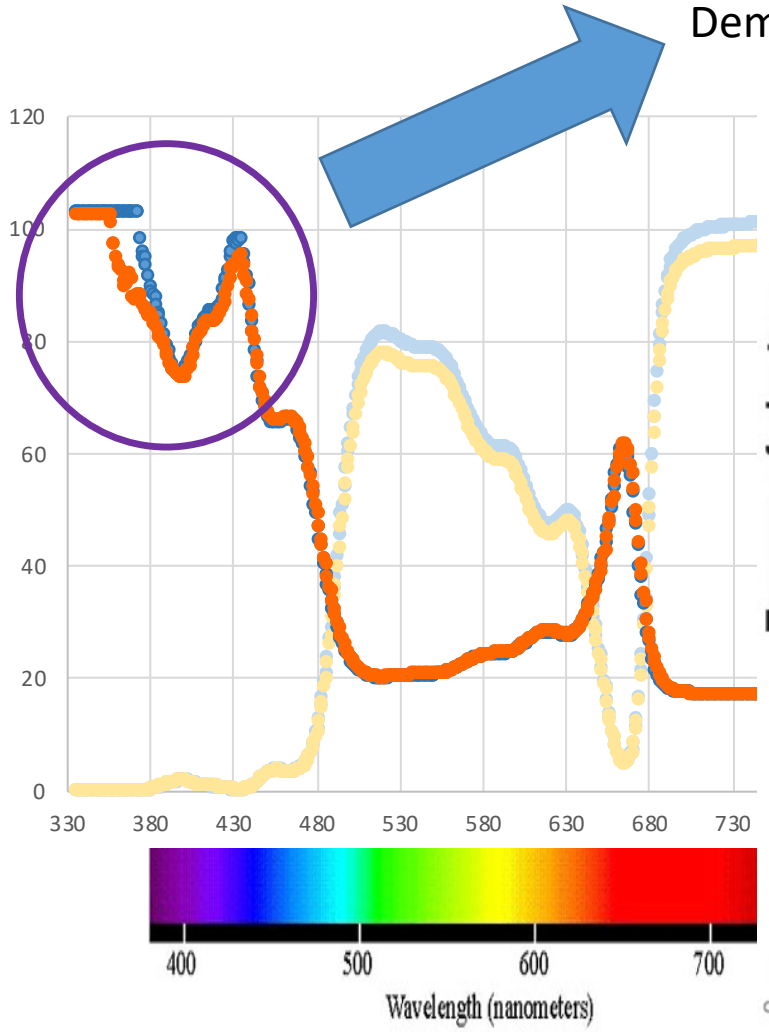
    Fluorescence, absorbance, chlorophyll content, temperature, relative humidity, barometric pressure, leaf temperature, light intensity, cardinal direction and tilt

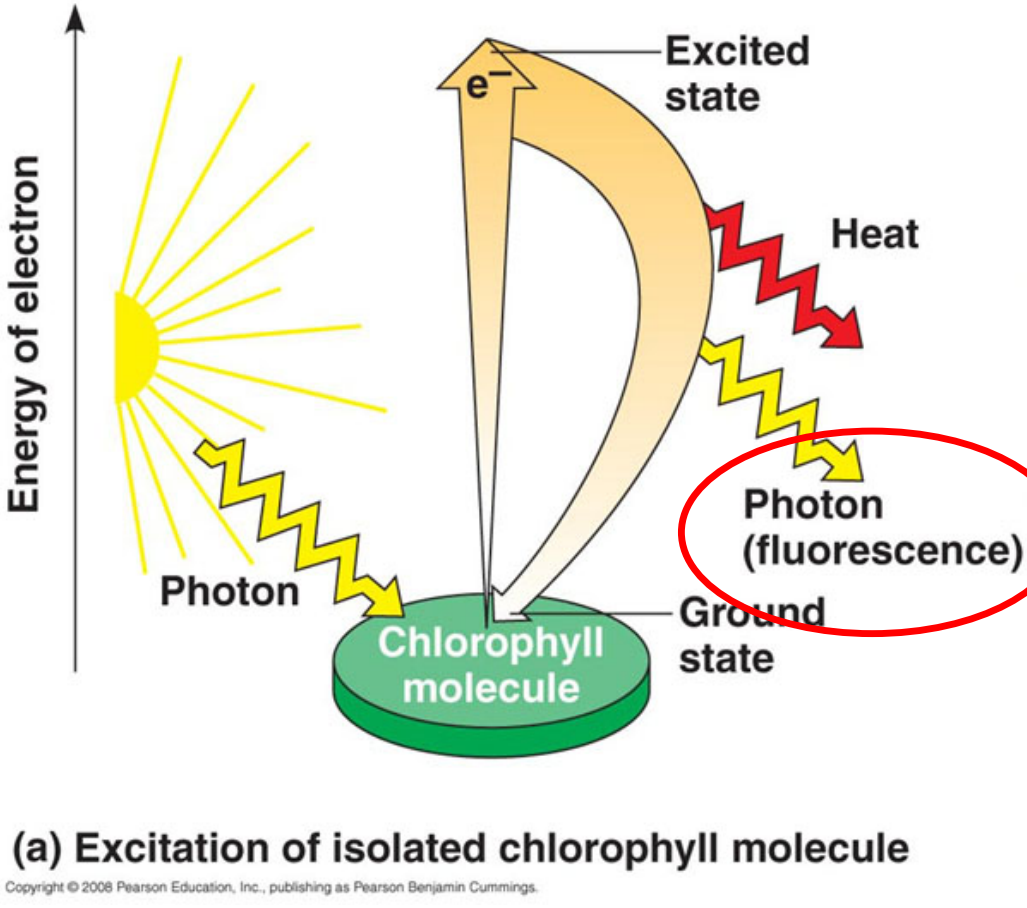
    Has issues with consistency/reliability currently, needs a phone connection

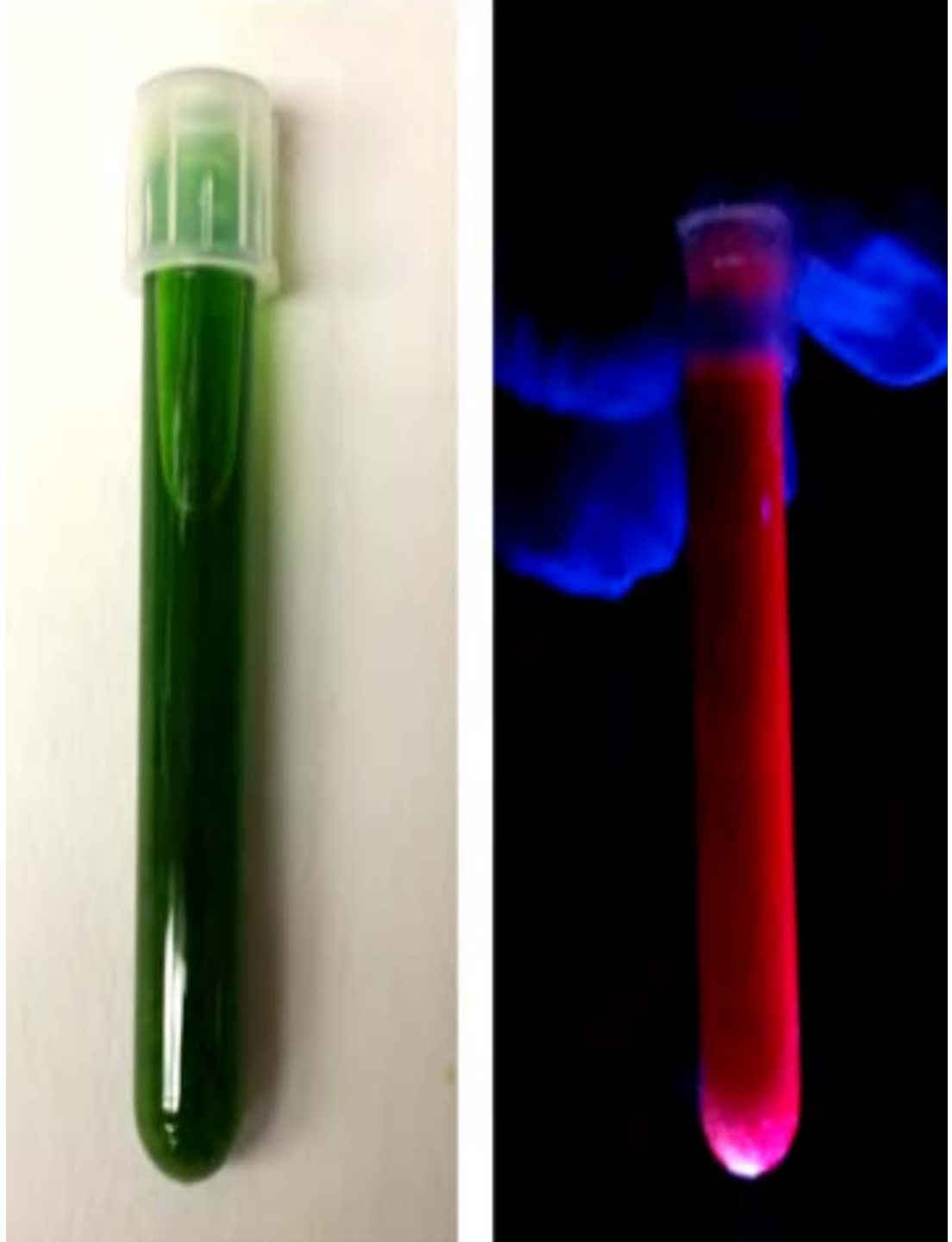
  - Other devices more promising



What is chlorophyll fluorescence?

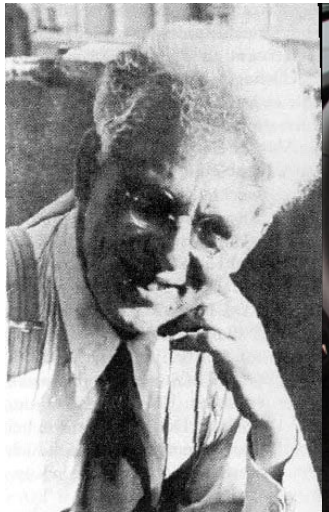




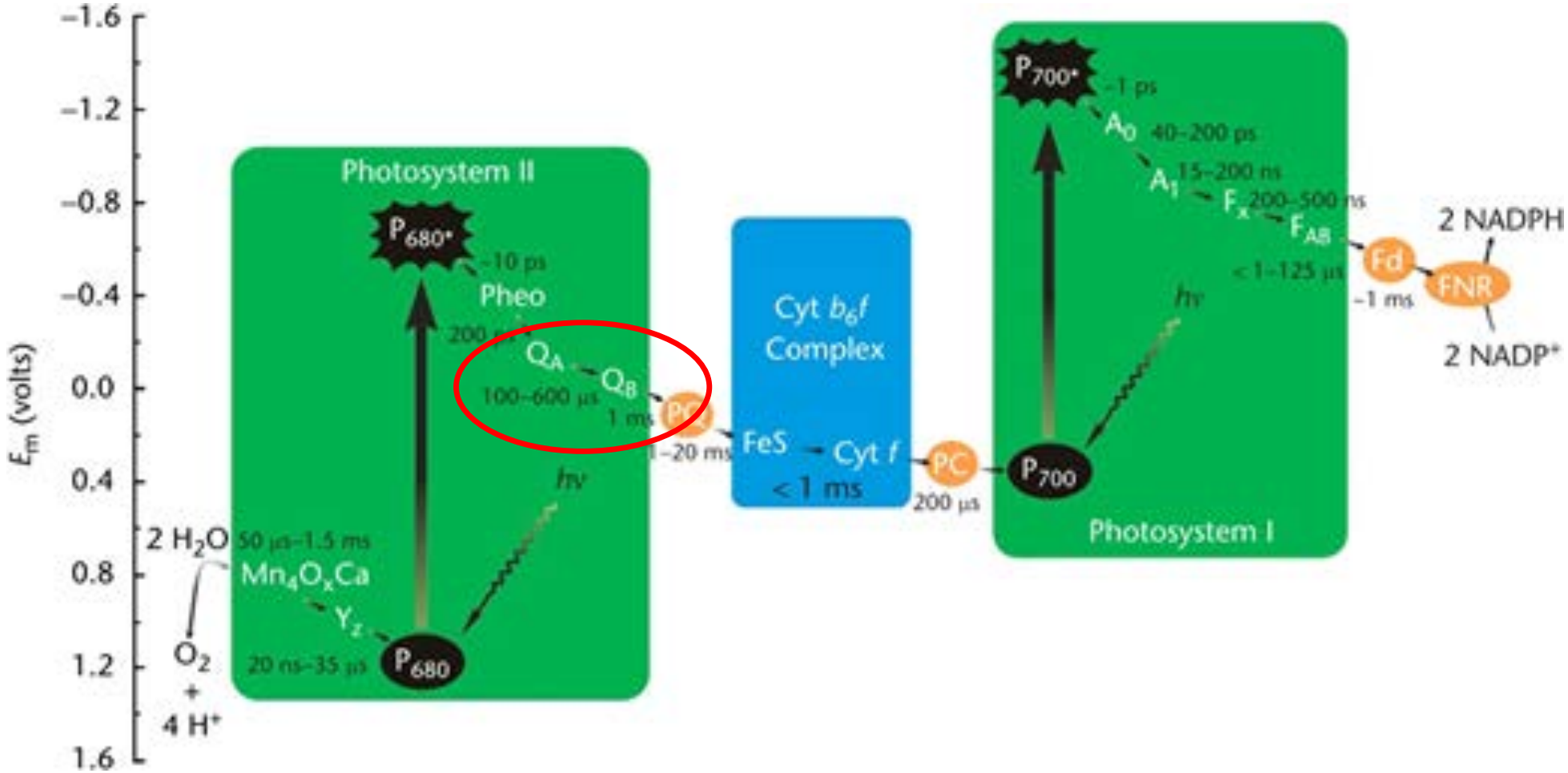


What is chlorophyll fluorescence?

- An energy overflow mechanism within photosynthesis
- A Proxy for measuring photosynthesis
- Used widely to detect and understand plant stress and stress responses.
- First observed visually in 1931 by H. Kautsky and A. Hirsch

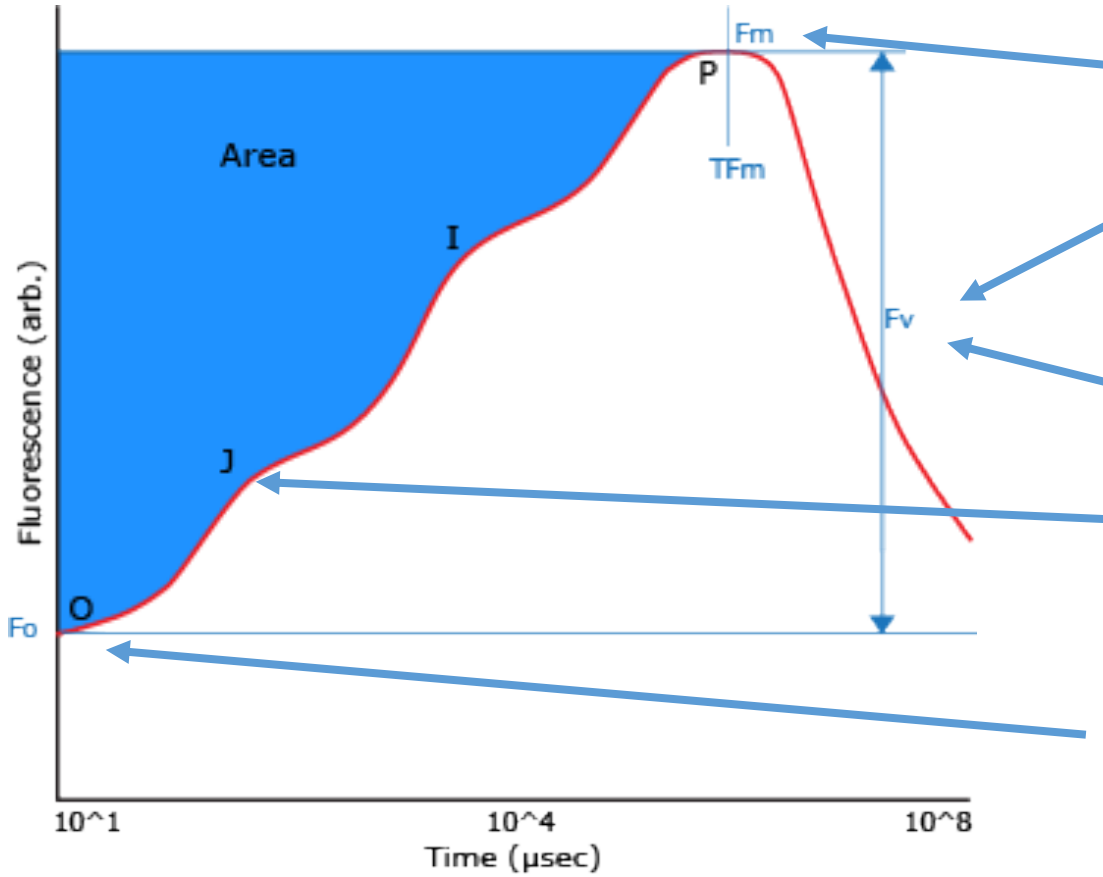


What is chlorophyll fluorescence?



Z scheme: ETC, Light-dependent reactions

Parameters



Fv/Fm (developed in 1975)

$$PI_{ABS} = \left(\frac{1}{3.3 \times \left(\frac{F_K - F_0}{F_V} \right)} \times \frac{F_J - F_0}{F_V} \times \frac{F_V}{F_M} \right) \times \left(\frac{F_V}{F_0} \right) \times \left(\frac{F_V - F_J + F_0}{F_J - F_0} \right)$$

(Developed in 2003/4)

(Dark Adapt)

Banks JM (2017) Continuous excitation chlorophyll fluorescence parameters: a review for practitioners. Tree Physiol 37:1128–1136.

55 parameters currently available!

Select Parameters

OJIP Data
- t for Fm

Normalised Data
- Fo / Fm
- Fv / Fm

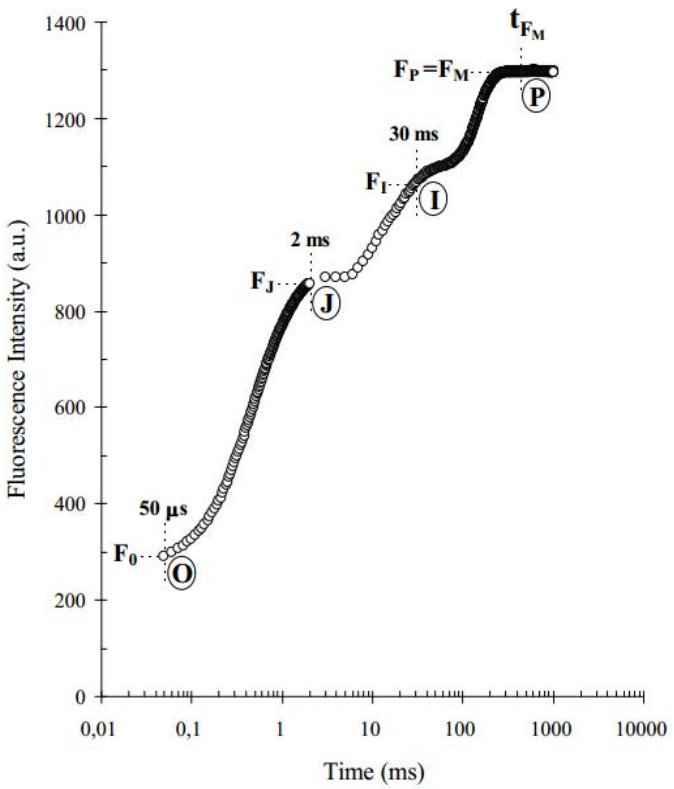
Specific Fluxes
- ABS / RC Antenna size

Apparent fluxes per CSo estimated
- (ABS / CSo) ~ Fo
- DIo / CSo
- TRo / CSo
- ETo / CSo
- REo / CSo
- On / Off

Partial Performances
- gamma(RC)/(1-gamma(RC))
- phi(Po)/(1-phi(Po))
- psi(Eo)/(1-psi(Eo))
- PI abs
- delta(Ro) / (1-delta(Ro))
- On / Off

Apparent fluxes per CSm estimated
- (ABS / CSm) ~ Fm
- DIo / CSm
- TRo / CSm
- ETo / CSm
- REo / CSm
- On / Off

Total Performance, Driving Force, rates etc
- PI total
- DF abs
- DF total
- kP / ABS * kF
- kN / ABS * kF
- On / Off



Arborcheck parameters selected

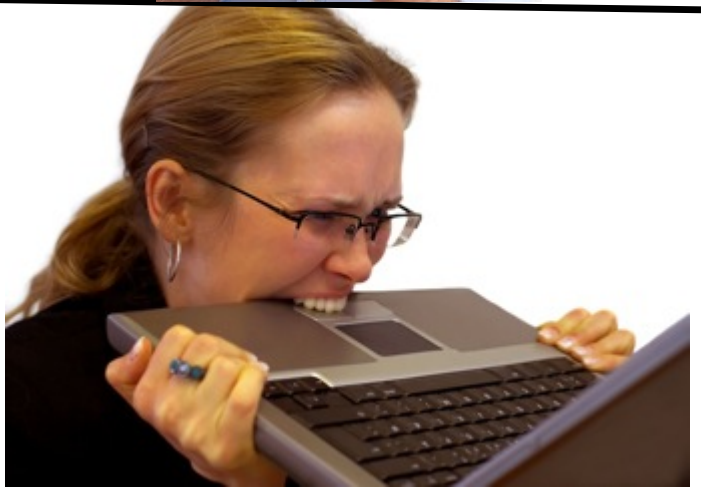
Fv/Fm

CC

"Vitality"

Si1: Fv/F0
Si2: F0
Si3: Fv
Si4: Area

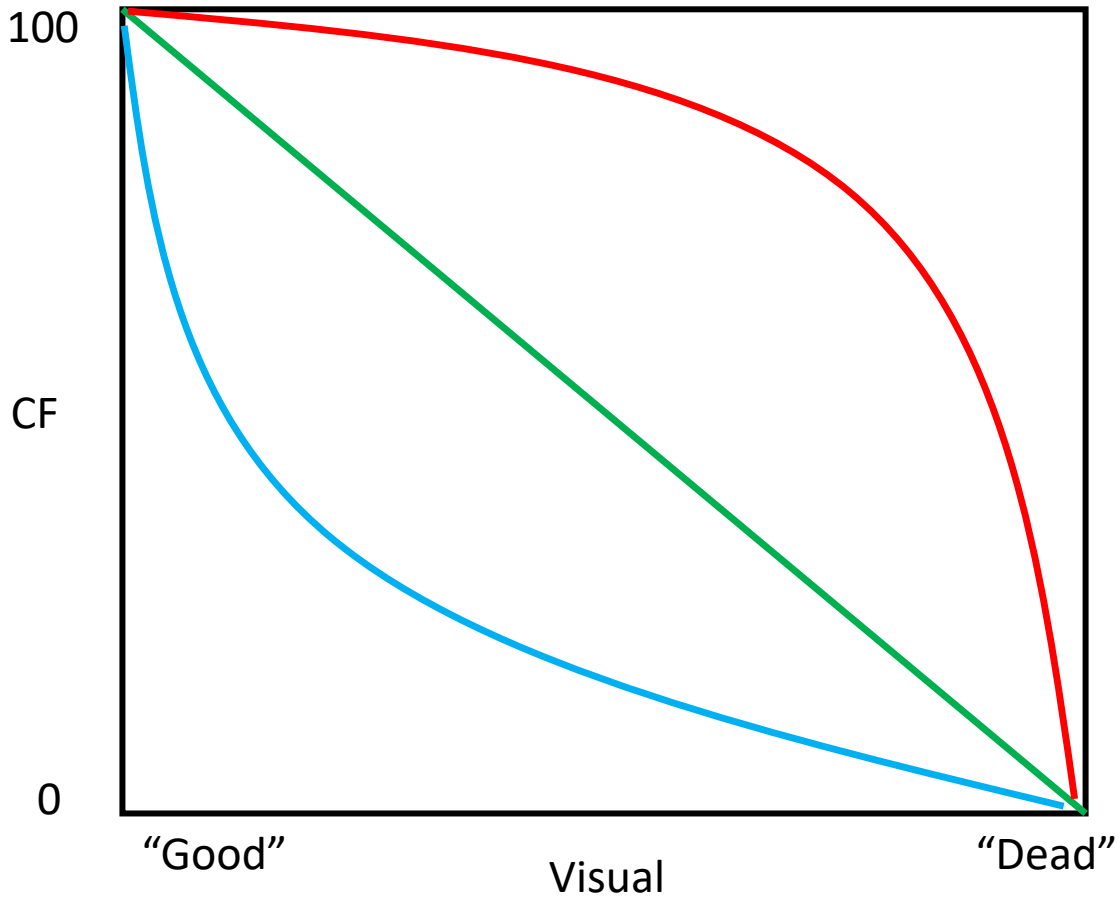
"Stress"

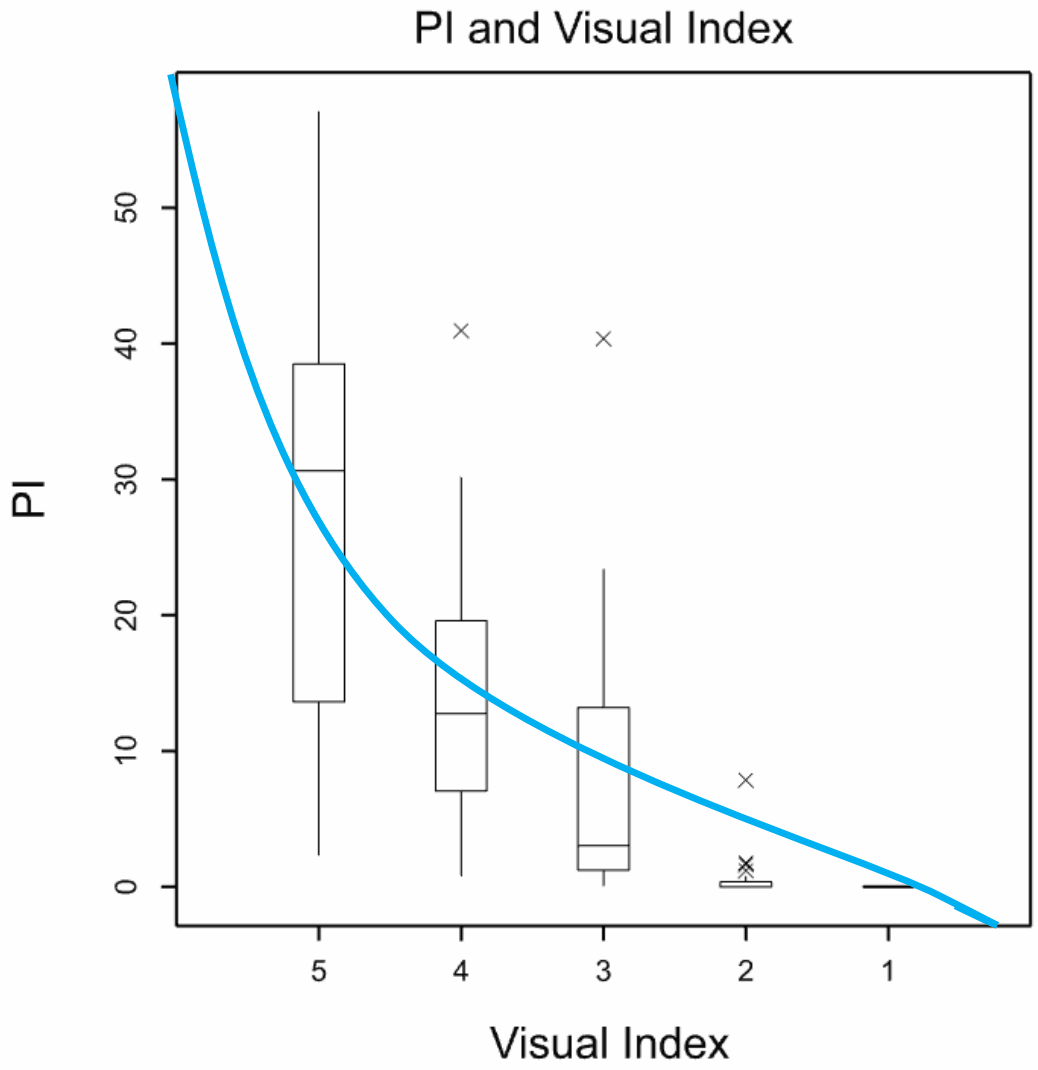


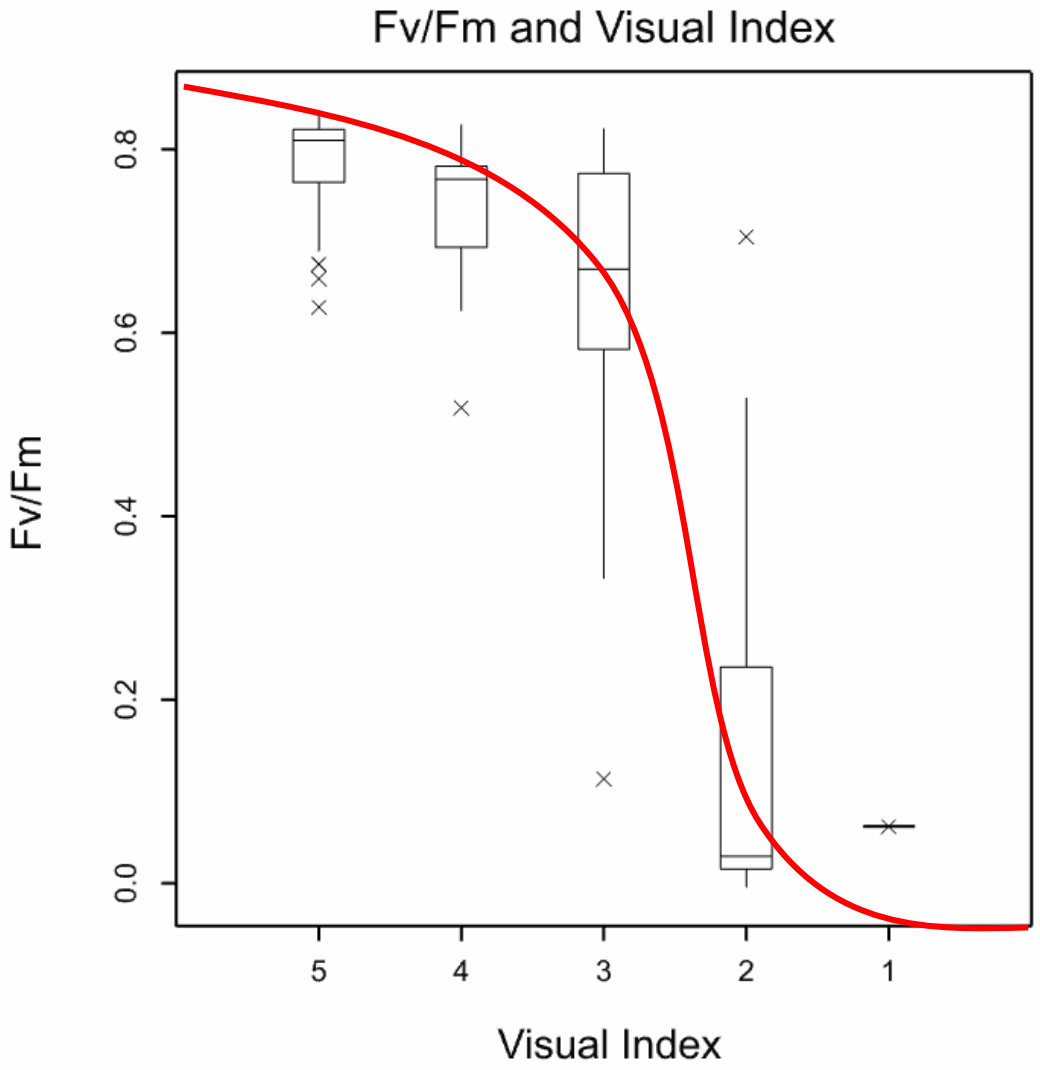
Six

Banks JM (2018) Chlorophyll fluorescence as a tool to identify drought stress in Acer genotypes. Environ Exp Bot 155:118–127.

How does CF compare to Visual Health?




PI and Visual Index
PI
0
10
20
30
40
50
5
4
3
2
1
Visual Index


Fv/Fm and Visual Index
Fv/Fm
0.0
0.2
0.4
0.6
0.8
5
4
3
2
1
Visual Index

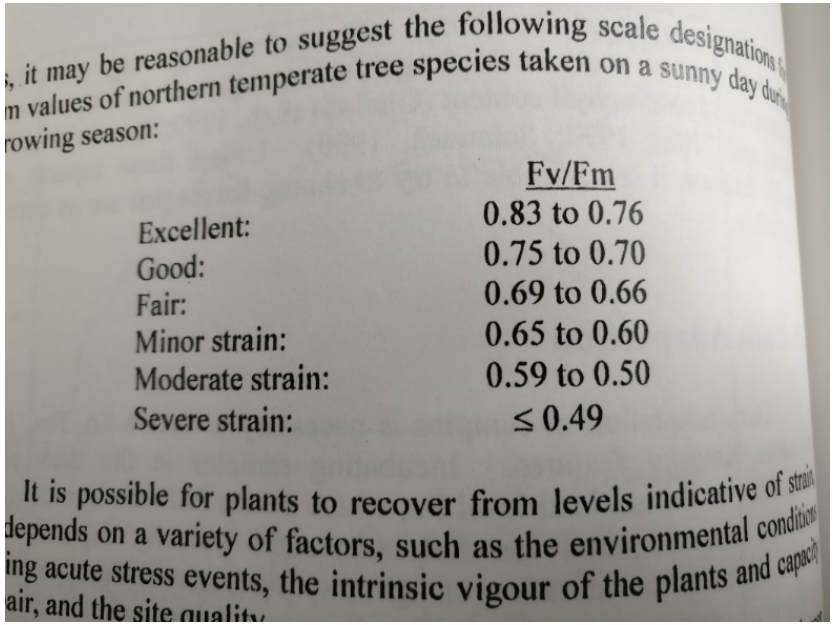
What's a healthy value?

1987 - Björkman & Demmig

Table 3. Comparison among taxonomic groups and life forms of the pho (α) and the F_V/F_M ratio (692 nm, 77 K) in leaves and fronds of 37 C_3 species

	Taxon Life form	No. of species	No. of families	F_V/F_M (mean ± SE)
I.	Pterophyta			
	Ferns	2	2	0.800 ± 0.017
II.	Coniferophyta			
	Coniferous trees	2	2	0.853 ± 0.004
III.	Anthophyta			
	A. Dicotyledonae	25	22	0.830 ± 0.004
	1. Herbaceous	8	5	0.827 ± 0.005
	2. Deciduous trees	4	4	0.843 ± 0.012
	3. Evergreen shrubs vines	5	5	0.824 ± 0.008
	4. Evergreen trees	8	8	0.830 ± 0.009
	B. Monocotyledonae	8	6	0.840 ± 0.008
	1. Grasses, sedges	3	3	0.849 ± 0.007
	2. Others	5	3	0.836 ± 0.011
Non-sclerophyllous		21	16	0.834 ± 0.004
Sclerophyllous		16	16	0.828 ± 0.006
All C_3 plants		37	32	0.832 ± 0.004

2003 – Mohammed et al.



, it may be reasonable to suggest the following scale designations f
n values of northern temperate tree species taken on a sunny day duri
rowing season:

	Fv/Fm
Excellent:	0.83 to 0.76
Good:	0.75 to 0.70
Fair:	0.69 to 0.66
Minor strain:	0.65 to 0.60
Moderate strain:	0.59 to 0.50
Severe strain:	≤ 0.49

It is possible for plants to recover from levels indicative of strain
depends on a variety of factors, such as the environmental conditions
ing acute stress events, the intrinsic vigour of the plants and capacity
air, and the site quality

"**Fv/Fm** tends to average **0.83** in healthy foliage…

But when does one begin to suspect trouble as foliage responses dip below this" (Mohammed et al. 2003)



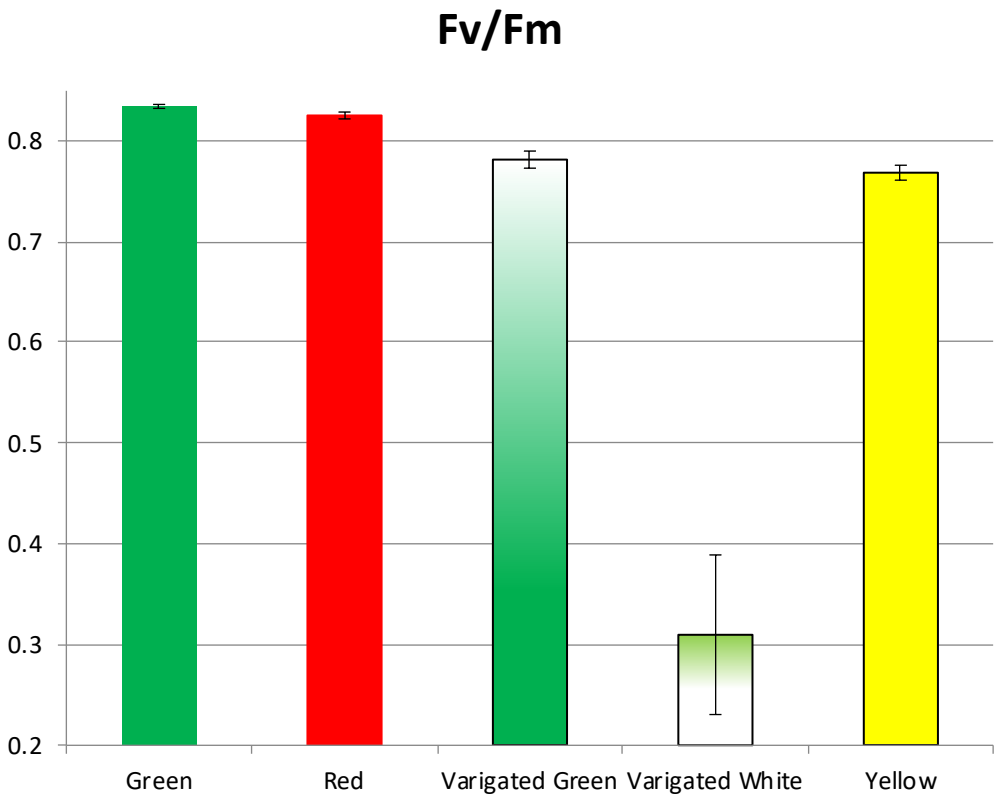

Complication

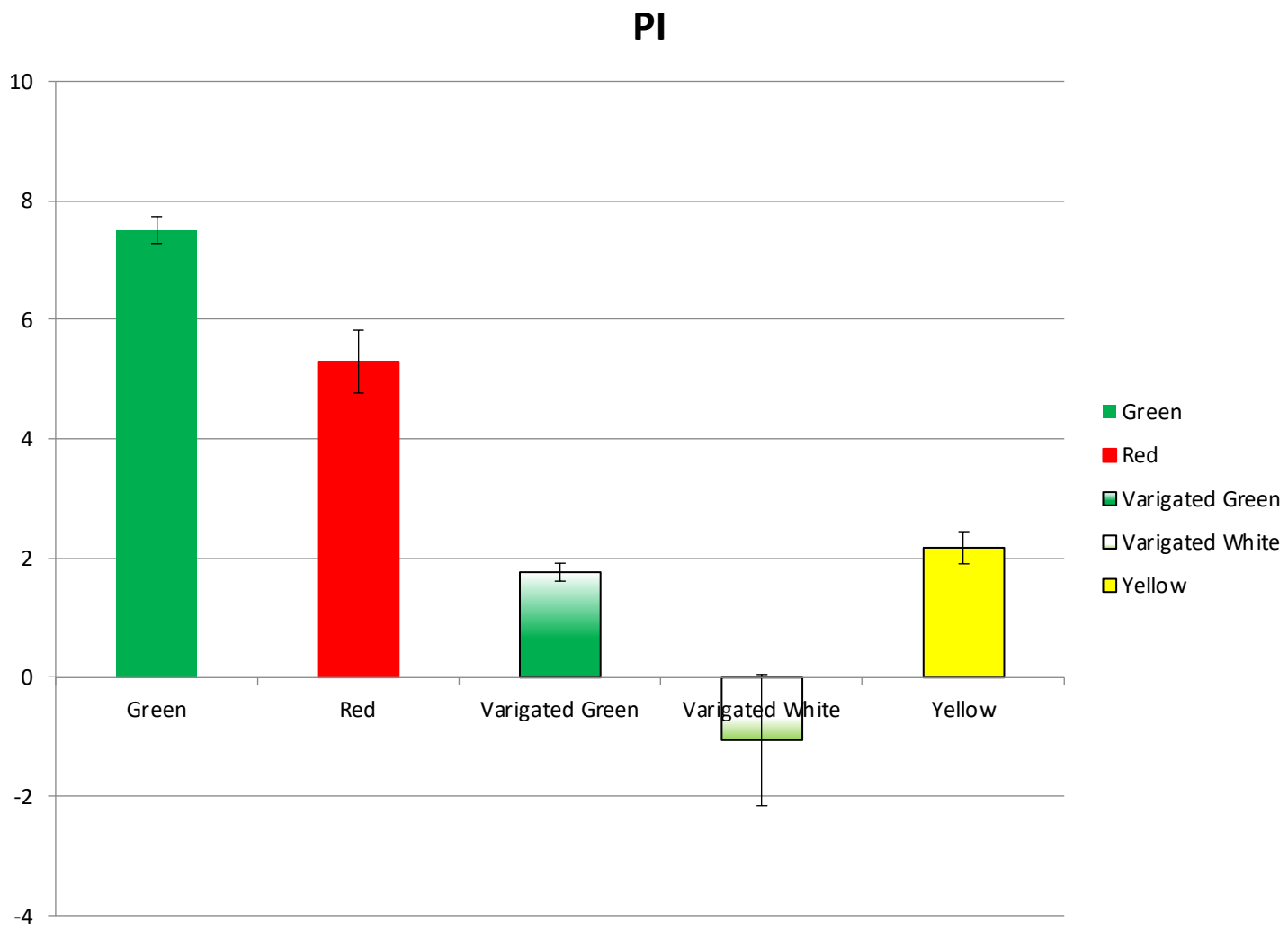
What about variation between species/cultivars?



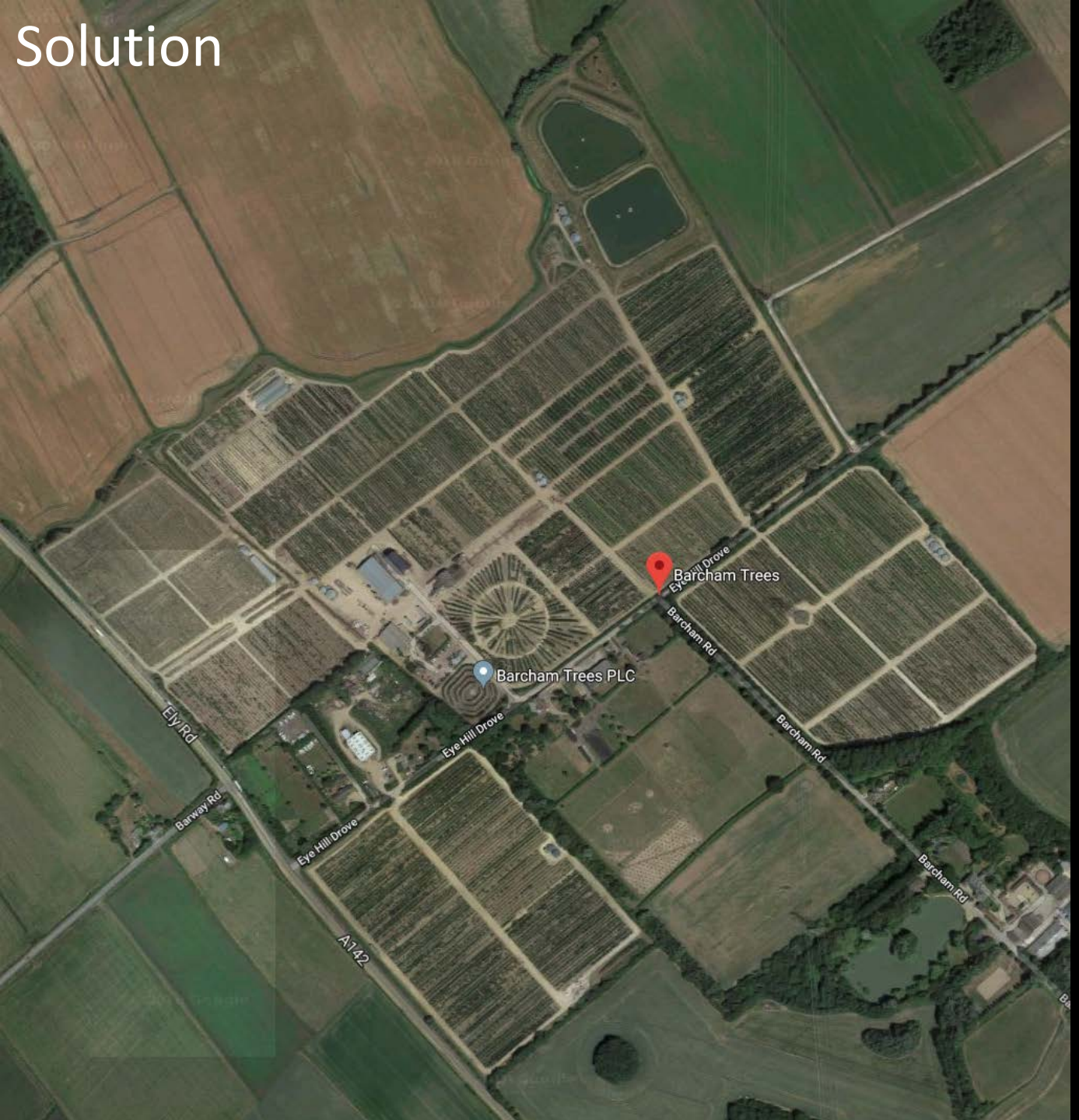


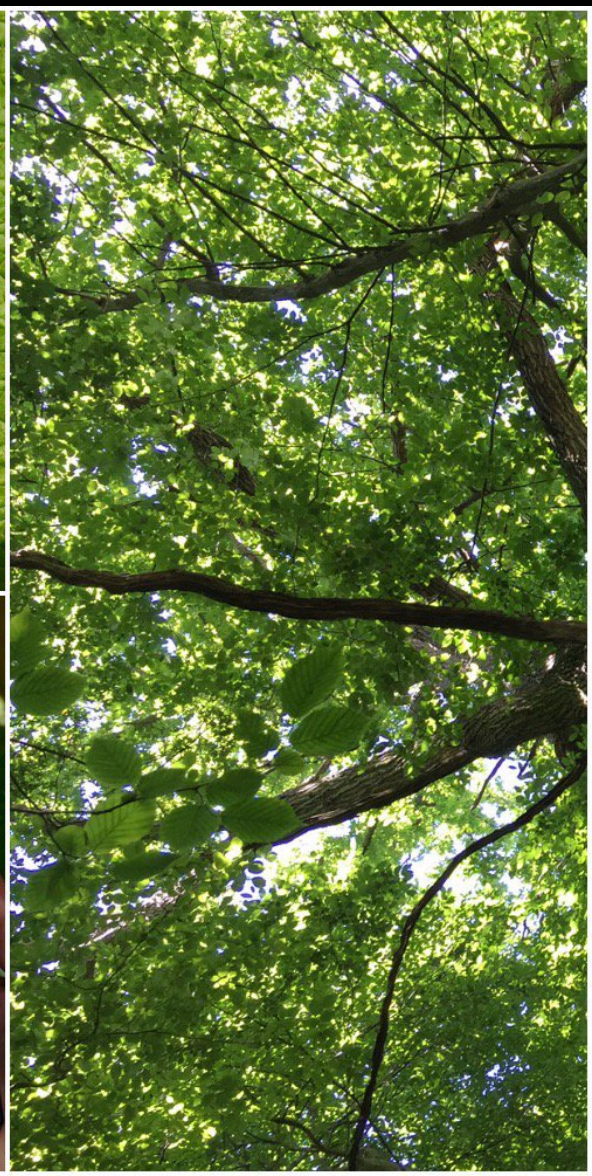
Complications





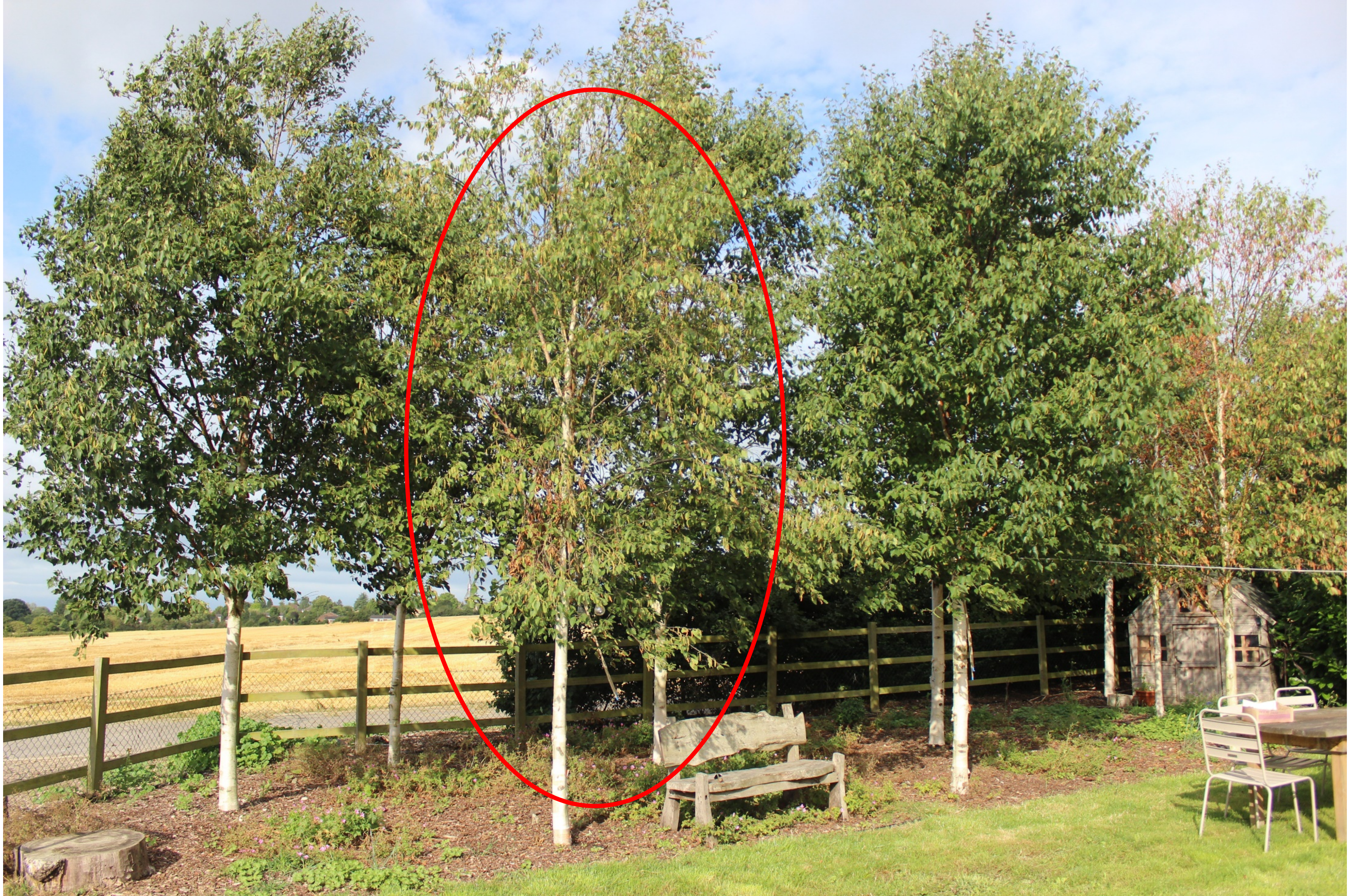
Solution





478 Genotypes Currently Covered

Case study: 1



(Neil Wilson, Beechwood Tree Care Ltd.)

10:34

Arborcheck

Result 30 of 31 (ARB-21-07-17_17-01.res)

Tree ID:

Genus: *Betula Genus*

Species: *None*

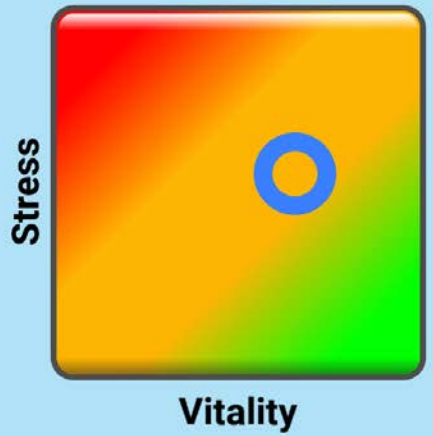
Cultivar: *None*

GPS: 51.4129, -0.9381

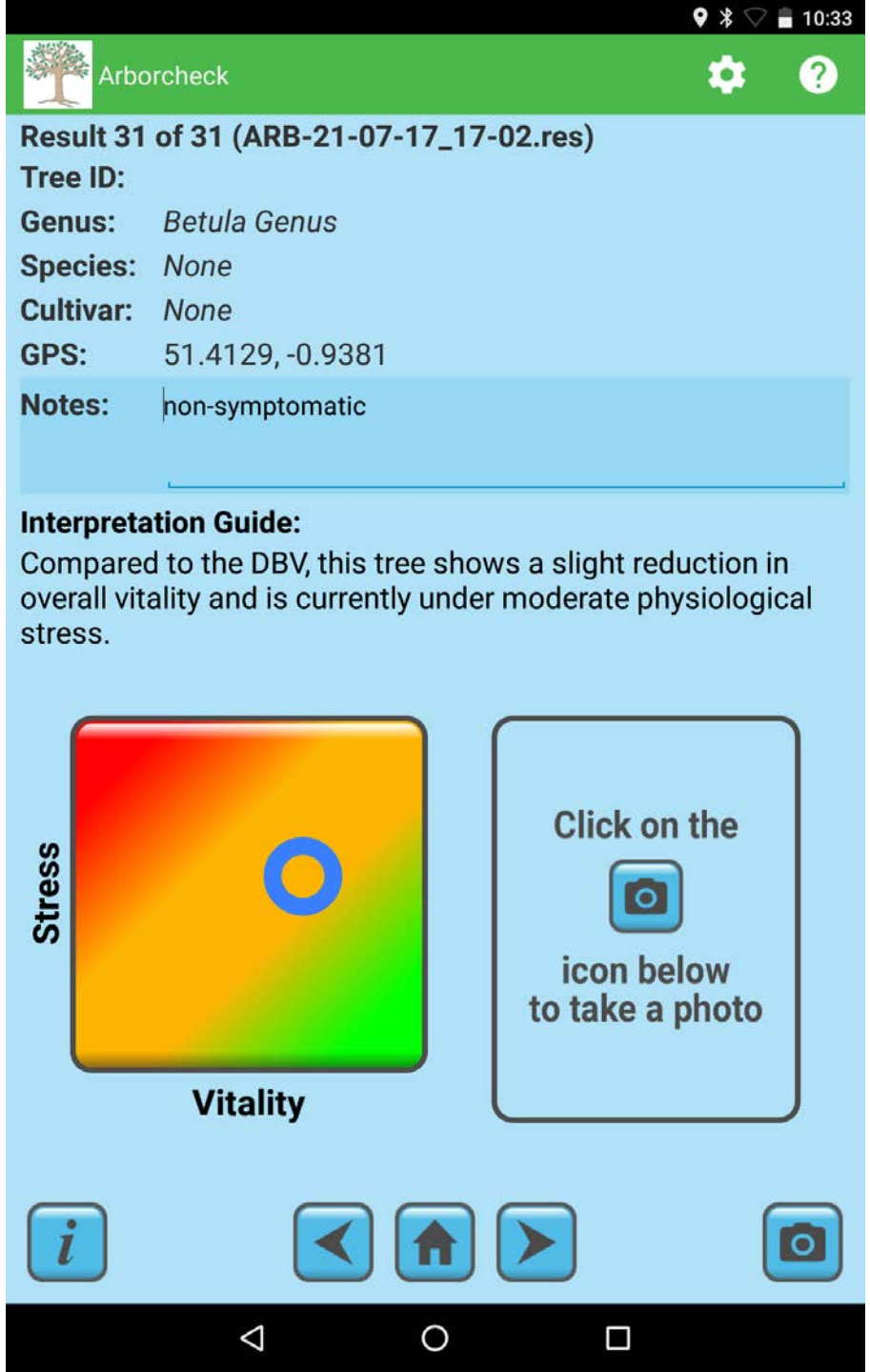
Notes: symptomatic tree

Interpretation Guide:

Compared to the DBV, this tree shows a slight reduction in overall vitality and is currently under moderate physiological stress.



Click on the icon below to take a photo


10:33
Arborcheck
Result 31 of 31 (ARB-21-07-17_17-02.res)
Tree ID:
Genus: Betula Genus
Species: None
Cultivar: None
GPS: 51.4129, -0.9381
Notes: non-symptomatic
Interpretation Guide:
Compared to the DBV, this tree shows a slight reduction in overall vitality and is currently under moderate physiological stress.
Stress
Vitality
Click on the
icon below
to take a photo

We were able to say:

- **No difference** between the trees, despite symptoms

so

- **Treat all trees –** the ones which look better will follow with time.

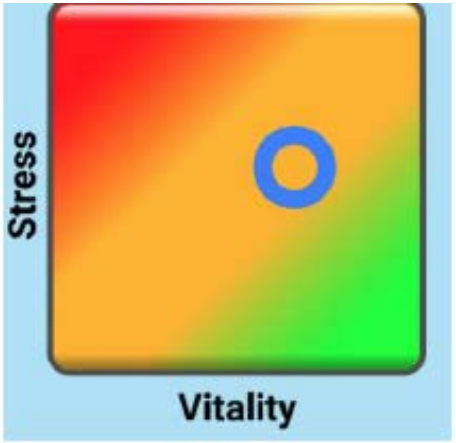
BARTLETT TREE EXPERTS

SCIENTIFIC TREE CARE SINCE 1907

PLANT DIAGNOSTIC REPORT

28 July 2017

Measurements of tree vitality using an ArborCheck® chlorophyll fluorescence device indicates that the trees show a slight reduction in overall vitality and are currently experiencing moderate physiological stress. No significant difference was observed in results between symptomatic and non-symptomatic trees. This suggests all trees require remedial action to return them to health, regardless of visual symptoms.



Case Study 2

- 18 rootball *Tilia cordata*
- 5 years post planting owner is concerned

- Arborcheck measurements taken 2016 **and** 2017

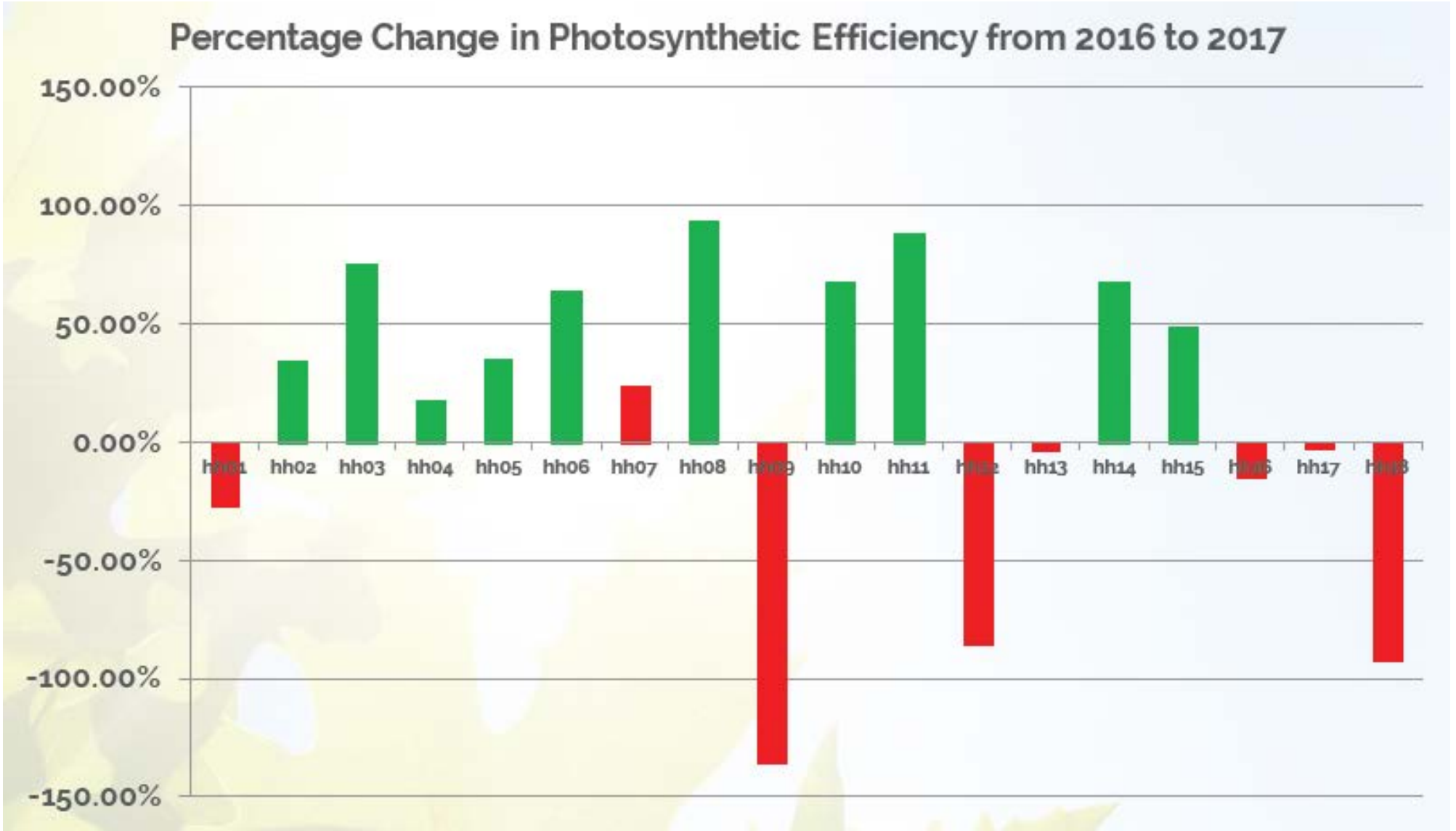
Arborcheck Parameters: Standard

		VITALITY			
ID	Species	Efficiency	Chlorophyll	Si:1	Si
DBV	-	0	0	0	
hh01	Tilia cordata	-2.5	-1.5	-1.7	0
hh02	Tilia cordata	-4.8	-3.1	-2.9	0
hh03	Tilia cordata	-10	-1.7	-2.9	3
hh04	Tilia cordata	-4.7	-2.1	-2.9	-0
hh05	Tilia cordata	-2.8	-0.6	-1.9	-0
hh06	Tilia cordata	-1.8	-1.3	-1.3	-0
hh07	Tilia cordata	-3.7	-1.7	-2.4	-0
hh08	Tilia cordata	-2.7	-1.5	-1.8	-0
hh09	Tilia cordata	-2.3	-2.7	-1.6	-1
hh10	Tilia cordata	-5.4	-2.8	-3	0
hh11	Tilia cordata	-6.3	-2.6	-3.1	0
hh12	Tilia cordata	-1.8	-1.4	-1.3	-0
hh13	Tilia cordata	-3.9	-2.2	-2.5	
hh14	Tilia cordata	-4.2	-1.1	-2.5	0
hh15	Tilia cordata	-5.5	-2.4	-3.2	-0
hh16	Tilia cordata	-3.9	-2.7	-2.6	-0
hh17	Tilia cordata	-2.9	0.0	-2	0
hh18	Tilia cordata	-2.2	-1.9	-1.6	-

Arborcheck Parameters: Standard Deviations from DBV

		VITALITY		STRESS			
ID	Species	Efficiency	Chlorophyll	Si:1	Si:2	Si:3	Si:4
DBV	-	0	0	0	0	0	0
hh01	Tilia cordata	-3.3	-2.5	-2.1	-0.2	-1.9	-1.1
hh02	Tilia cordata	-4.0	-2.6	-2.4	-1.5	-2.8	-2.4
hh03	Tilia cordata	-2.9	-2.6	-1.8	-1.2	-2.2	-1.7
hh04	Tilia cordata	-3.9	-2.6	-2.5	-0.5	-2.3	-2.2
hh05	Tilia cordata	-2.2	-2.5	-1.3	-1.1	-1.8	-0.6
hh06	Tilia cordata	-0.4	-1.3	0.0	0.5	0.5	0.1
hh07	Tilia cordata	-4.6	-2.2	-2.1	1.2	-1.5	0.2
hh08	Tilia cordata	-0.4	-1.5	-0.1	-0.3	-0.3	0.2
hh09	Tilia cordata	-4.8	-2.3	-2.5	-0.3	-2.4	-2.0
hh10	Tilia cordata	-2.0	-1.6	-1.3	0.4	-0.8	0.5
hh11	Tilia cordata	-0.9	-1.3	-0.6	-0.2	-0.6	1.9
hh12	Tilia cordata	-2.9	-2.2	-2.0	-0.3	-1.8	-0.8
hh13	Tilia cordata	-4.9	-2.3	-2.9	1.0	-2.1	-1.6
hh14	Tilia cordata	-1.4	-1.8	-0.9	-0.6	-1.1	0.7
hh15	Tilia cordata	-2.8	-2.4	-1.9	0.1	-1.5	-1.0
hh16	Tilia cordata	-4.3	-2.1	-2.7	-0.5	-2.6	-2.0
hh17	Tilia cordata	-2.9	-2.3	-2.0	-0.3	-1.9	-1.1
hh18	Tilia cordata	-4.6	-2.5	-2.8	-1.5	-3.1	-2.4

Working with avenues – or monitoring



FAQ

Functional Unit	Efficiency	Chlorophyll	SI1	SI2	SI3	SI4	Interpretation
FU 1	-3.2	-0.2	-2.7	-1.5	-2.7	-0.6	Reduced Vitality, Significant Physiological Stress
FU 2	-0.9	-0.5	-0.9	-1.0	-1.4	-1.2	Healthy, Mild to Moderate Physiological Stress
FU 3	-0.4	0.3	-0.5	-1.7	-1.6	-0.3	Healthy, Mild to Moderate Physiological Stress

Crown partitioning

Side	Fv/Fm	Area	Fv / Fo	PI
Grassed	0.840	403670	5.27	21.0
car park	0.818	314159	4.62	13.6
% change	-3	-22	-12	-35

FAQ: *How do I measure needles?*

- A: Make a mat of leaves

(no chlorophyll content)

FAQ When can I measure?

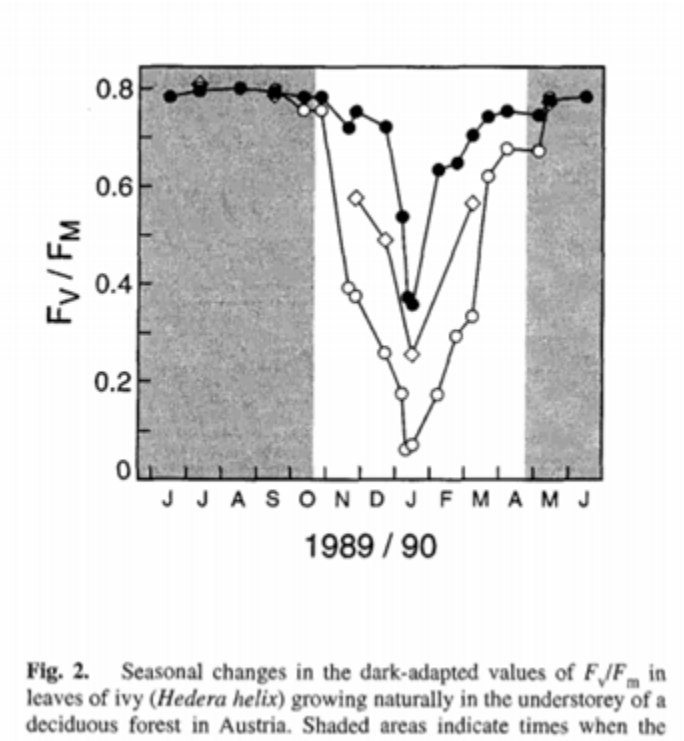
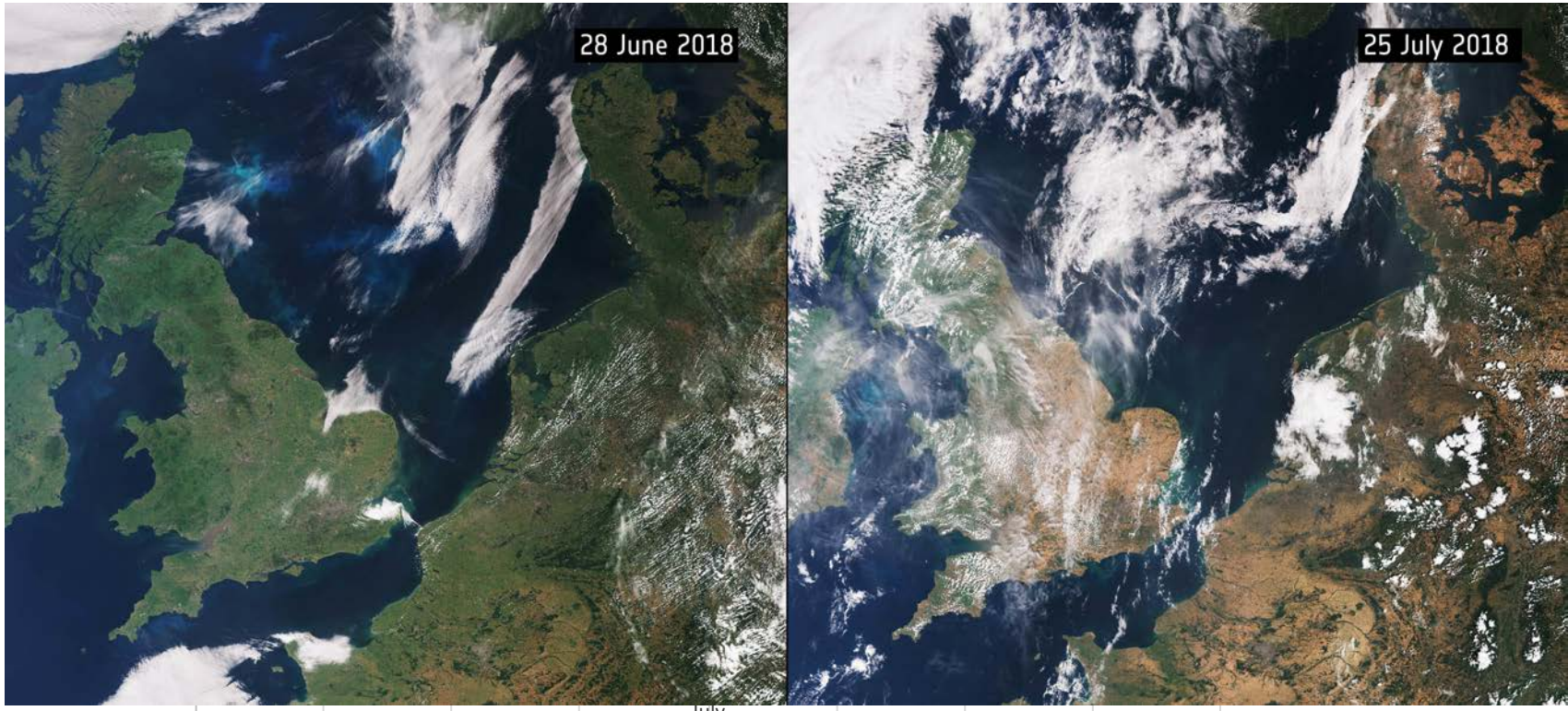


Fig. 2. Seasonal changes in the dark-adapted values of F_v/F_m in leaves of ivy (*Hedera helix*) growing naturally in the understorey of a deciduous forest in Austria. Shaded areas indicate times when the

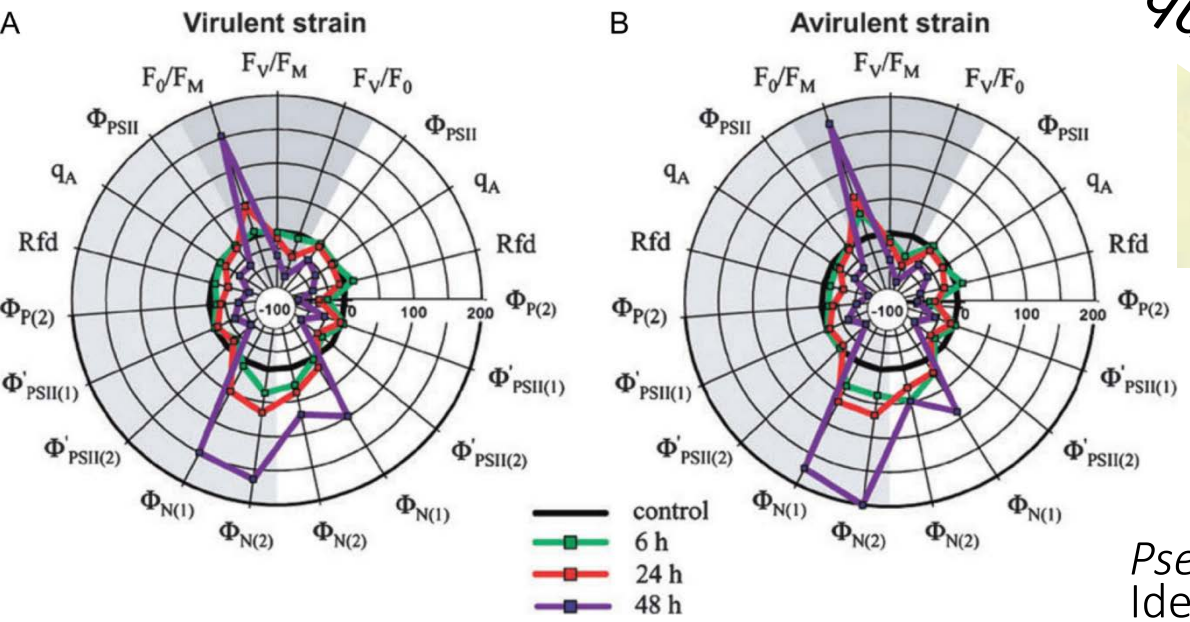


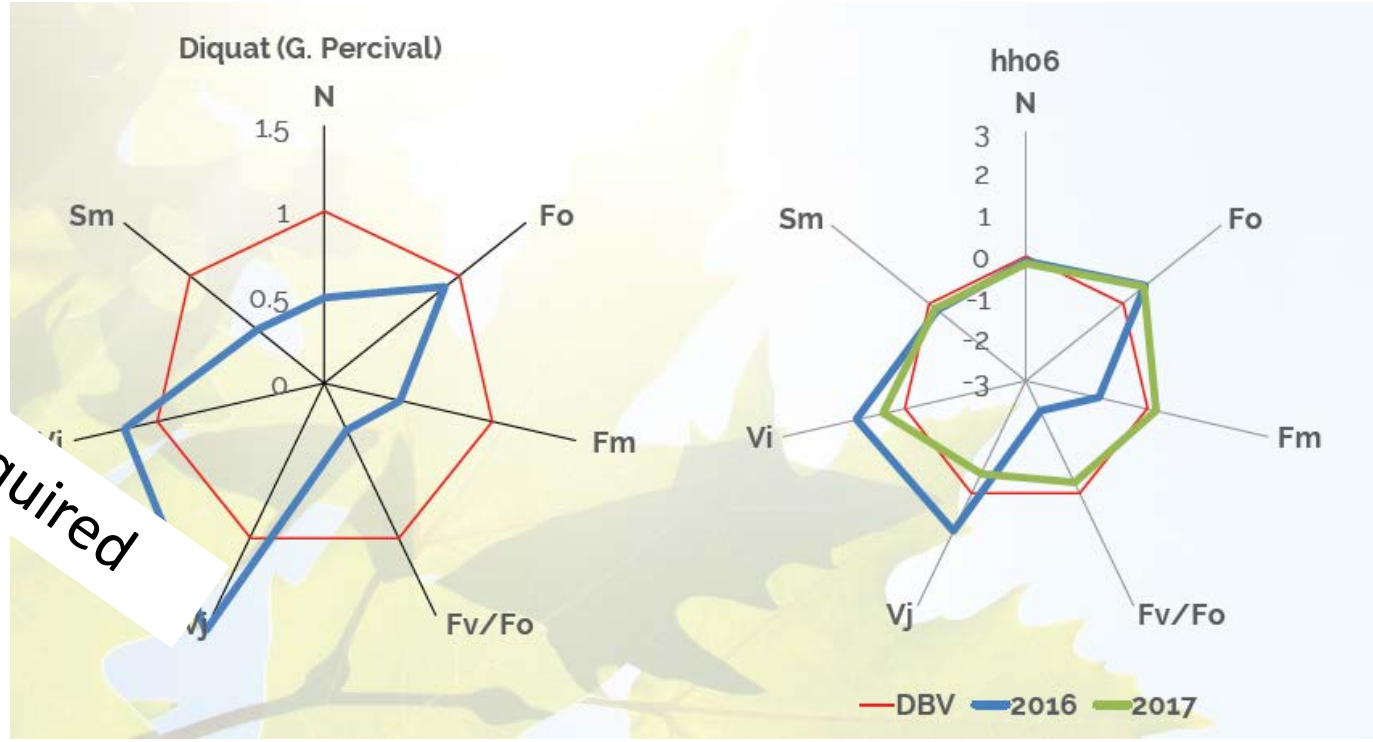
(Ball et al. 1994. Applications of Chlorophyll Fluorescence to Forest Ecology)

Something for the future: Diagnostic tool?

Herbicide ID Avenue case study

More research required





Pseudomonas syringae Identification

Conclusion:

- Future P & D “load” will influence vitality (& *vice versa*)
- Technology is available for practitioners to independently identify this
- CF has wide range of applications
- Important to stress that CF is not a decay detector, doesn’t replace an arborist