The effect of drought and frost cycles on cavitation resistance of clonal *Populus* 84K

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Research Background

Primary productivity is one of the key factors affecting the dynamics and development of ecosystems.

In terrestrial systems, plant hydraulic conductance has been identified as a limiting factor of primary production.

Hydraulic conductance is continuously impacted by cavitation and embolism, the processes by which xylem conduits become air filled as a result of **drought** or **frost** and temporarily or permanently cease to function.

Do cavitated and refilled conduits (induce by drought or frost) regain their initial resistance to cavitation and embolism?

YES **NO**

Is their resistance altered by the previous cavitation and embolism process?

NO **YES**

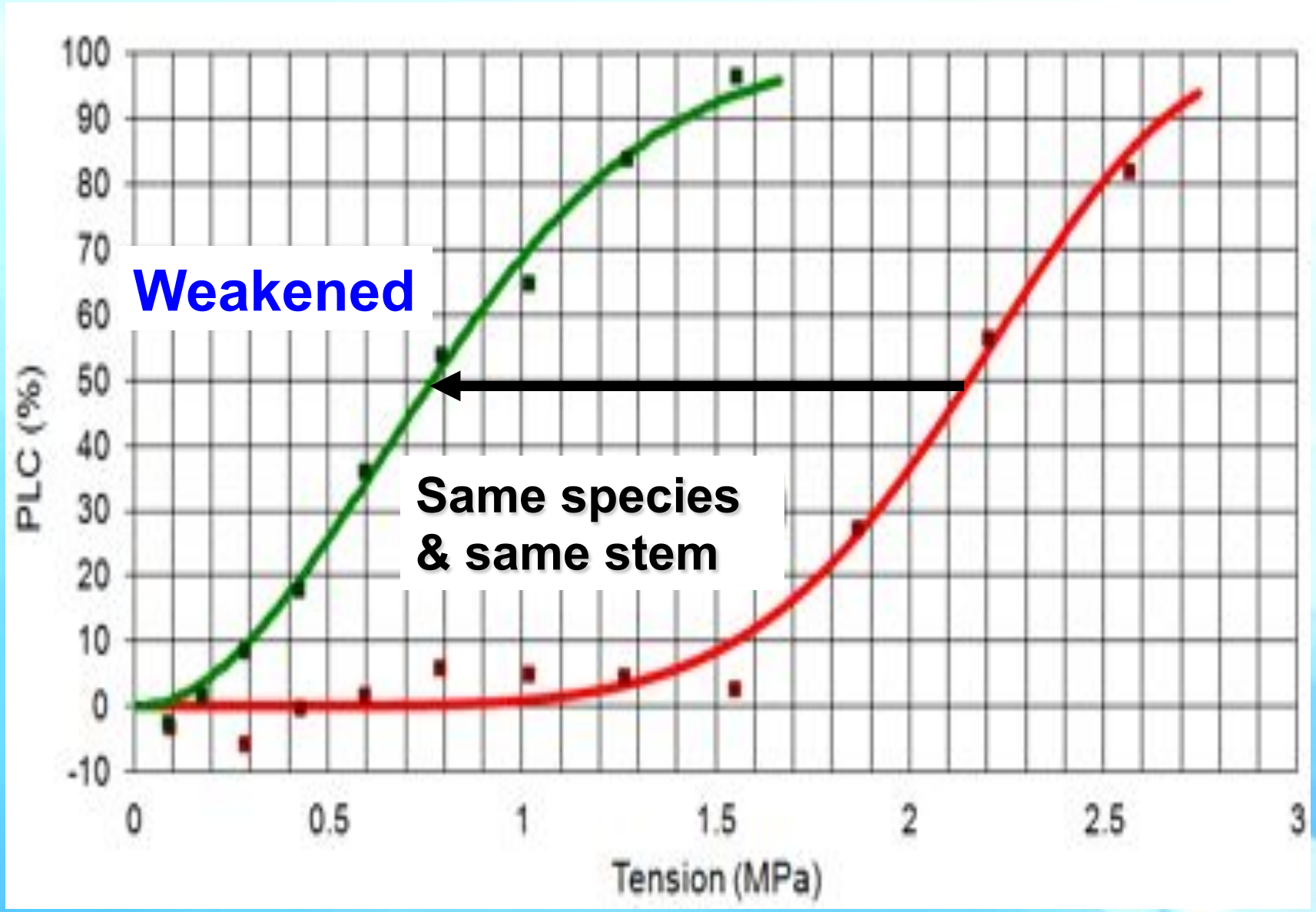
Resilient **Weakened**

Cavitation fatigue

is the increased susceptibility of a xylem conduit to cavitation as a result of its prior cavitation.

Frost fatigue

Trees that refill their conduits in spring could be impacted by frost-induced damage to the conduits that reduce cavitation resistance, making them more susceptible to future drought events.


Weakened
Same species
& same stem
PLC (%)
100
90
80
70
60
50
40
30
20
10
0
-10
0
0.5
1
1.5
2
2.5
3
Tension (MPa)

Research Purpose

We studied whether drought and freeze-thaw cycles could reduce the cavitation resistance in first-year shoots of 84K poplar (*Populus alba*×*Populus glandulosa*).

Plant Material

84K (*Populus alba*×*Populus glandulosa*)

Cavitation Fatigue

Sample

↓

1st Flush 0.5h

↓

K_{h1} + 1st VC

↓

2nd Flush 0.5h

↓

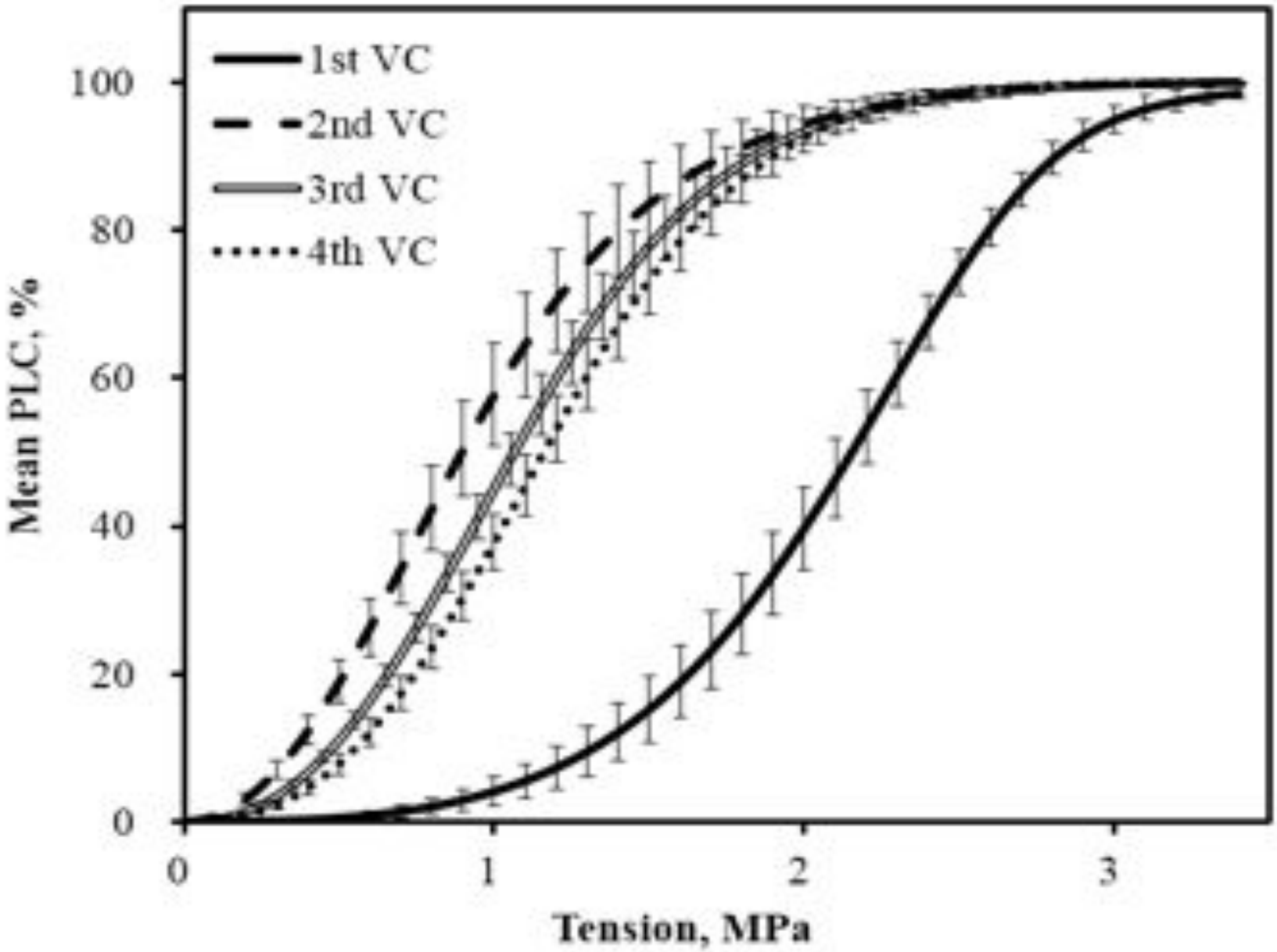
K_{h2} (>95%K_{h1}) + 2nd VC

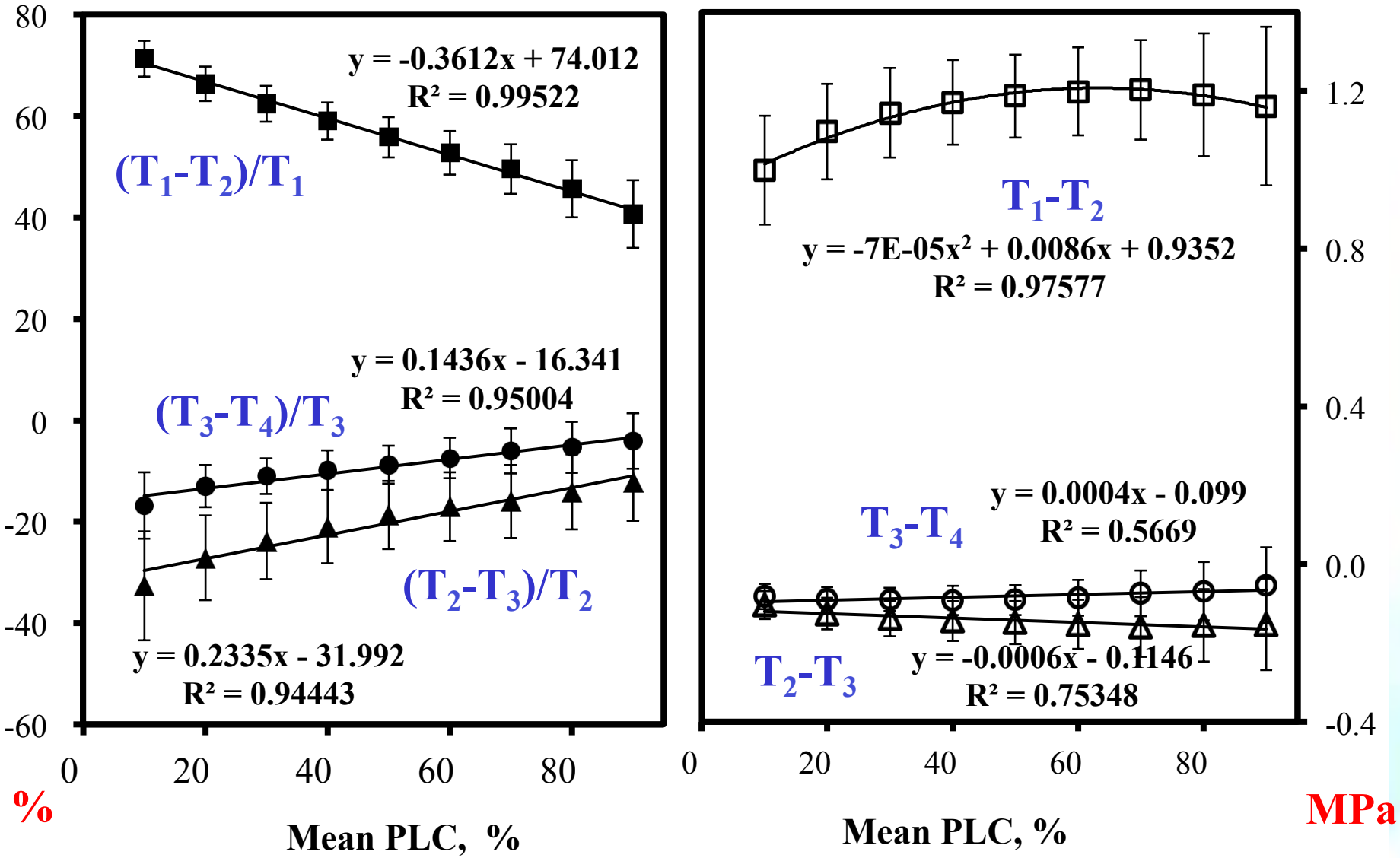
↓

3rd Flush 0.5h

↓

K_{h3} (>95%K_{h1}) + 3rd VC → 4th Flush 0.5h → K_{h4} (>95%K_{h1}) + 4th VC


1st VC
2nd VC
3rd VC
4th VC
Mean PLC, %
100
80
60
40
20
0
0
1
2
3
Tension, MPa


y = -0.3612x + 74.012
R² = 0.99522
(T1-T2)/T1
y = 0.1436x - 16.341
R² = 0.95004
(T3-T4)/T3
(T2-T3)/T2
y = 0.2335x - 31.992
R² = 0.94443
80
60
40
20
0
-20
-40
-60
0
20
40
60
80
%
Mean PLC, %
T1-T2
y = -7E-05x² + 0.0086x + 0.9352
R² = 0.97577
T3-T4
y = 0.0004x - 0.099
R² = 0.5669
T2-T3
y = -0.0006x - 0.1146
R² = 0.75348
1.2
0.8
0.4
0.0
-0.4
0
20
40
60
80
Mean PLC, %
MPa

Freeze-thaw Treatment

Sample

↓

Flush 0.5h

↓

K_{h1}

↓

freeze-thaw
(room temp~-5℃~room temp)
water stress
(0.08, 0.5,1.0,1.5MPa)

↓

K_{h2}

↓

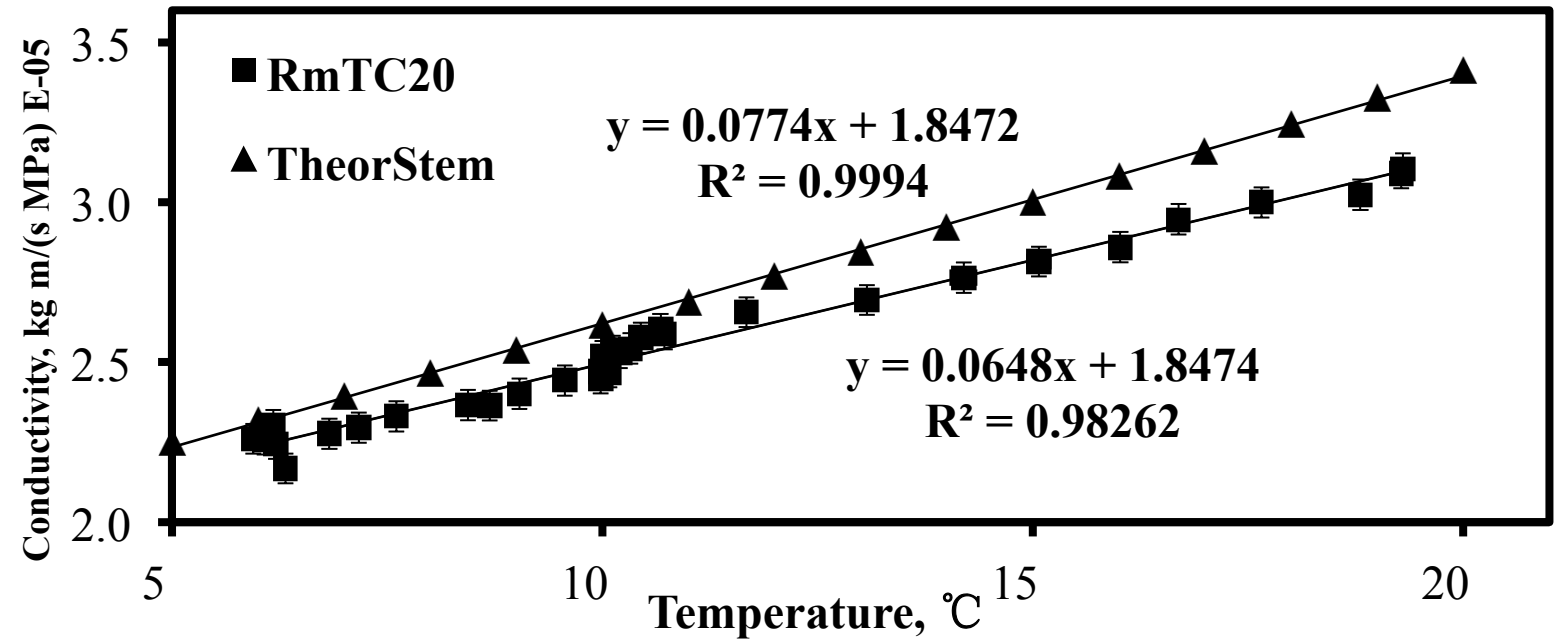
Flush 0.5h → K_{h3} (>95% K_{h1}) → Vulnerability Curve

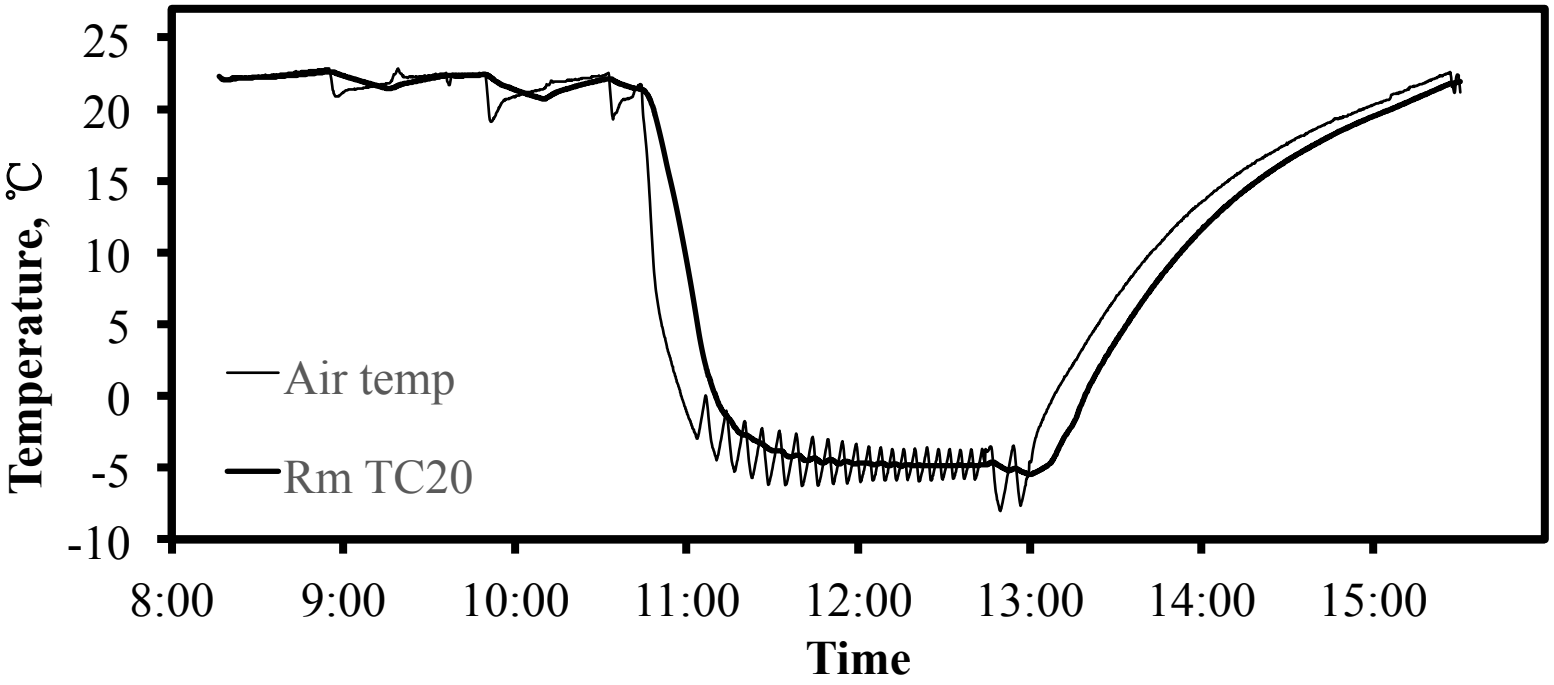
0.08MPa → 1000rpm

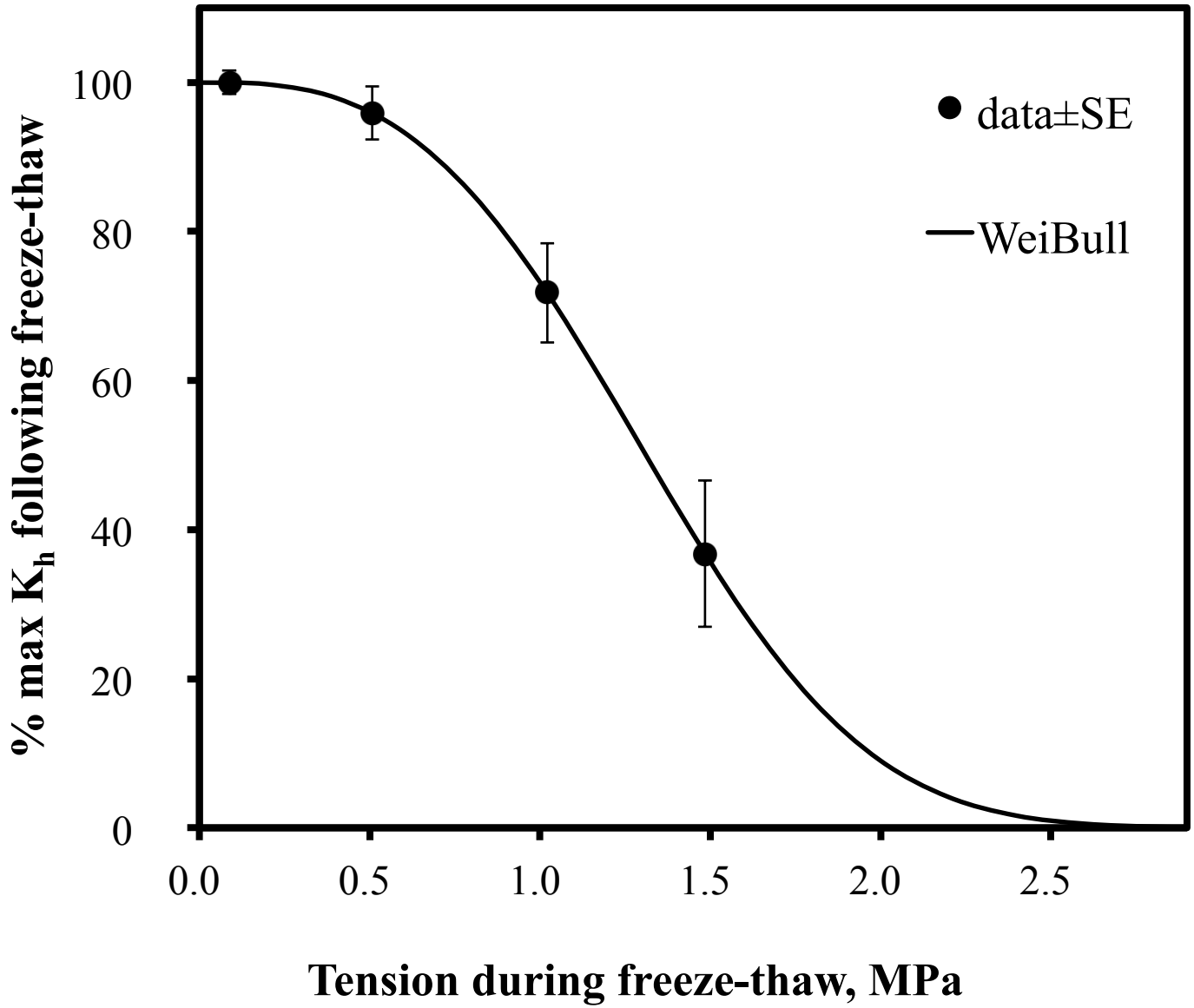
0.5MPa → 2400rpm

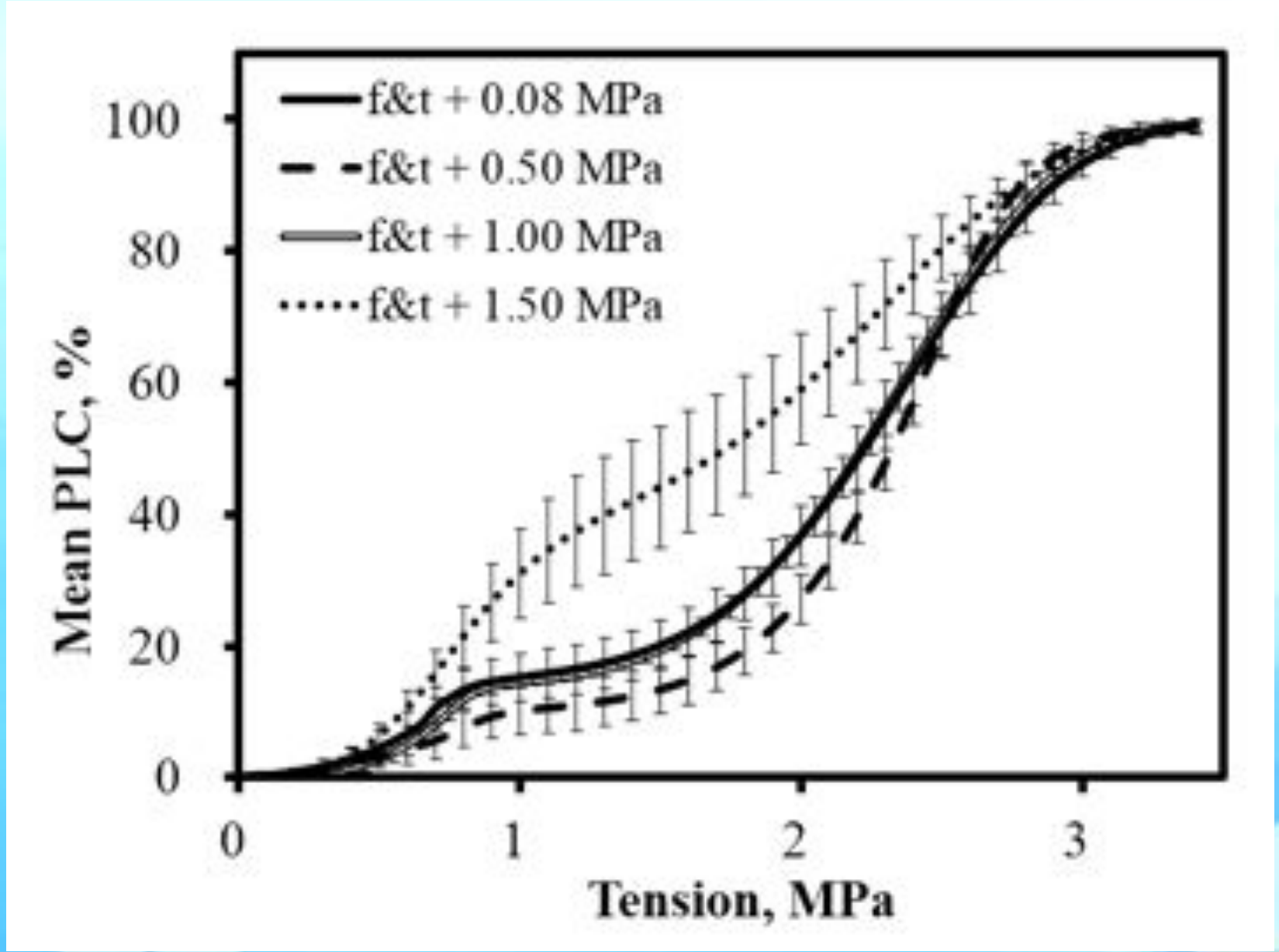
1.0MPa → 3400rpm

1.5MPa → 4100rpm


RmTC20
TheorStem
y = 0.0774x + 1.8472
R² = 0.9994
y = 0.0648x + 1.8474
R² = 0.98262
Conductivity, kg m/(s MPa) E-05
3.5
3.0
2.5
2.0
5
10
15
20
Temperature, ℃


Temperature, ℃
25
20
15
10
5
0
-5
-10
Air temp
Rm TC20
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
Time


% max K_h following freeze-thaw
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
data±SE
WeiBull
Tension during freeze-thaw, MPa


f&t + 0.08 MPa
f&t + 0.50 MPa
f&t + 1.00 MPa
f&t + 1.50 MPa
Mean PLC, %
100
80
60
40
20
0
0
1
2
3
Tension, MPa

2VCs Test

Sample

↓

Flush 0.5h

↓

K_{h1}

↓

1st VC

50% embolism

↓

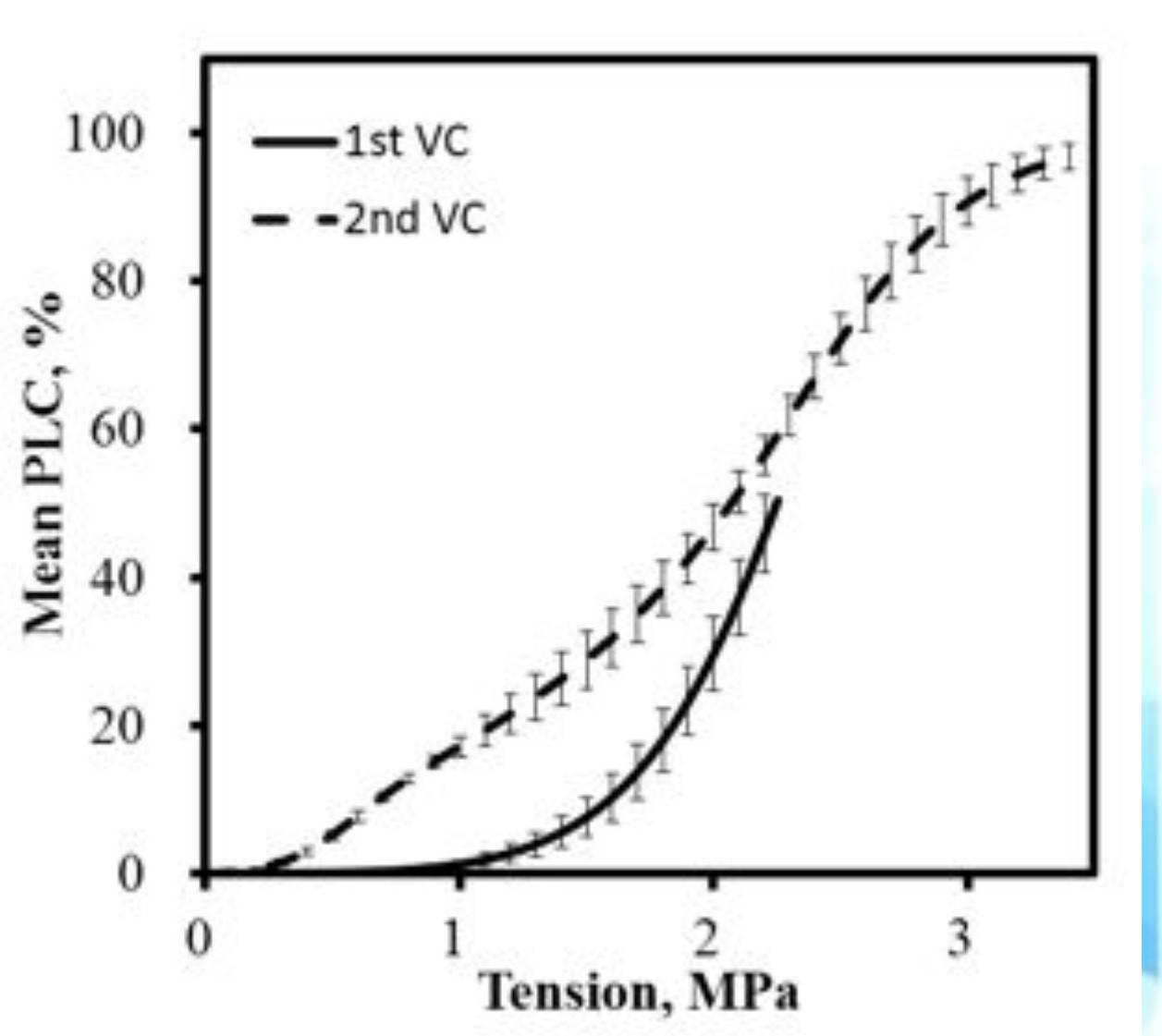
Flush 0.5h

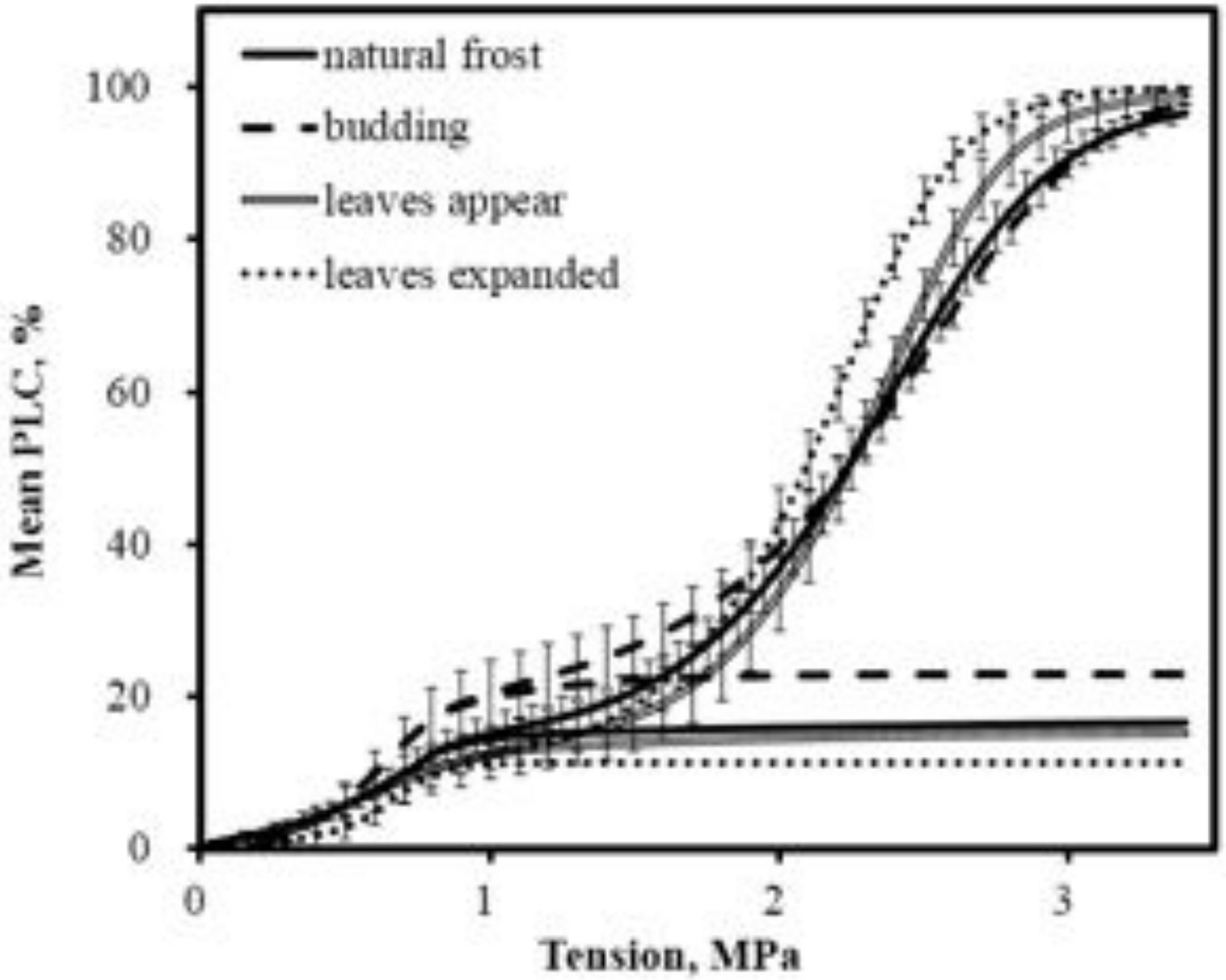
↓

K_{h2} (>95% K_{h1})

↓

2nd VC




natural frost
budding
leaves appear
leaves expanded
Mean PLC, %
100
80
60
40
20
0
0
1
2
3
Tension, MPa

Results and Discussion

1. The cavitation resistance was substantially reduced following a cavitation-refilling cycle, indicating that “cavitation fatigue” happened in 84K poplar.
2. Freeze-thaw cycles induced a loss of conductivity and the loss increased with increasing tension at the time of the freeze-thaw event.
3. Cavitation fatigue is similar to frost fatigue. But frost fatigue only damage some of the most vulnerable vessels not all the vulnerable vessels.

Results and Discussion

4. Natural frost fatigue only damage 20% conduits at early winter. Both lab and field frost experiments showed almost the same dual Weibull.

5. Freeze-thaw treatment changed the shape of VCs but the vulnerability curve above P_{50} was not significantly changed. Hence 84K poplar is unlikely to be severely impacted by drought events in early spring while new wood is growing.

THE END