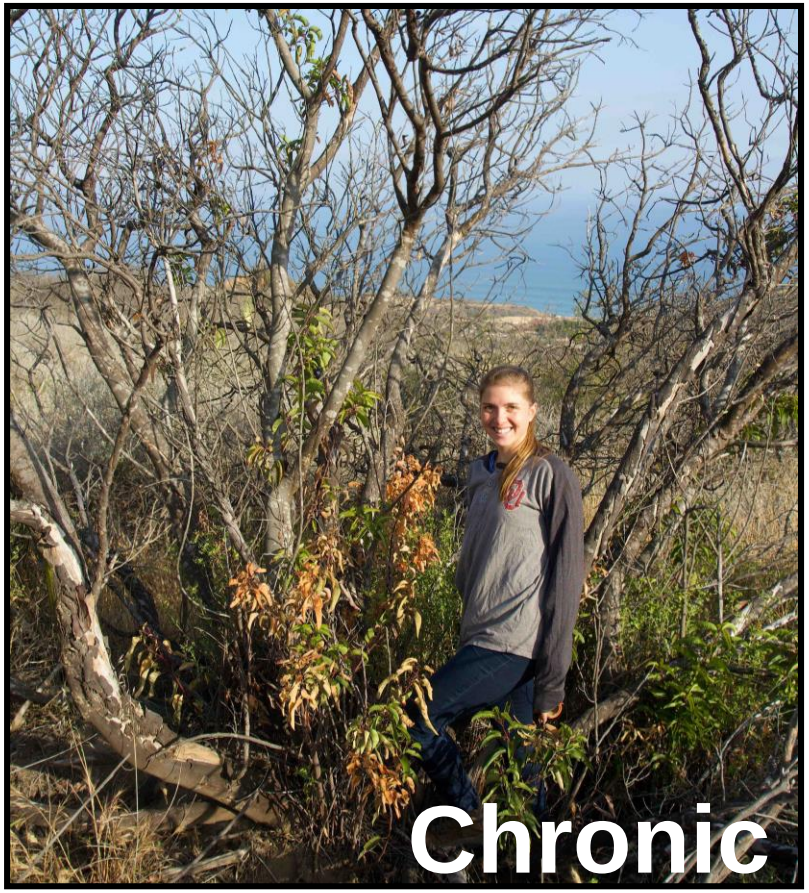
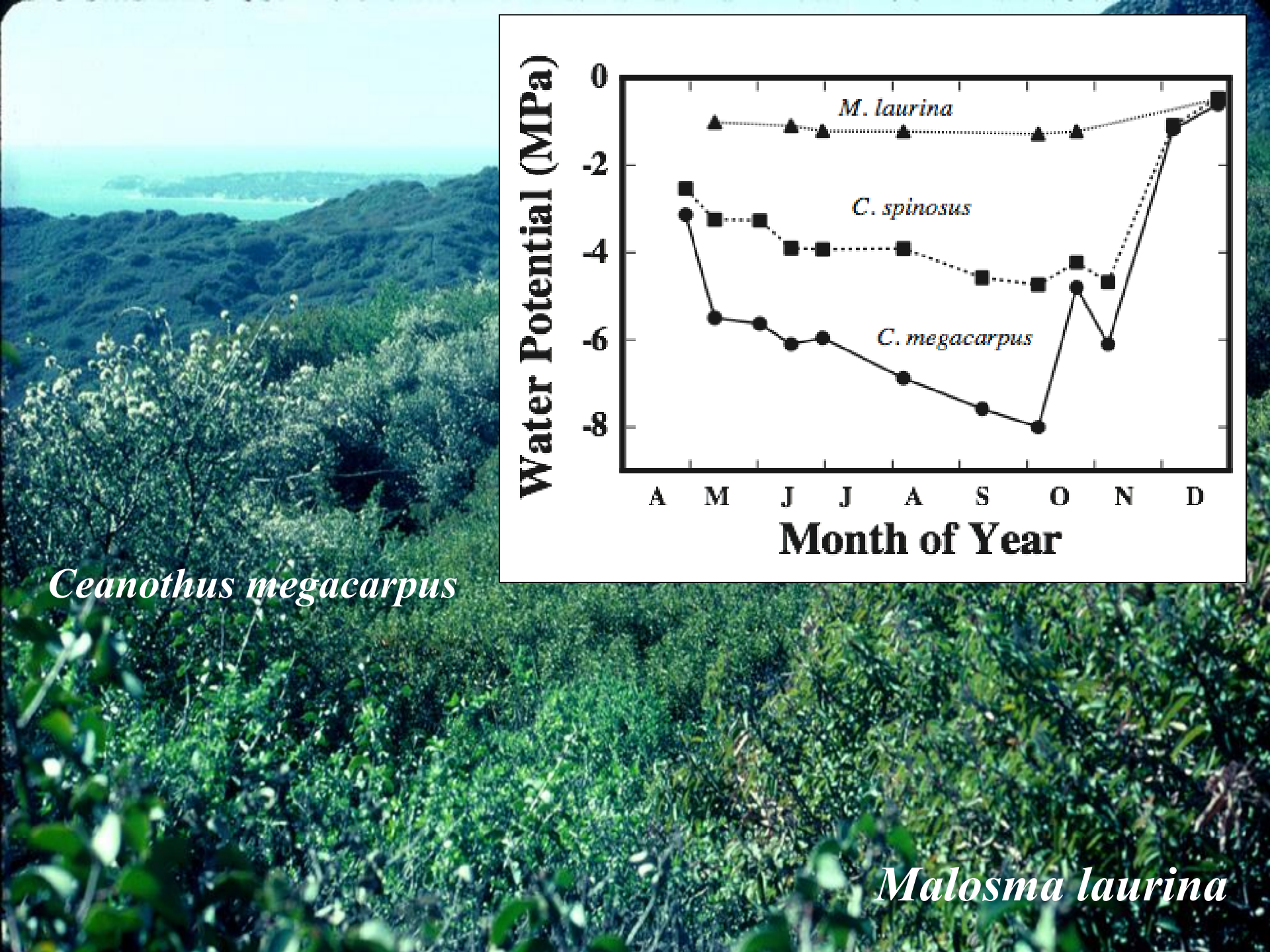
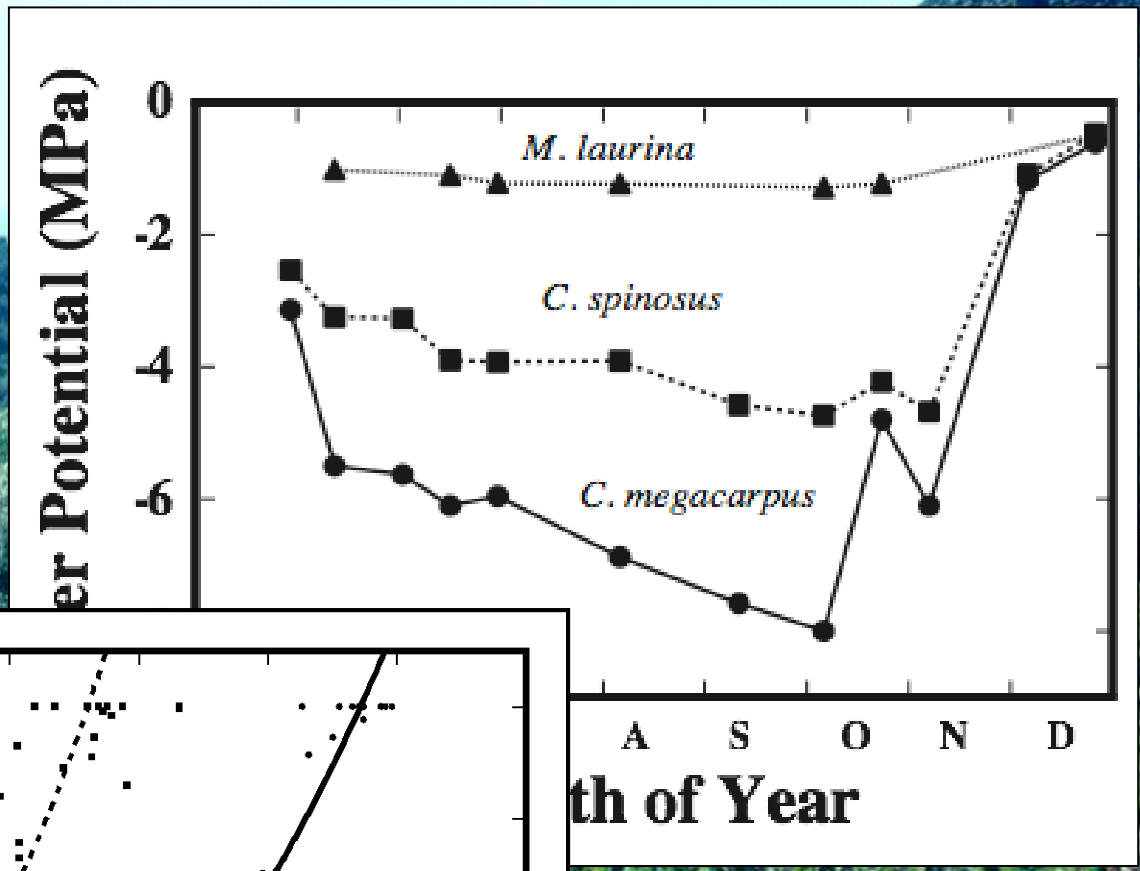
Global Change and the Vulnerability of Chaparral to Acute Drought versus Chronic Drought



Southern California Chaparral Symposium, Arcadia CA
Stephen D. Davis, Pepperdine University, Malibu CA, 14 May 2018


Ceanothus spinosus
Ceanothus megacarpus
Malosma laurina


Water Potential (MPa)
0
-2
-4
-6
-8
M. laurina
C. spinosus
C. megacarpus
A
M
J
J
A
S
O
N
D
Month of Year
Ceanothus megacarpus
Malosma laurina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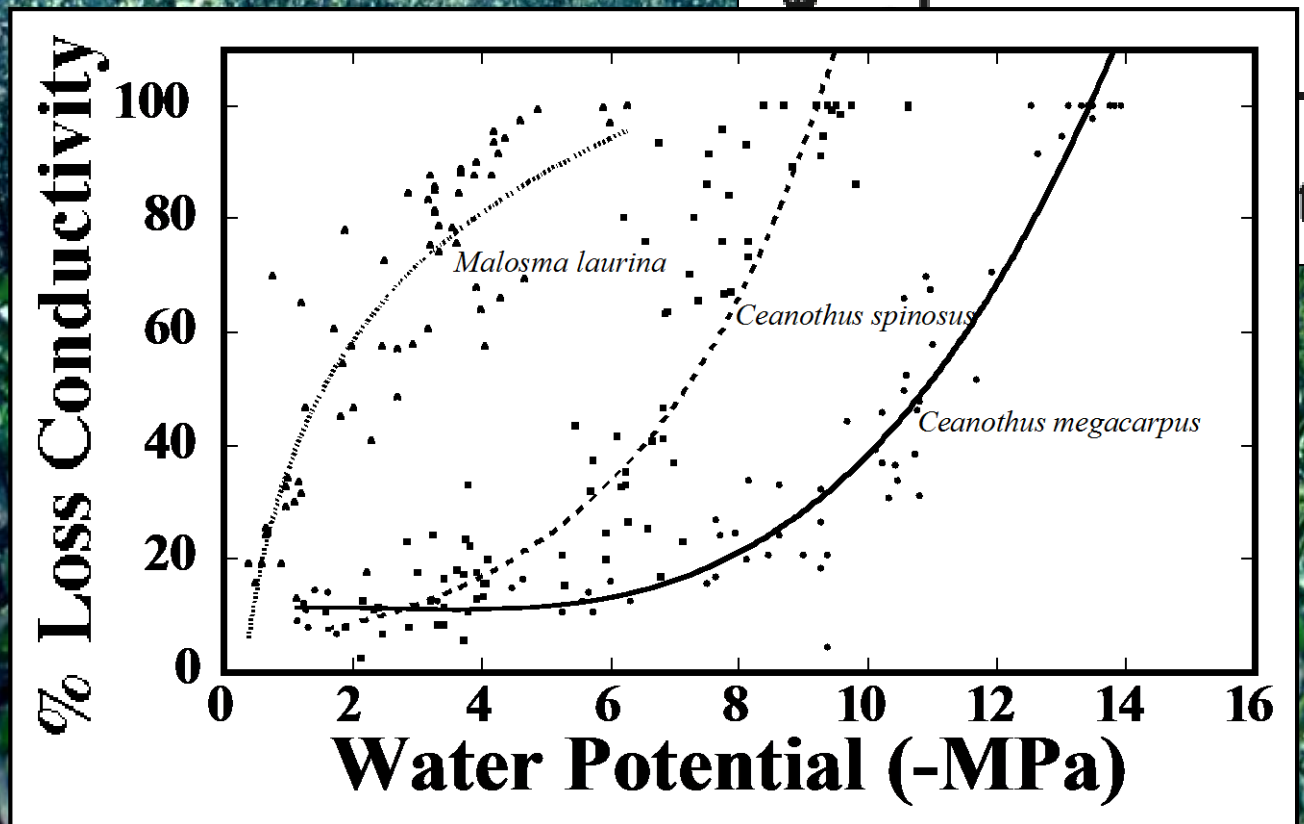
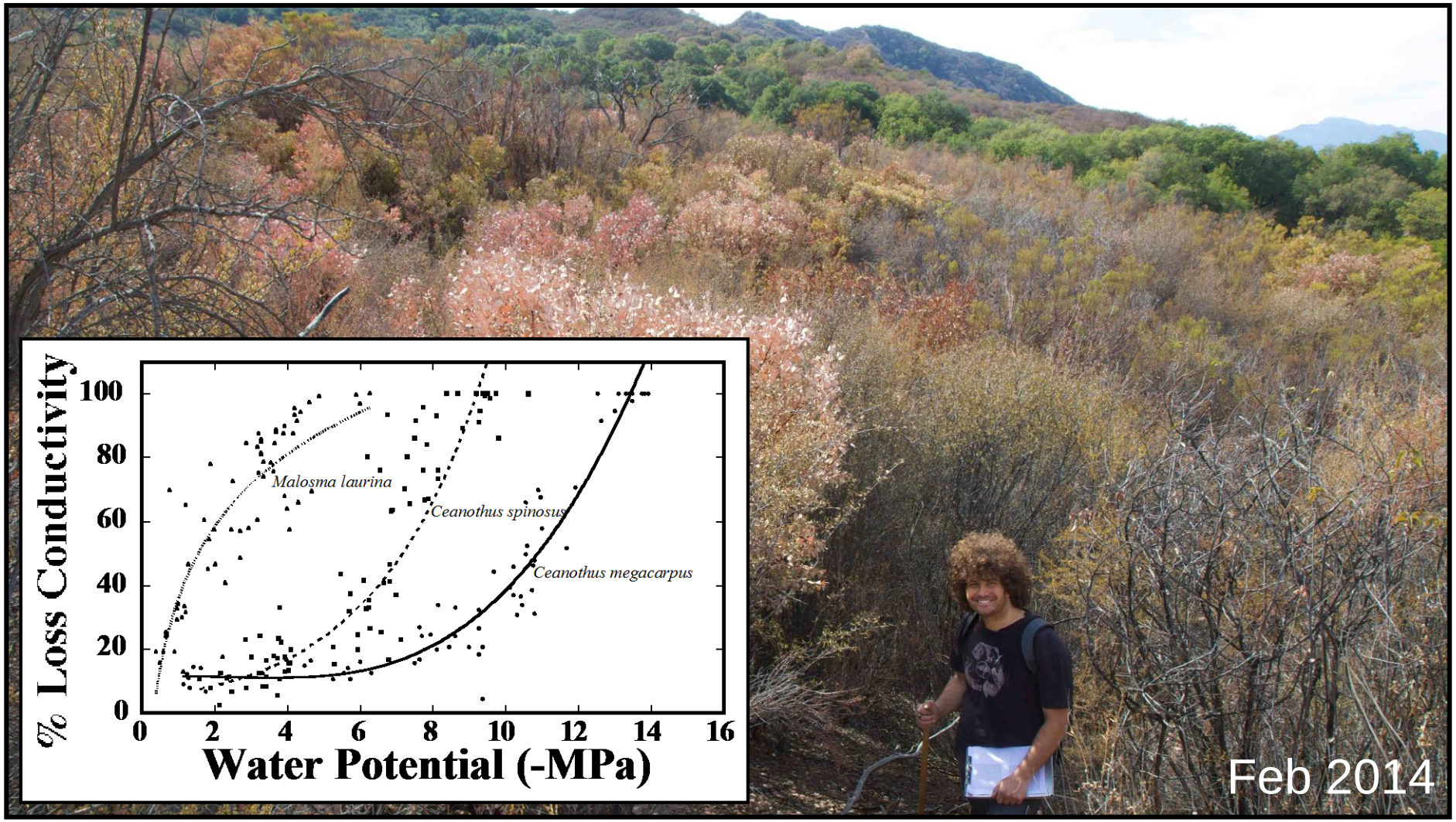
0
-2
-4
-6
M. laurina
C. spinosus
C. megacarpus
A
S
O
N
D
th of Year

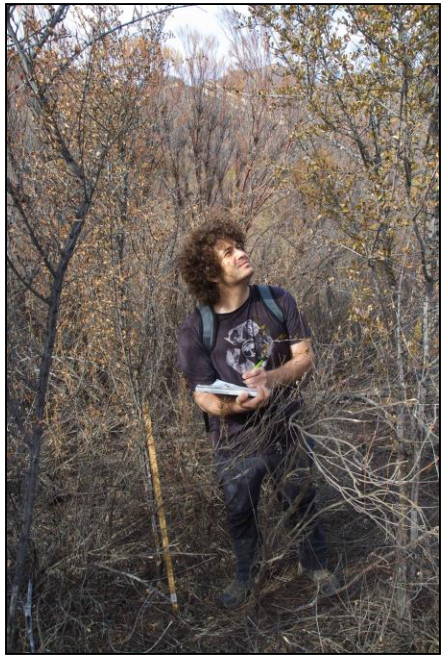

% Loss Conductivity
100
80
60
40
20
0
Malosma laurina
Ceanothus spinosus
Ceanothus megacarpus
0
2
4
6
8
10
12
14
16
Water Potential (-MPa)


Malosma laurina

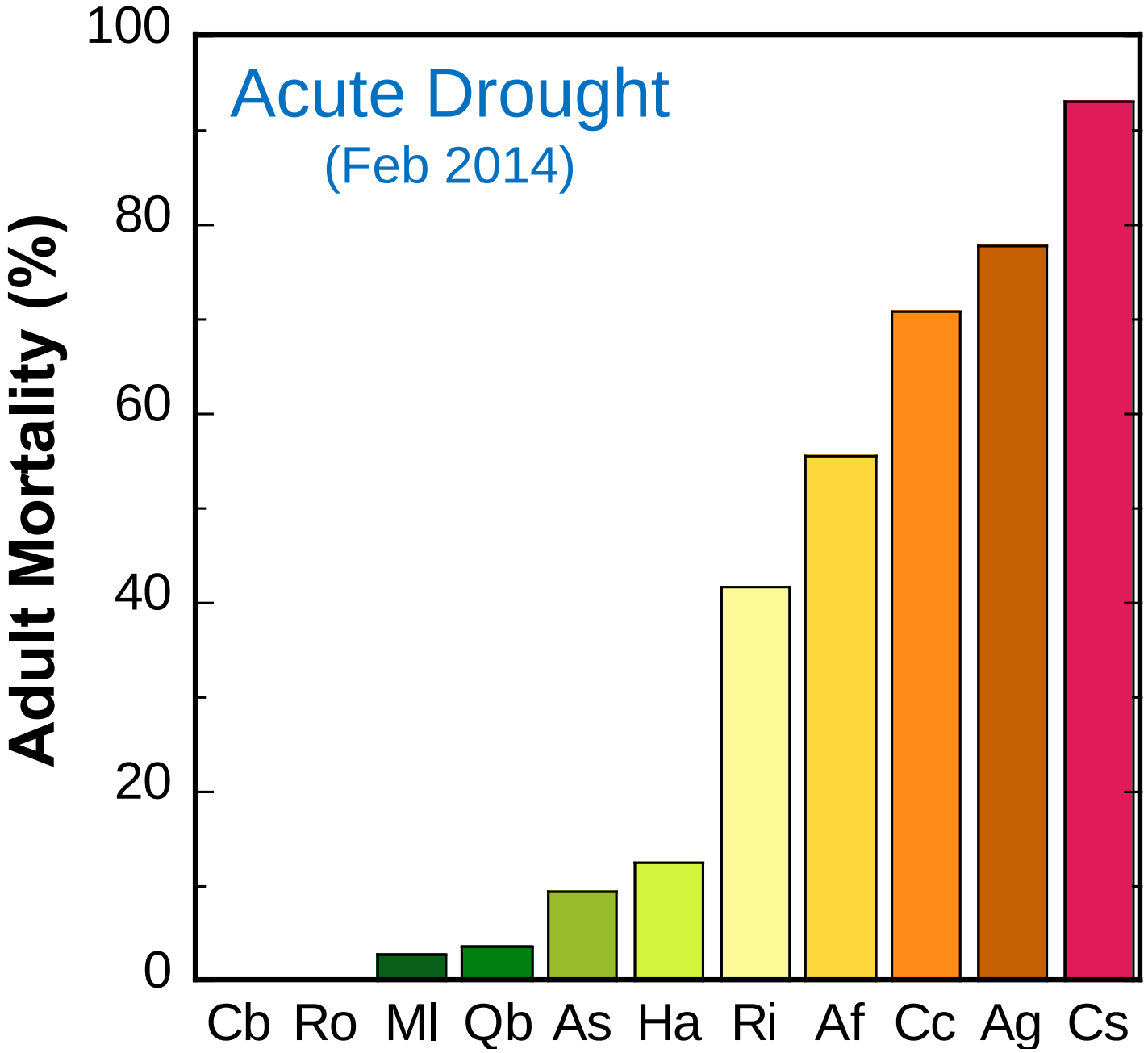
Acute Drought Causes Differential Dieback

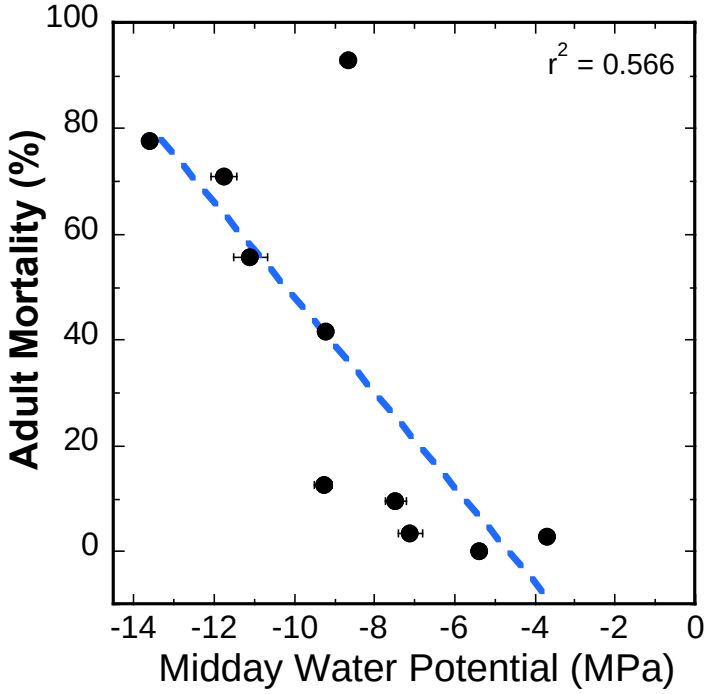
Acute Drought Causes Differential Dieback

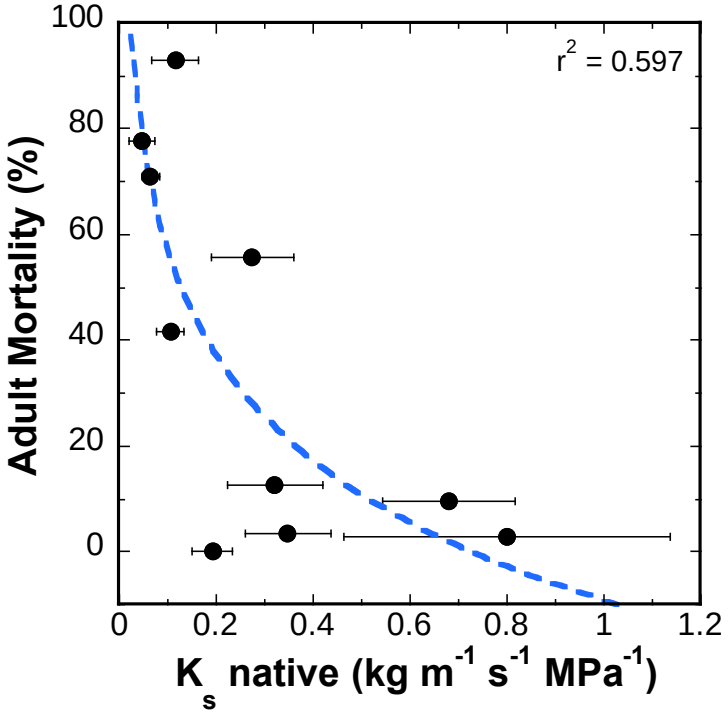


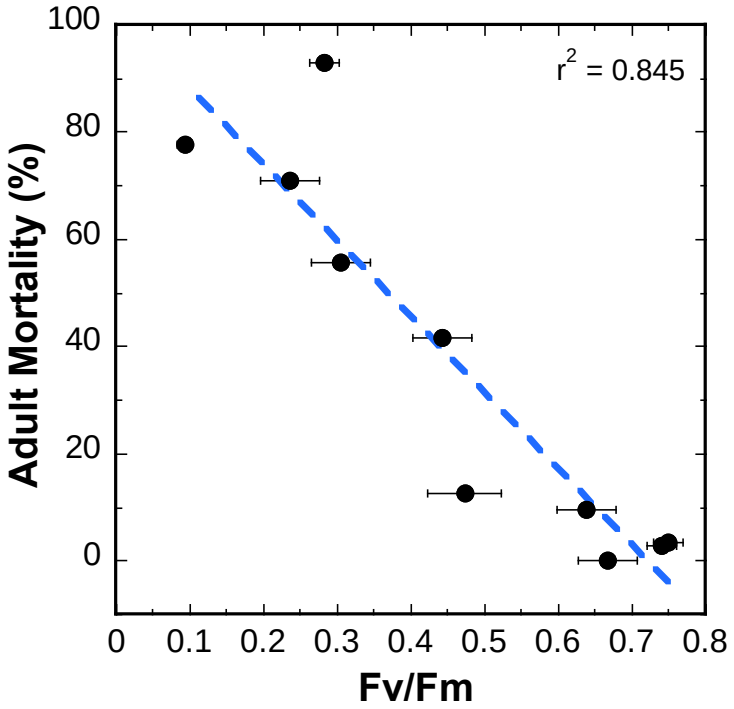


63 pts. 252 obs.

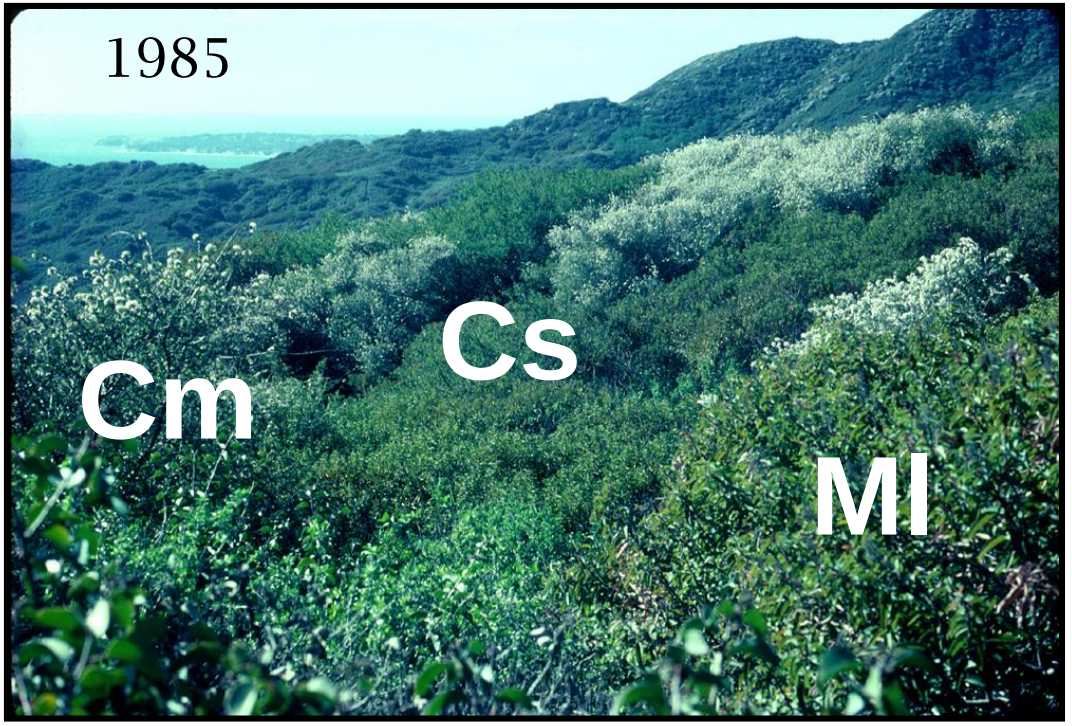



Adult Mortality (%)
Midday Water Potential (MPa)
r2 = 0.566
100
80
60
40
20
0
-14
-12
-10
-8
-6
-4
-2
0


Adult Mortality (%)
Ks native (kg m-1 s-1 MPa-1)
r2 = 0.597
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2


Adult Mortality (%)
Fv/Fm
r2 = 0.845
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Chaparral Decline
1985 vs. 2018

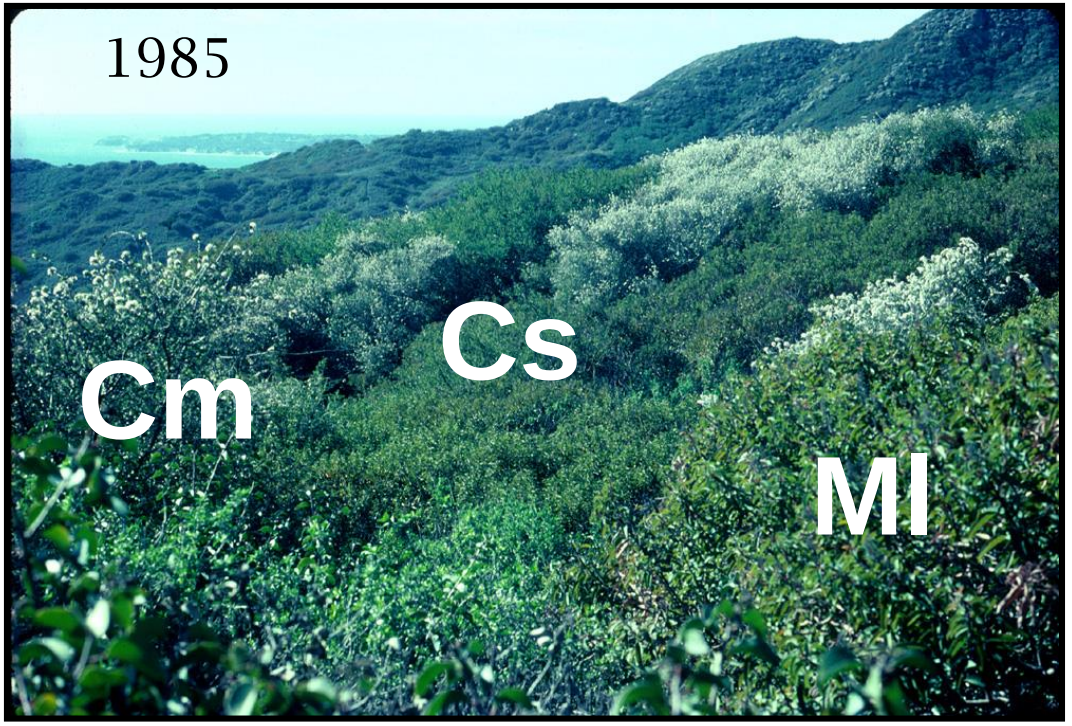


Chaparral Decline 1985 vs. 2018

Caused by:

- Increased fire frequency

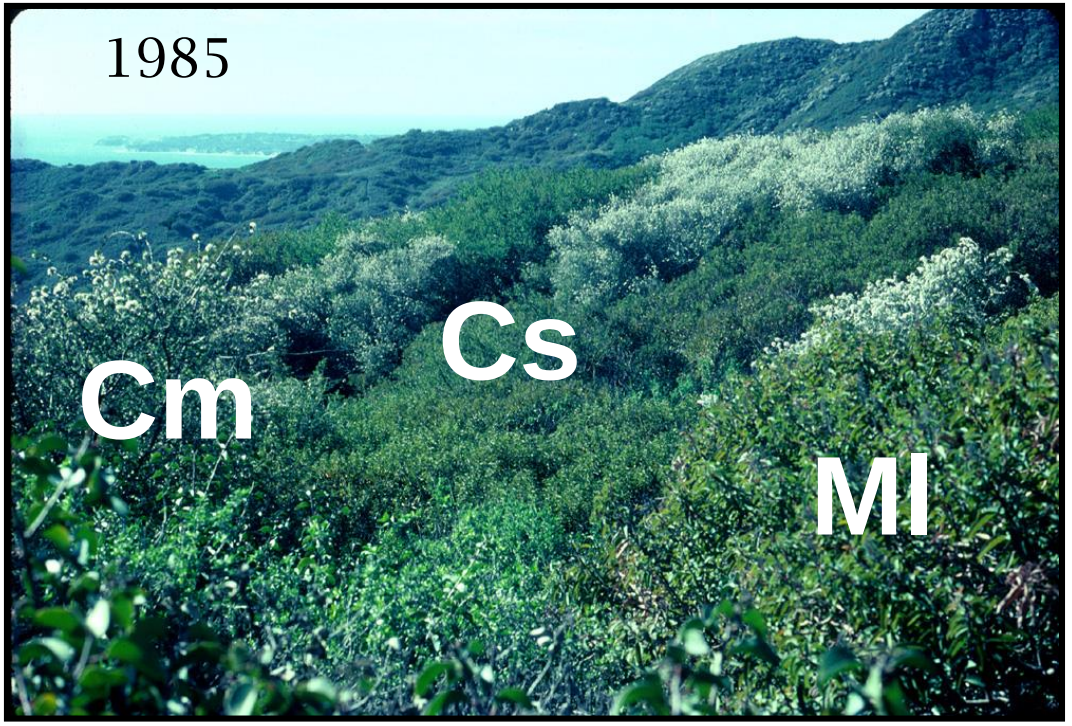
-- *Ceanothus megacarpus*



Chaparral Decline 1985 vs. 2018

Caused by:

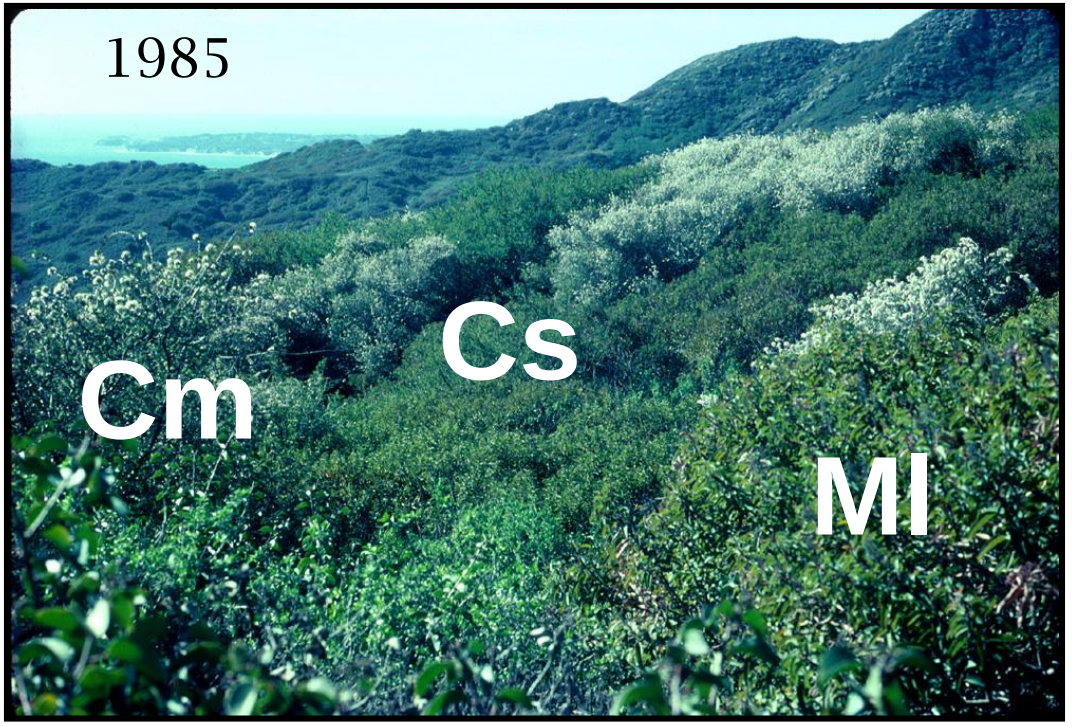
- Increased fire frequency
  -- *Ceanothus megacarpus*
- Drought-induced mortality
  -- *Ceanothus spinosus*



Chaparral Decline 1985 vs. 2018

Caused by:

- Increased fire frequency
  -- *Ceanothus megacarpus*
- Drought-induced mortality
  -- *Ceanothus spinosus*
- Fungal-induced mortality?
  -- *Malosma laurina*



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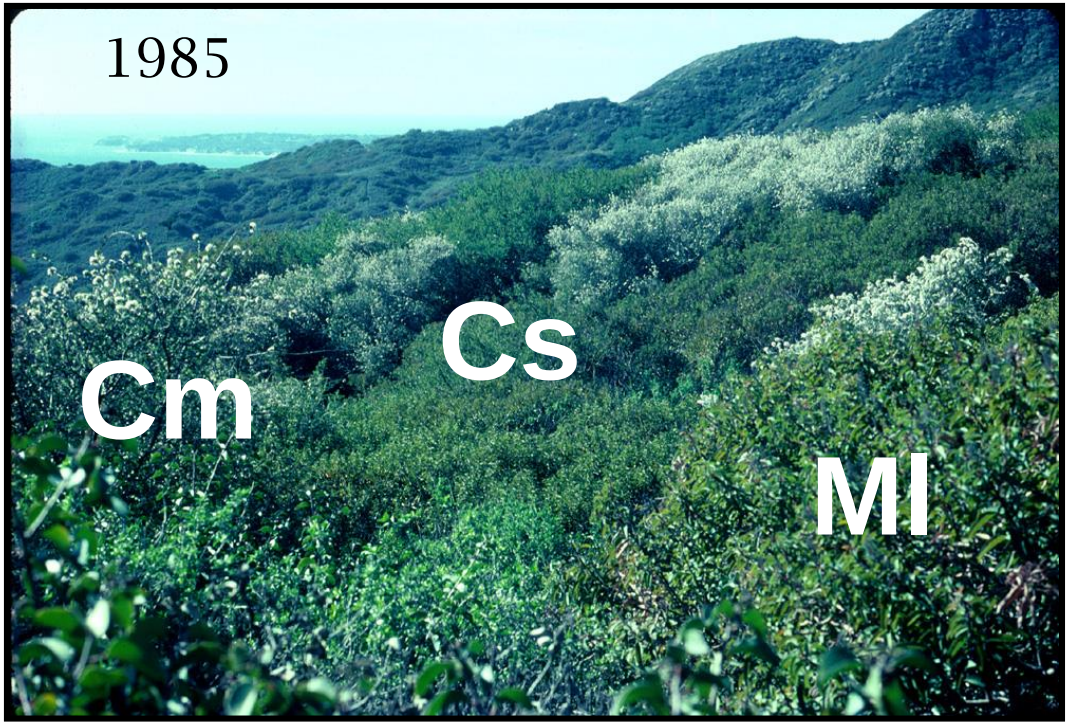


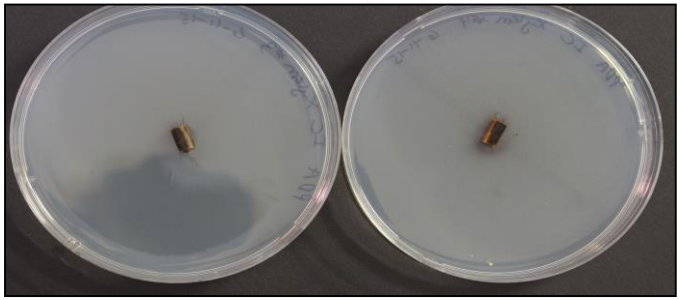
Question

What causes dieback in *M. laurina*?

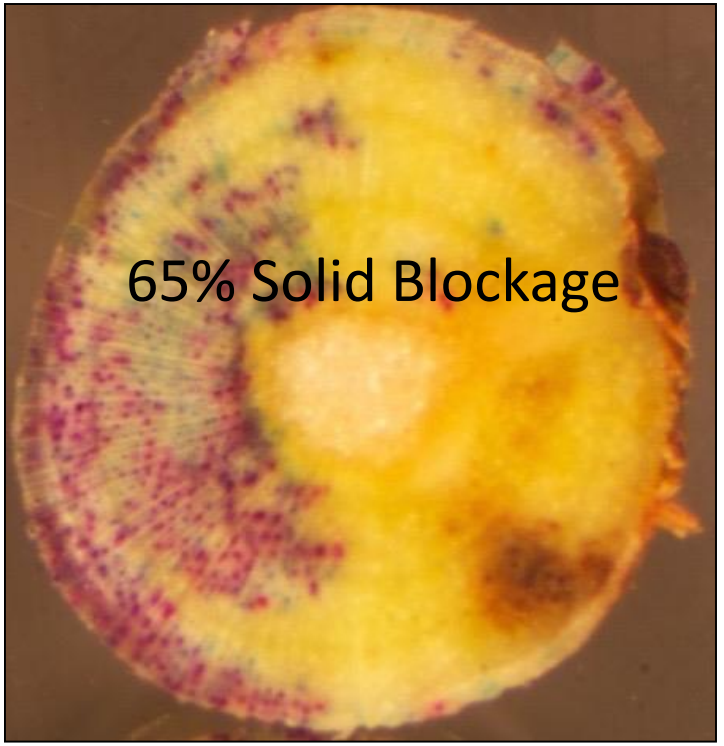
- Water stress-induced air blockage of xylem?
- Solid blockage of xylem?

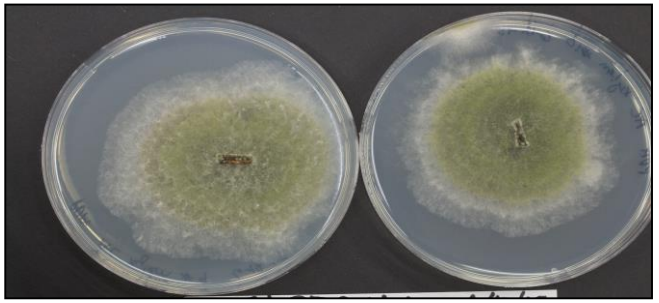
Dieback is **not** caused by water stress-induced air blockage but **solid blockage** of xylem

Healthy Control



Dieback





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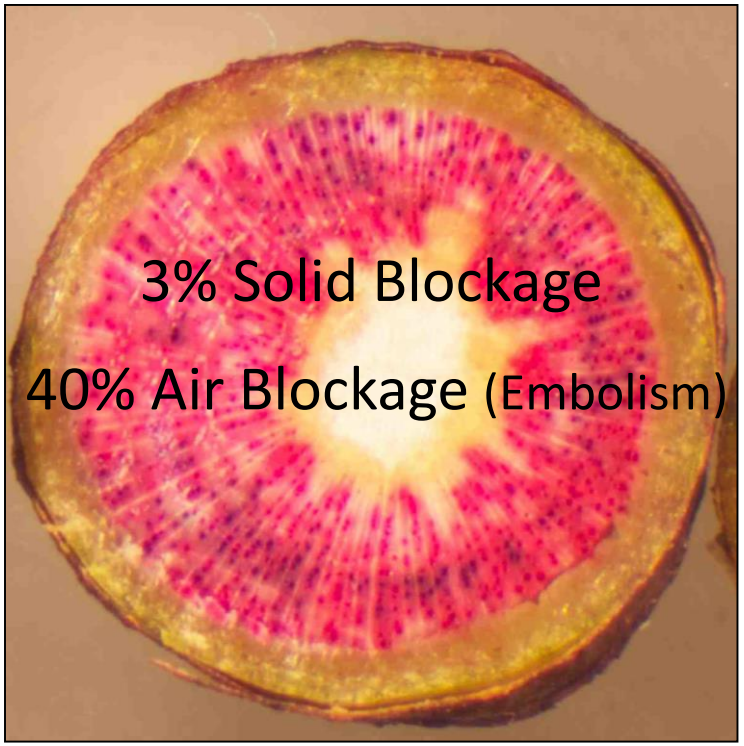
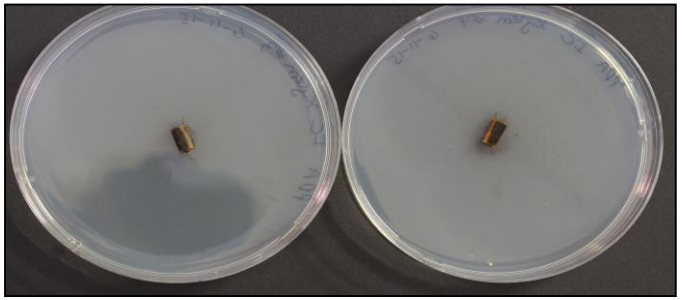
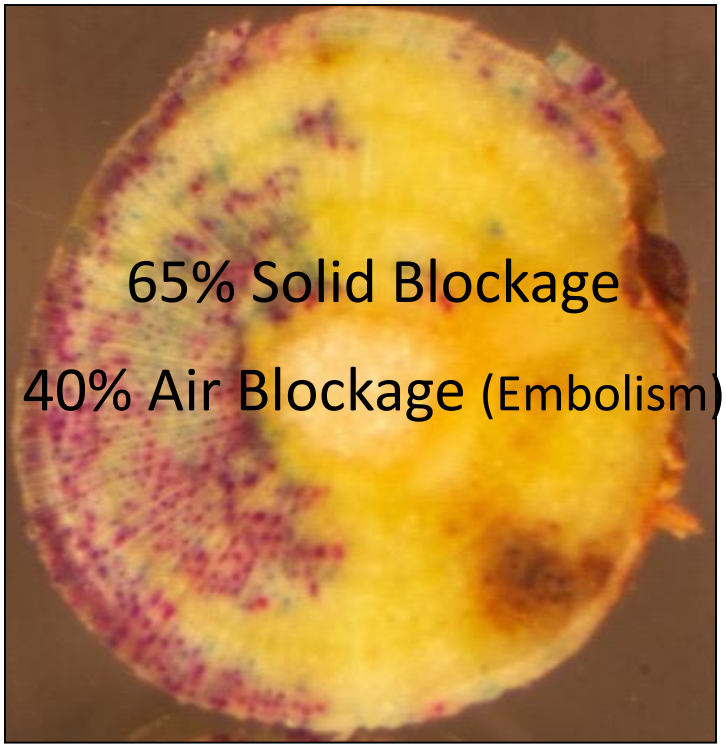
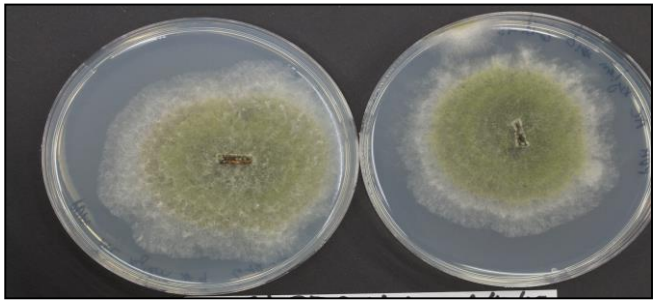
Healthy Control





Dieback





Hypotheses

H1: The cause of observed dieback is chronic drought, predisposing *M. laurina* to fungal infection and spread

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H3: Both water starvation and carbon starvation will enhance growth rates of the fungal pathogen

Hypotheses

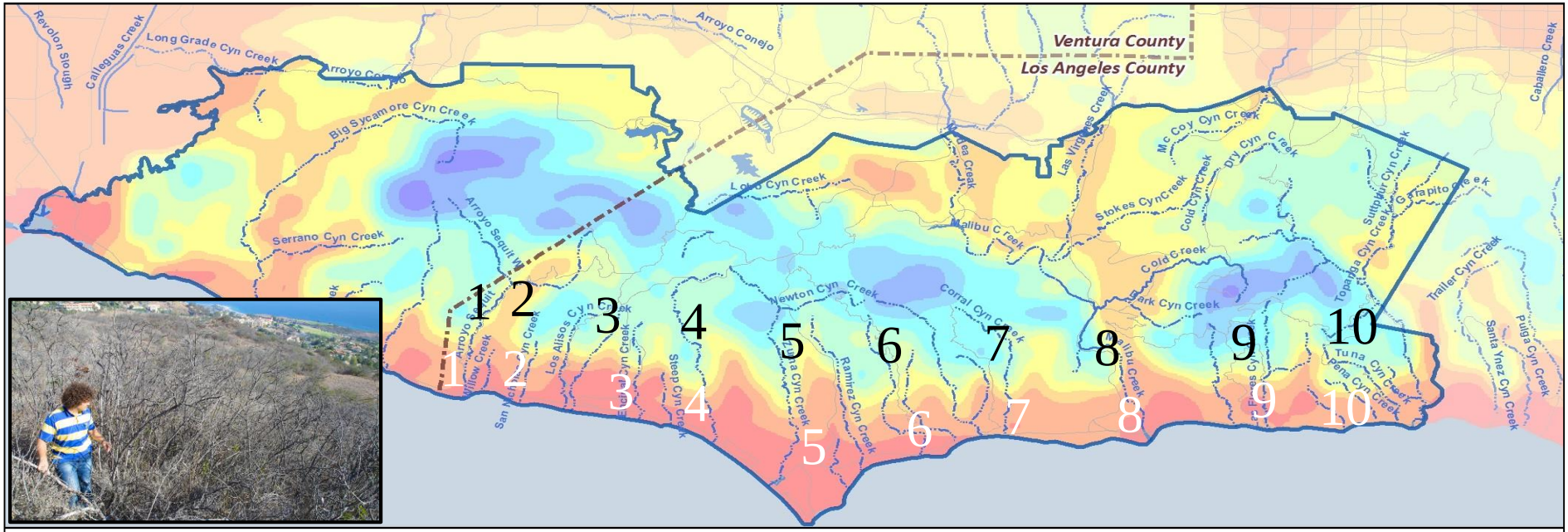
H1: The cause of observed dieback is chronic drought, predisposing *M. laurina* to fungal infection and spread

H2: Koch's Postulate will elucidate the fungal pathogen of dieback

H3: Both water starvation and carbon starvation will enhance fungal growth rates

H4: The dehydration tolerance of the pathogen will exceed the dehydration survival limits of the host

H1: The cause of dieback is chronic drought



Santa Monica Mountains Hydrology and Precipitation

Stream data from USGS, mean precipitation data by Joel Michaelsen (UCSB Geography Dept) predicted from 40 years of data from 175 weather stations across southern CA, and digital elevation model from USGS.

Map by NPS- SAMO Fire GIS, 6/25/2010

Scale 1:200,000 1 inch = 3 miles

0 0.5 1 2 3 4 5 6 7 8 9 10 Miles

N

Perennial Stream
Intermittent Stream
CWPP Boundary
Major Roads

Average rainfall/ year (inches)

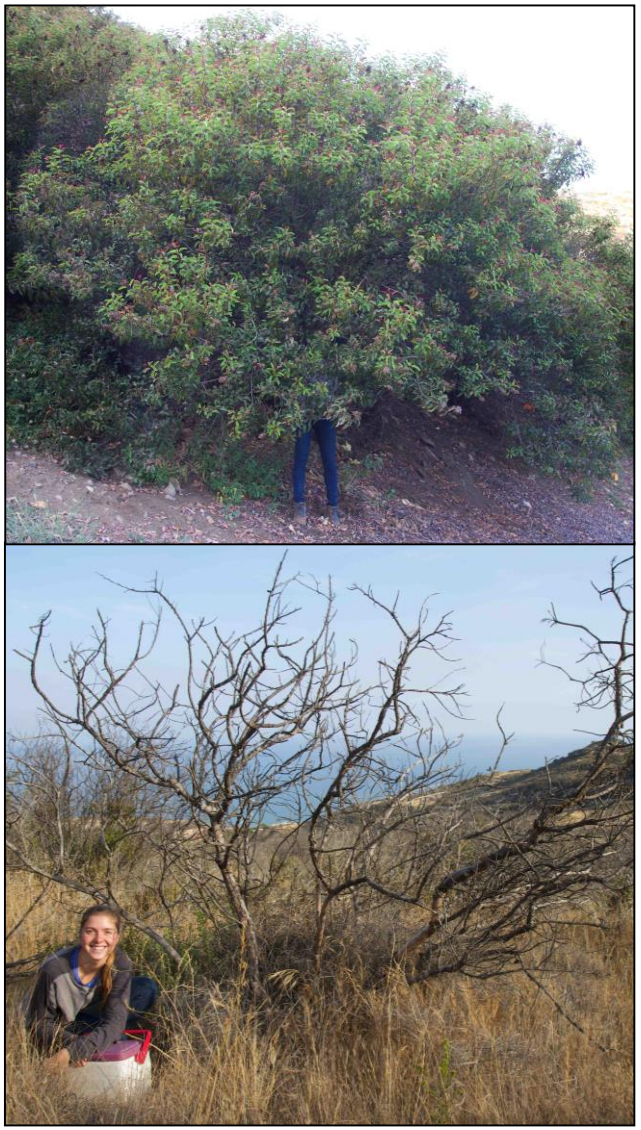
12.5 - 13.7	17.6 - 18.6
13.8 - 14.9	18.7 - 20.1
15.0 - 15.7	20.2 - 21.7
15.8 - 16.5	21.8 - 23.8
16.6 - 17.5	23.9 - 27.6

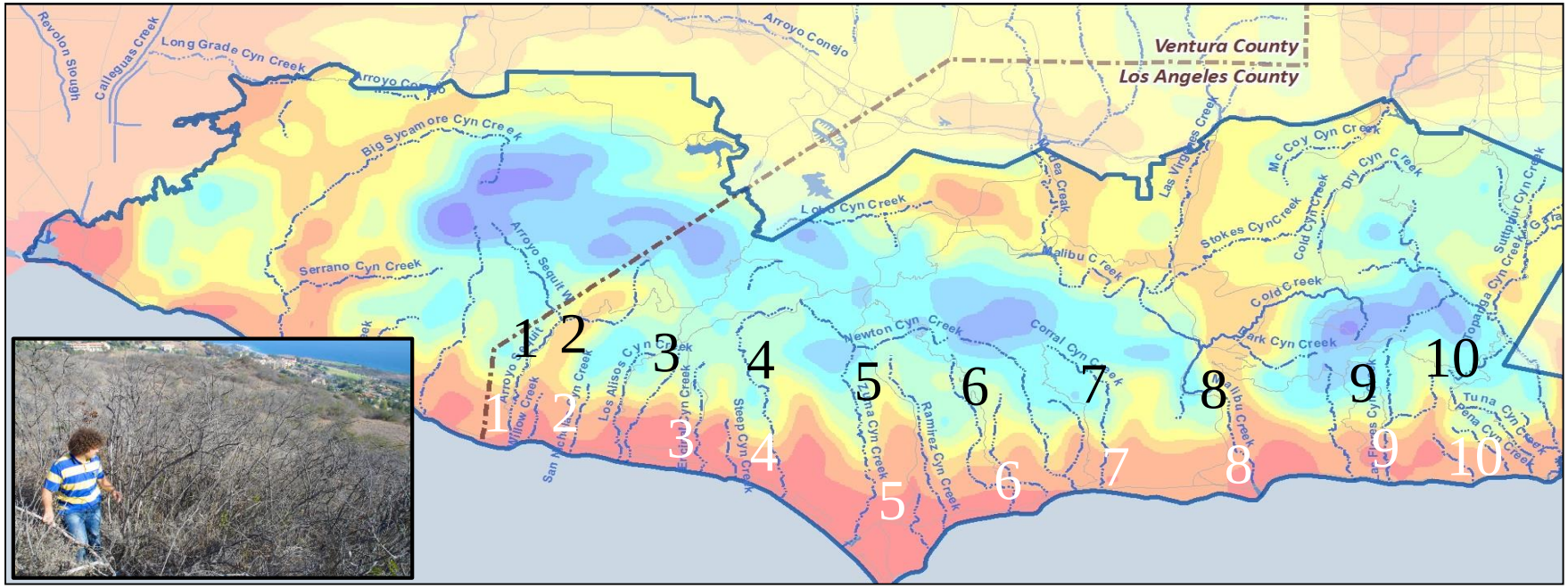
Map name: SAMO_CWPPstreamshydrologyMap85x11c.mxd, Jun 25, 2010 robert_s_taylor@nps.gov

H1: The cause of dieback is chronic drought

Score	Dieback
5	0-20%
4	20-40%
3	40-60%
2	60-80%
1	80-99%
0	Dead

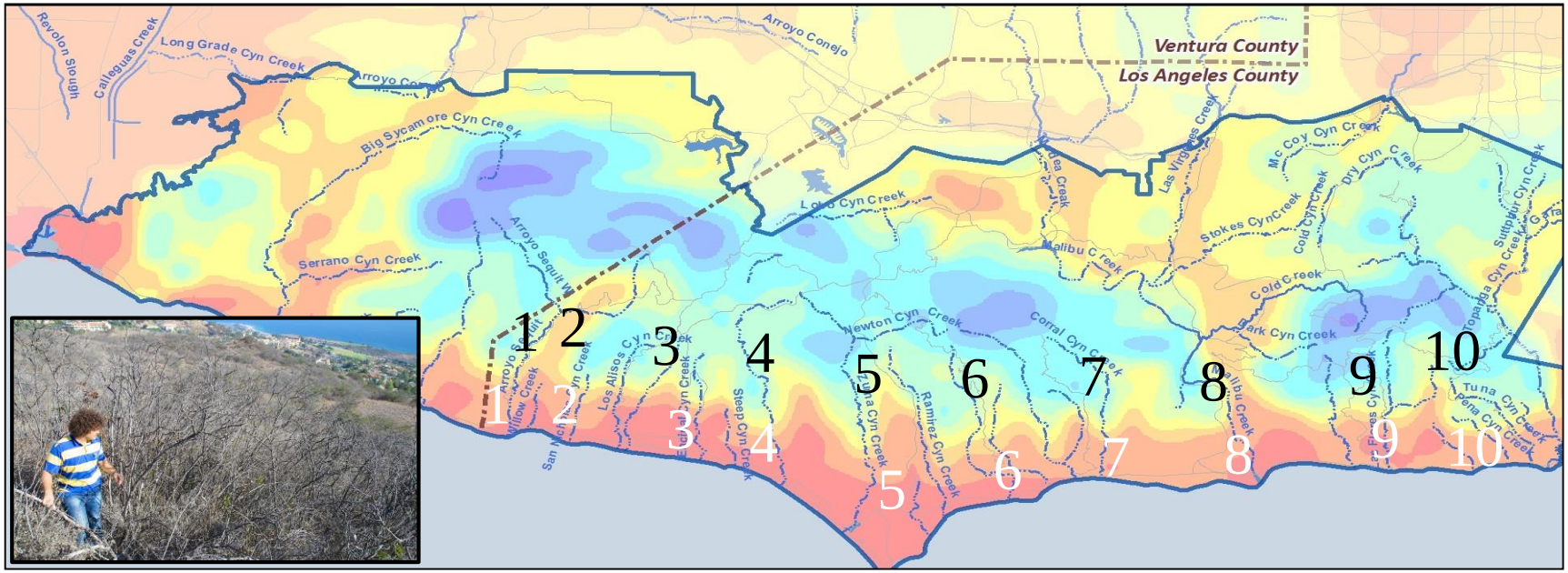
n = 30-90





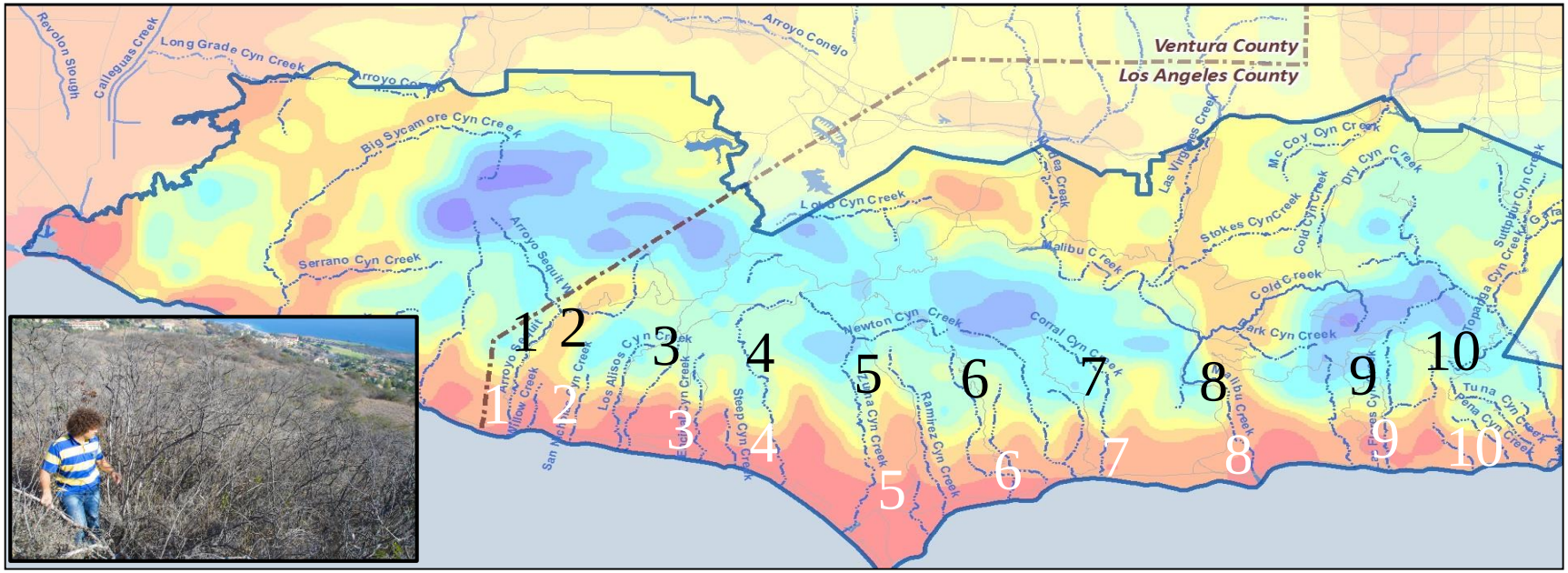
Plant Vigor (score)

Control	3.42	1.5	3.6	3.6	3.81	4.95	5.0	3.12	4.13	4.04
Dieback	0.5	0.9	0.4	0.9	0.7	1.1	1.0	0.5	0.9	0.9



Plant Vigor (score)	Control	3.42	1.5	3.6	3.6	3.81	4.95	5.0	3.12	4.13	4.04
	Dieback	0.5	0.9	0.4	0.9	0.7	1.1	1.0	0.5	0.9	0.9

Plant Mortality (%)	Control	0.0	25	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dieback	12	19	56	39	39	18	44	52	26	41



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	Dieback	12	19	56	39	39	18	44	52	26	41

Plant Fitness (% flowering)										
	Control	72	11	53	100	76	92	84	64	85	100
	Dieback	5.6	2.6	5.6	0	0	0	0	0	11.9	0

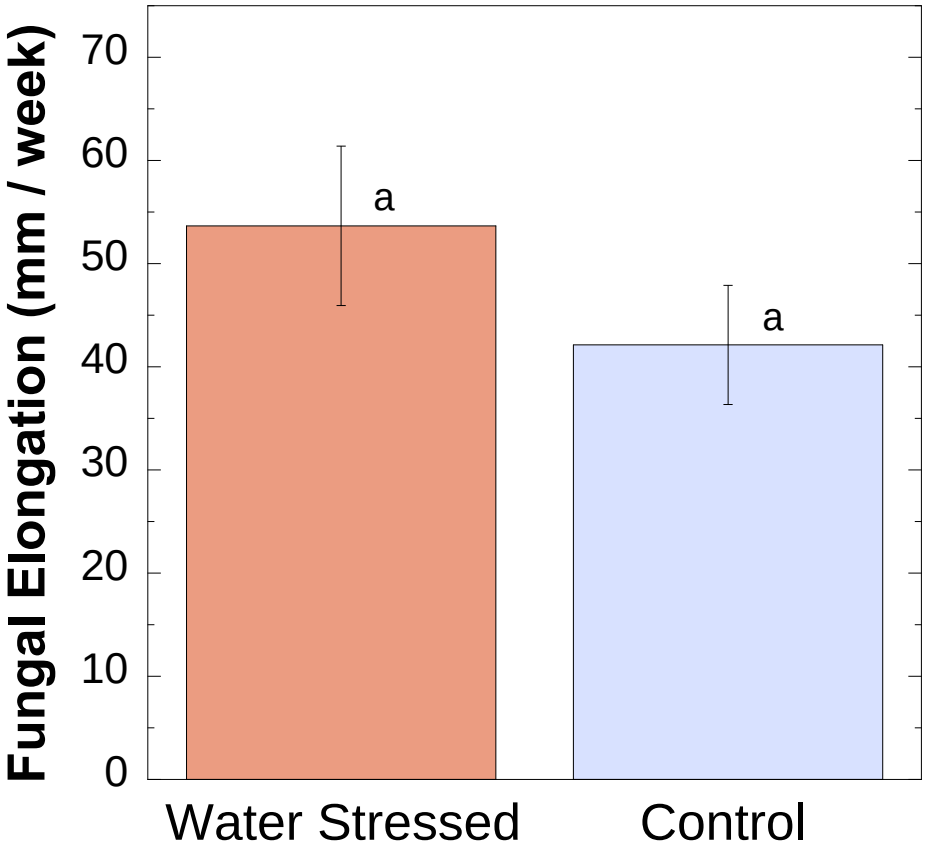
H1: The cause of dieback is chronic drought

Acute Drought
Chamber Experiment

Chronic Drought
Field Experiment

H1: The cause of dieback is chronic drought

Acute Drought
Chamber Experiment



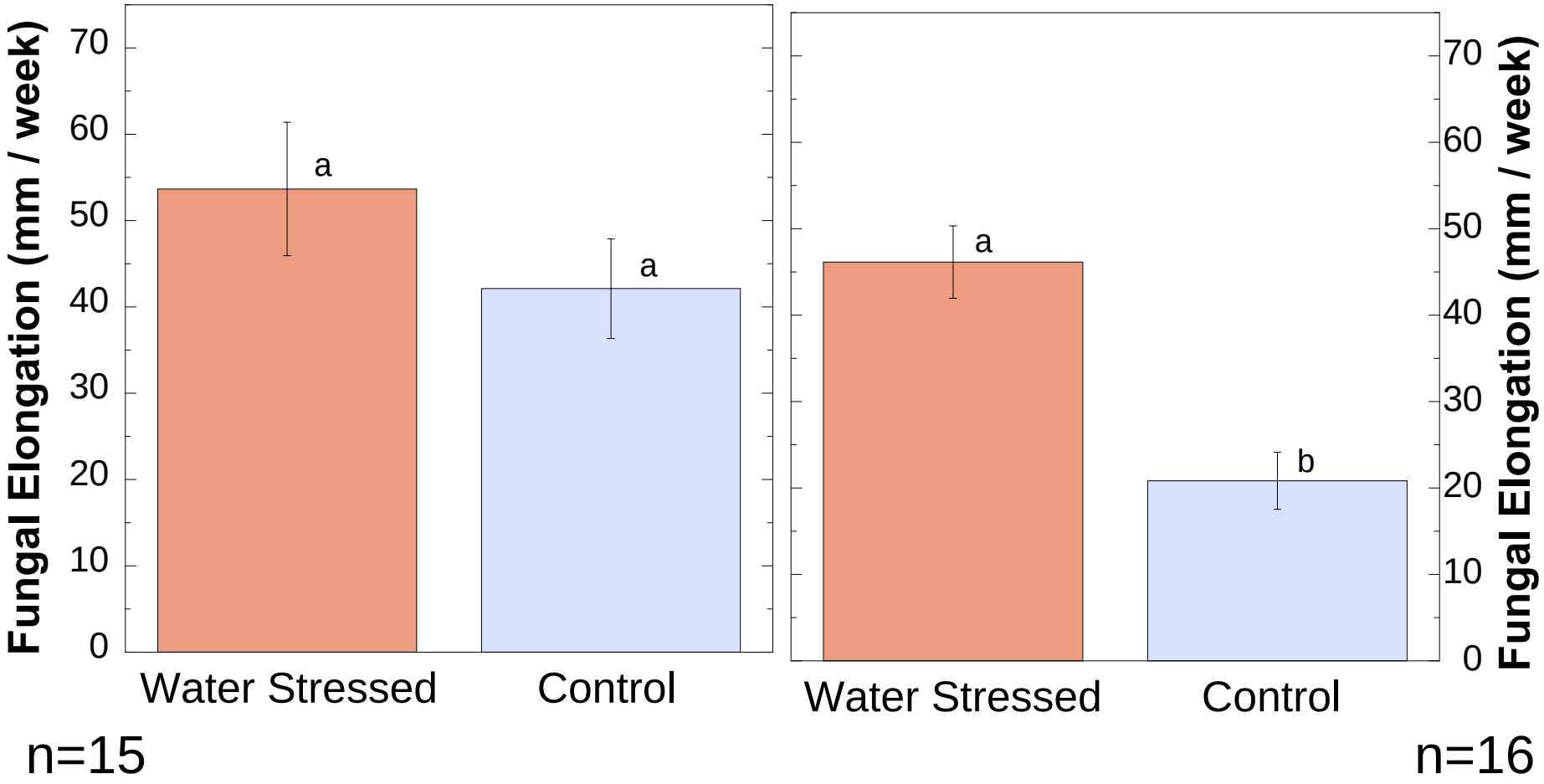
n=15

Chronic Drought
Field Experiment

H1: The cause of dieback is chronic drought

Acute Drought
Chamber Experiment

Chronic Drought
Field Experiment



H2: Koch's Postulate will elucidate the fungal pathogen causing dieback

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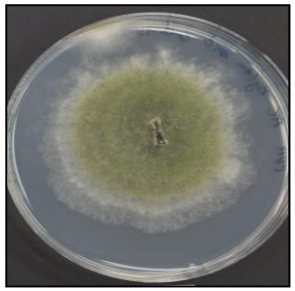


Positive cultures (%)

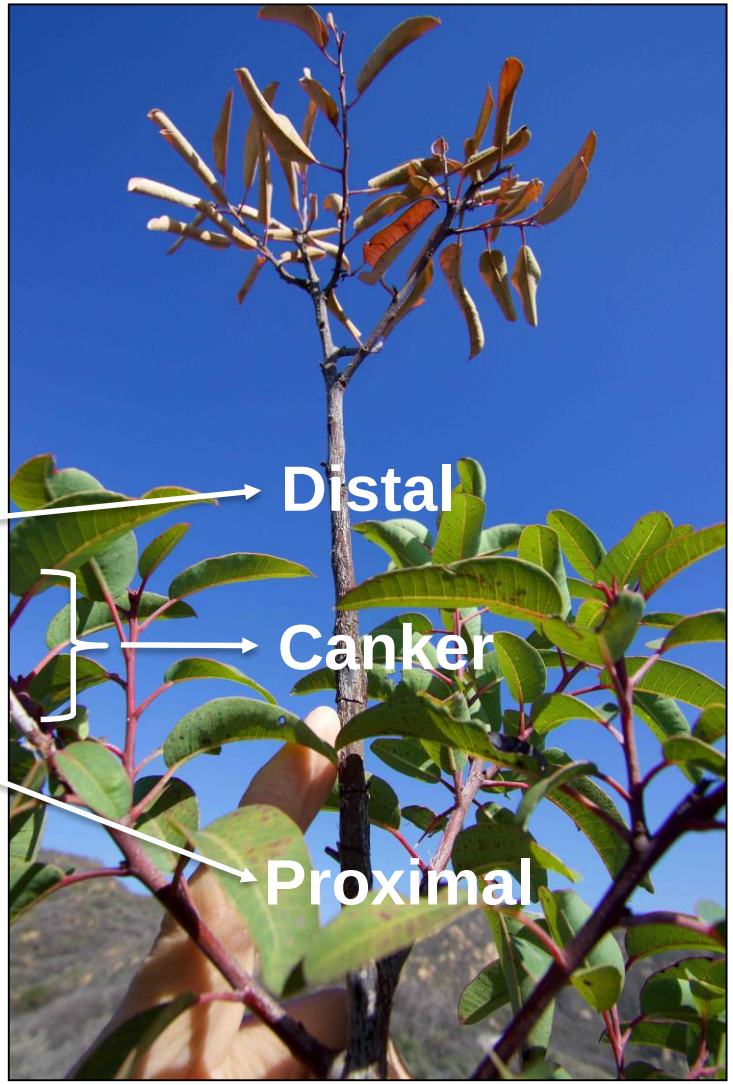
Dieback Adult Plants

distal canker xylem	85%
canker xylem	100%
canker phloem	95%
proximal canker xylem	45%

Dieback Resprouts

xylem	45%

(n = 20)



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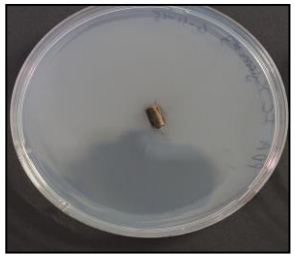

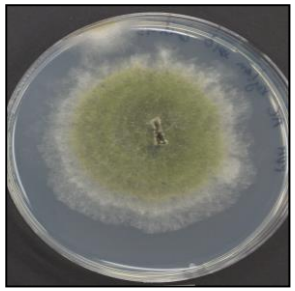

Positive cultures (%)

Control Plants	
xylem	0%
phloem	0%
Dieback Adult Plants	
distal canker xylem	85%
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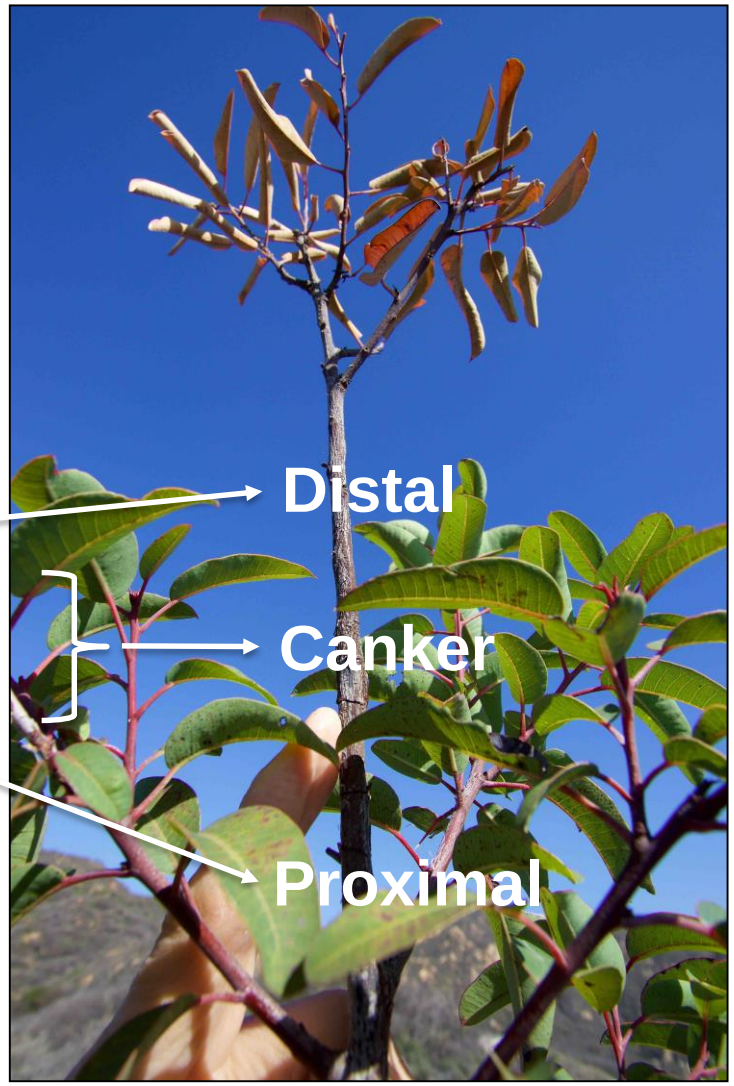
proximal canker xylem	45%
Dieback Resprouts	
xylem	45%

(n = 20)

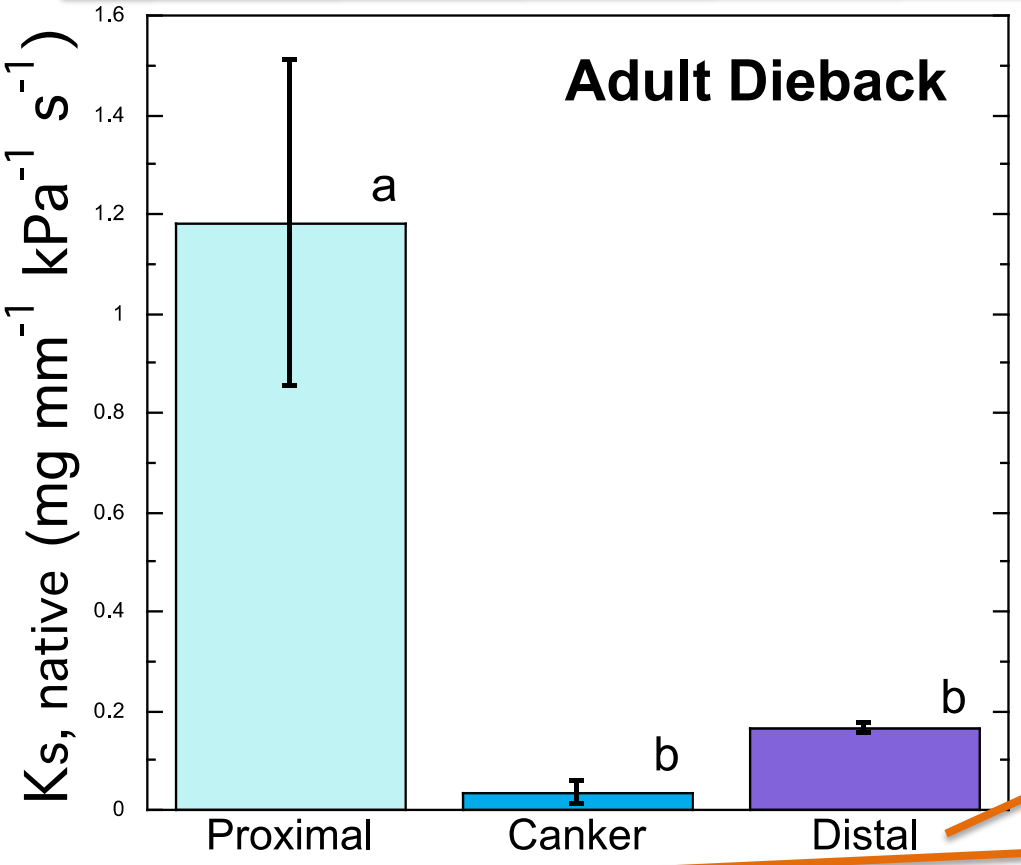


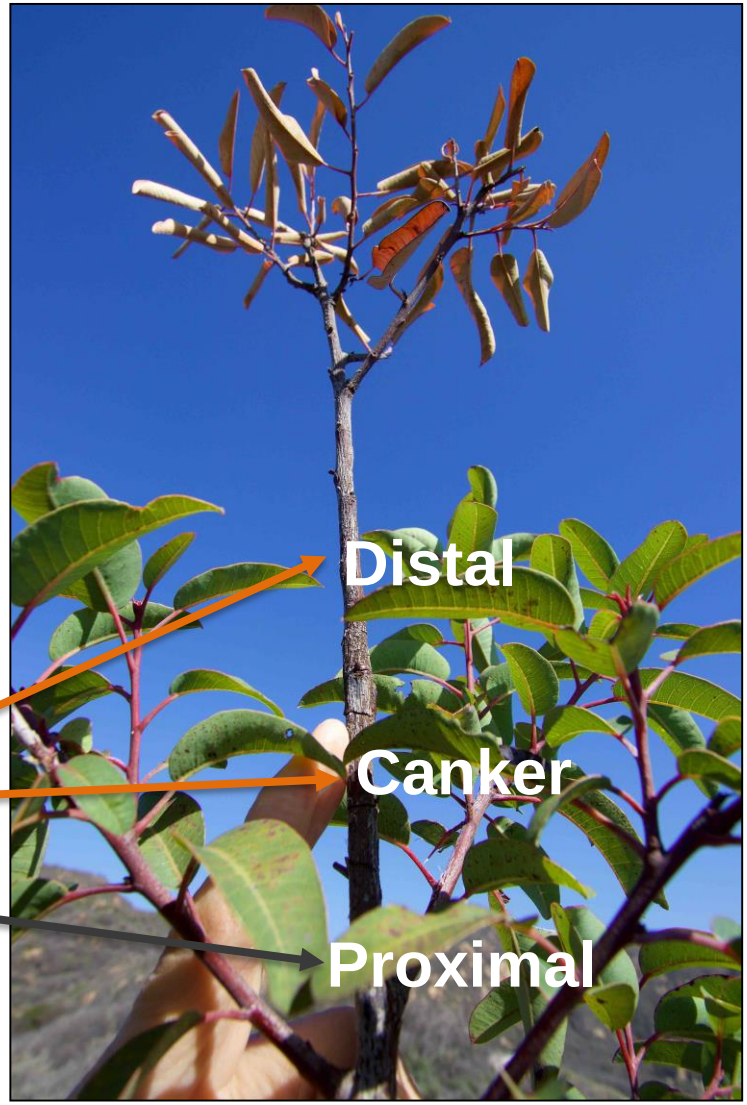
The fungal pathogen will reduce stem water transport (Ks)

Toilet Plunger Method

Sperry Method

The fungal pathogen will reduce stem water transport (Ks)





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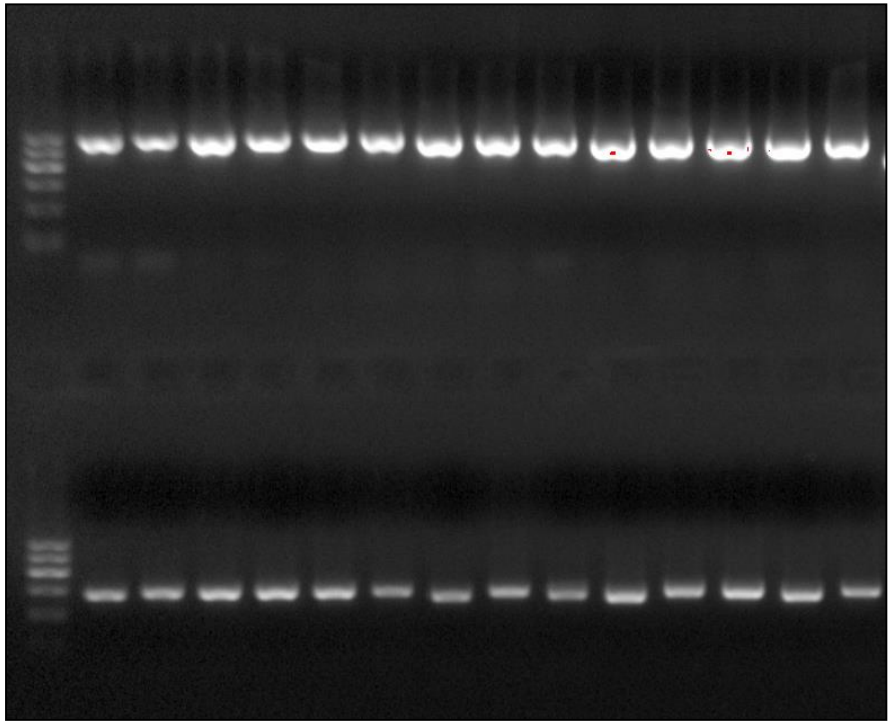


Genetic Primers > 99% Match to *Botryosphaeria dothidea*

- Internal Transcribed Spacer (ITS)
- Beta tubulin 2 gene (Bt2)
- Elongation Factor 1 α (EF1)

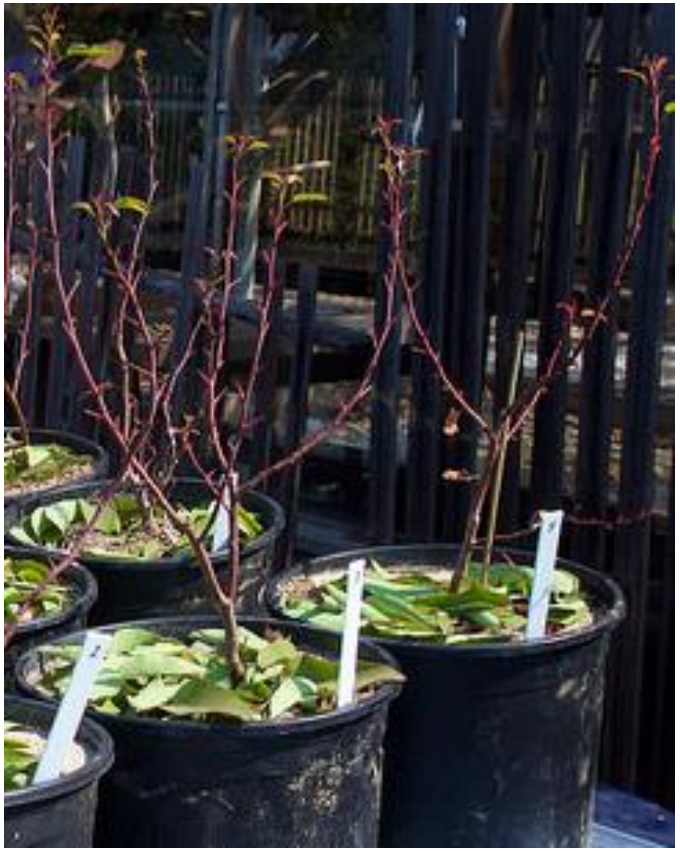
(Slippers et al. 2004).

H3: Both water starvation and carbon starvation will enhance fungal growth rates

Non-Irrigated

Water Starved

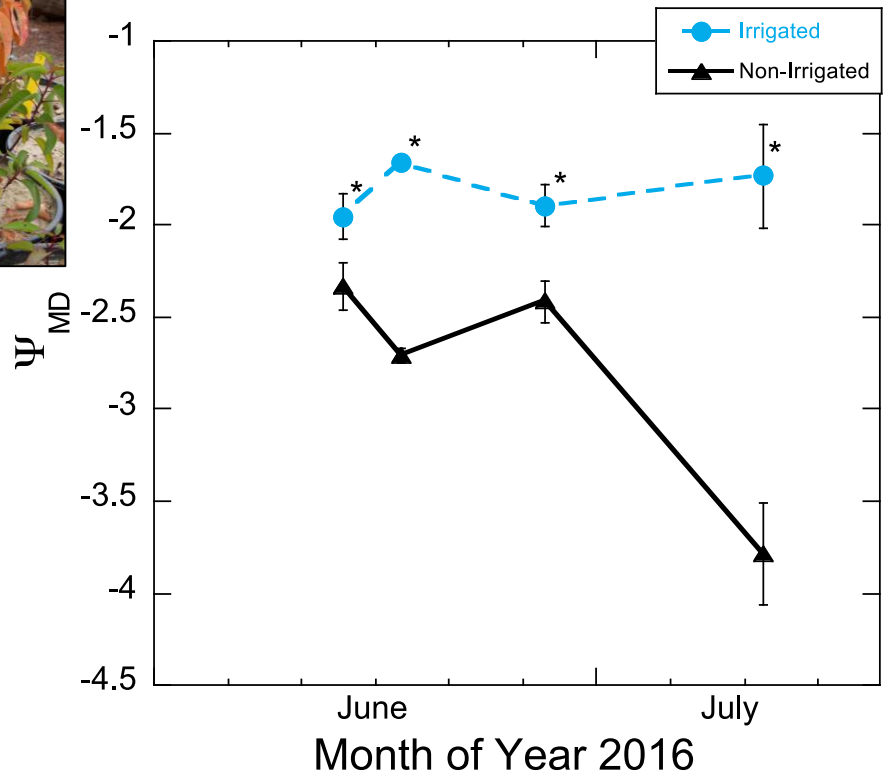
Defoliated



Carbon Starved

Fungal Inoculation

Non-Irrigation: Impact on Plant Water Status



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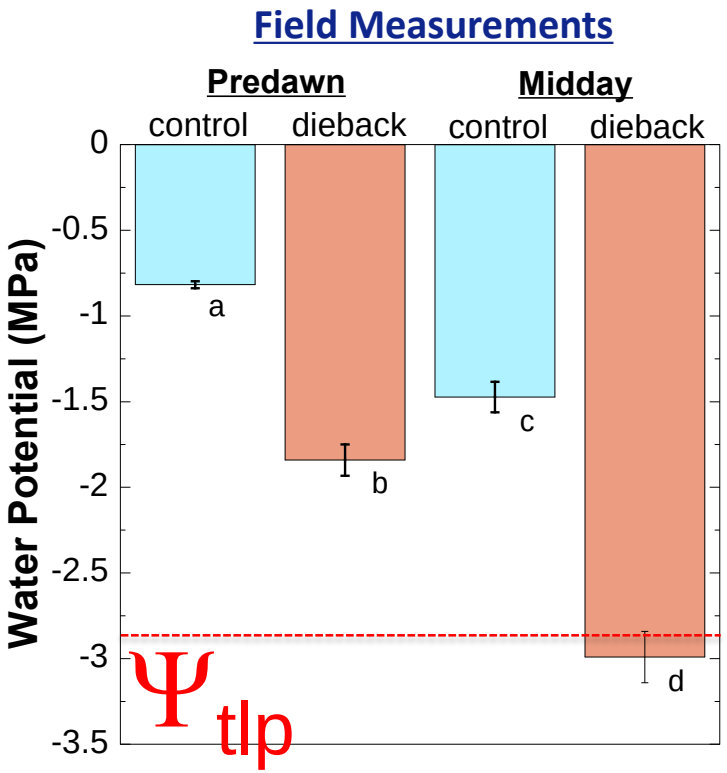
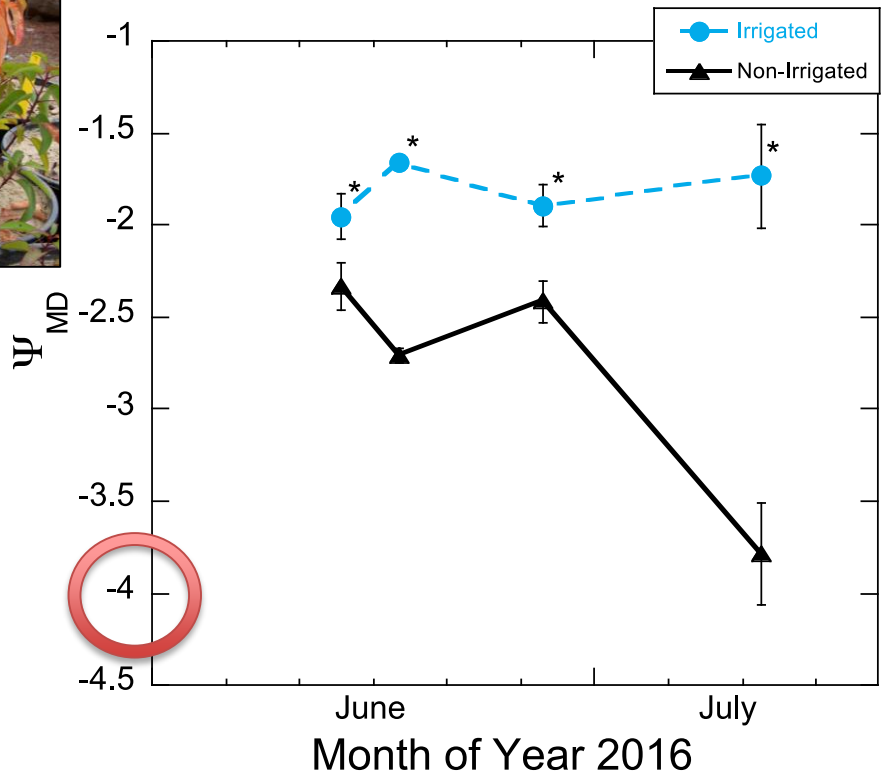
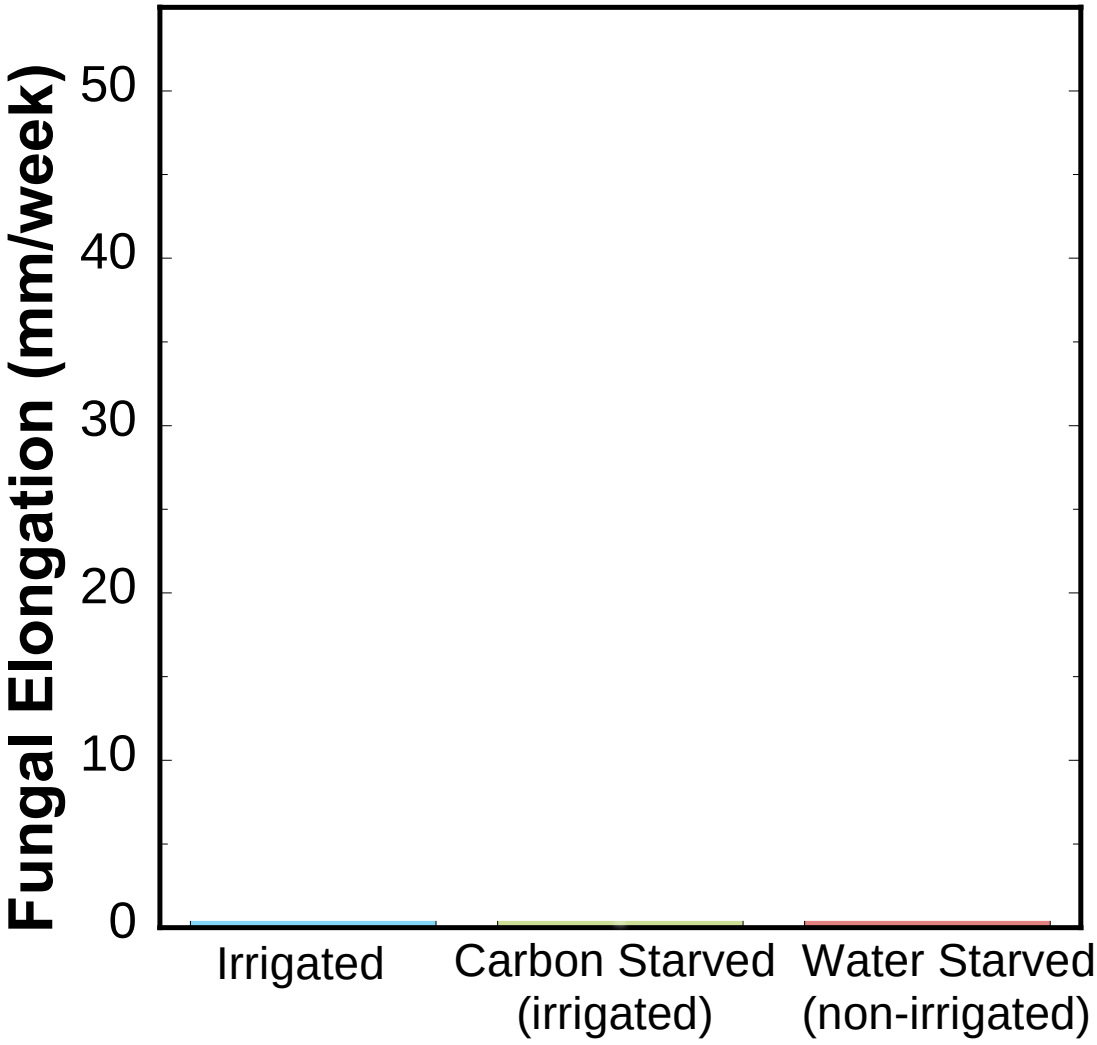
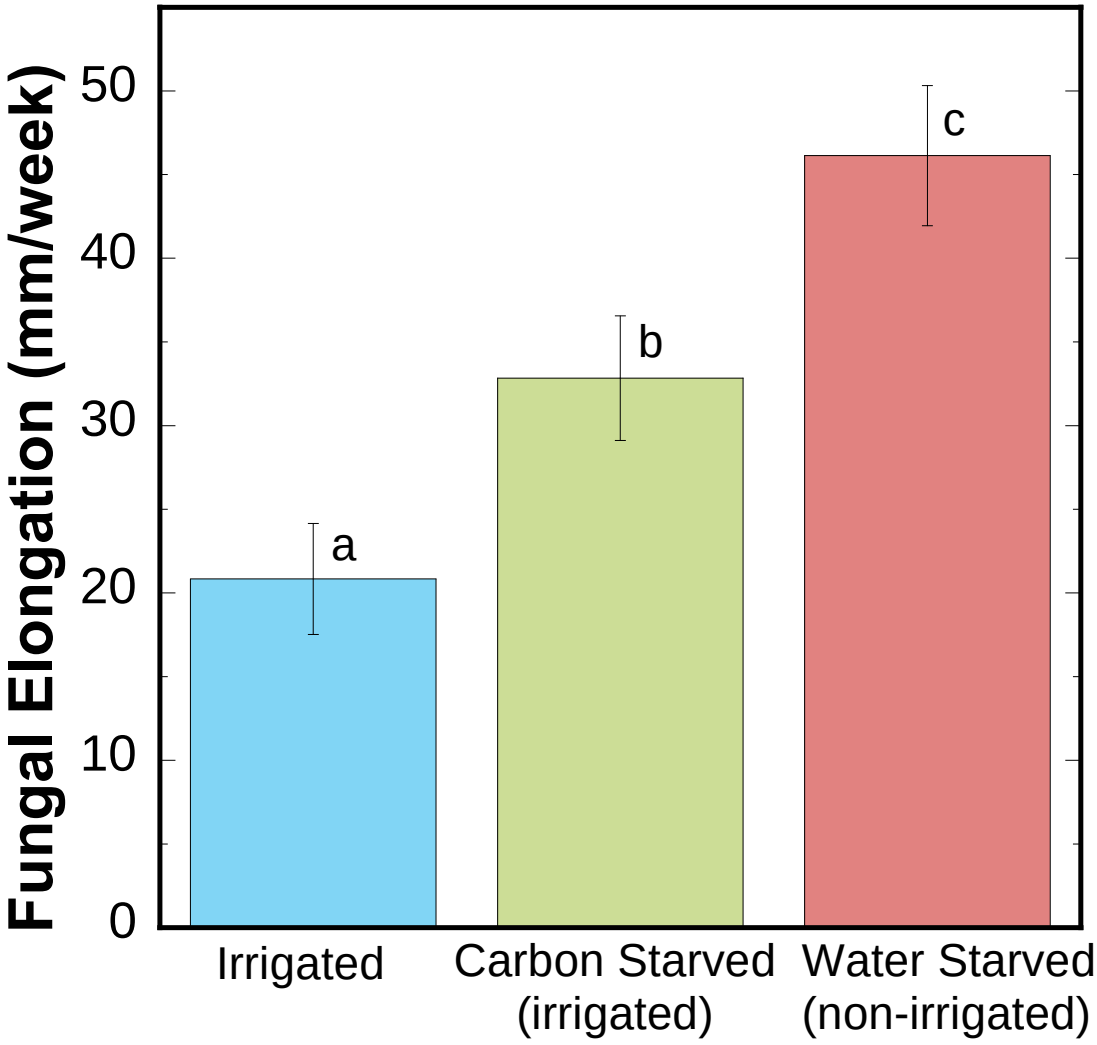




H3: Both water starvation and carbon starvation enhance fungal growth rates

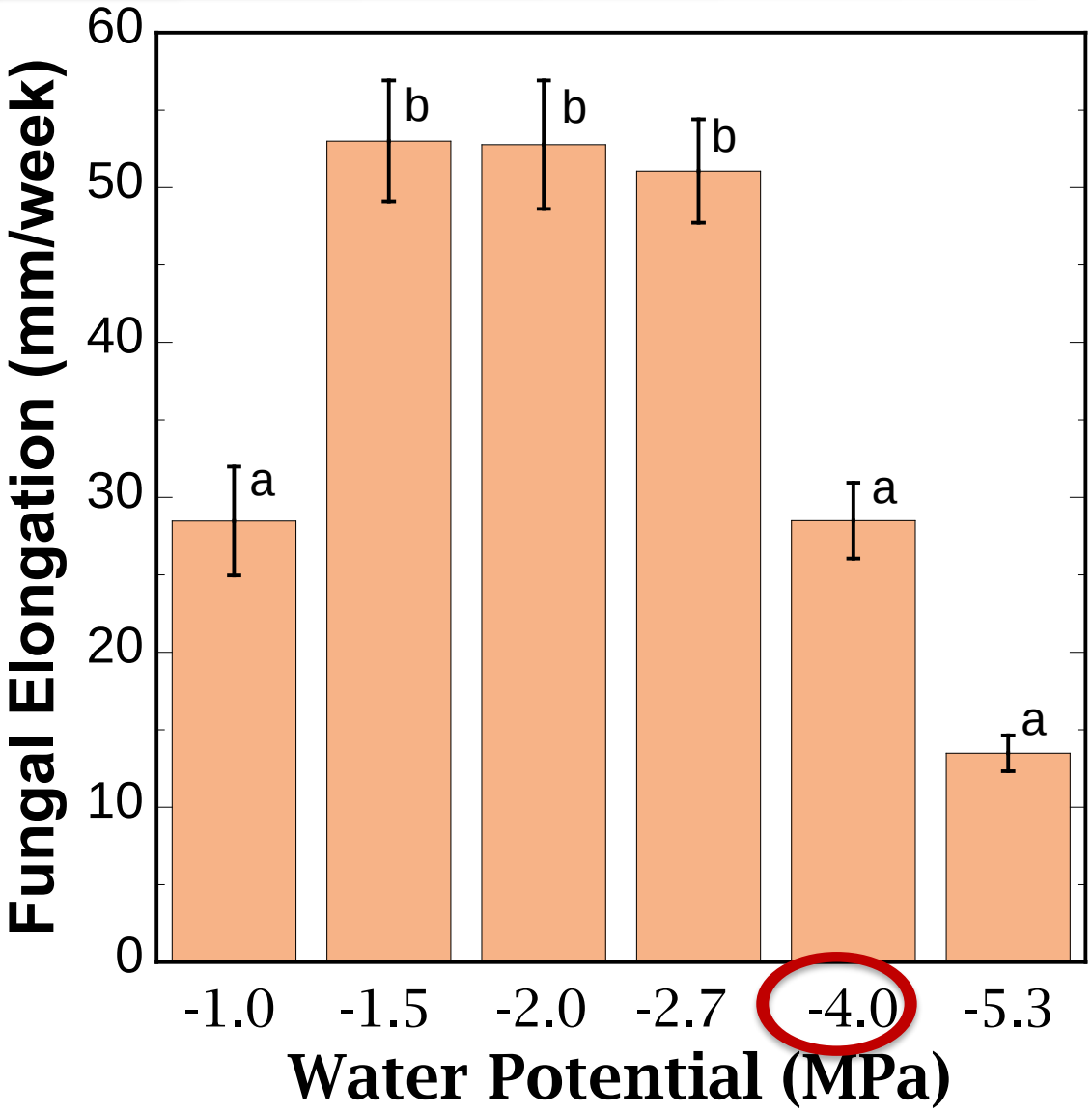


H3: Both water starvation and carbon starvation enhance fungal growth rates



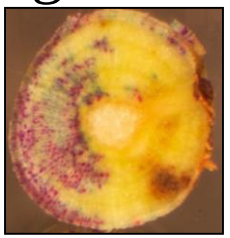
H4: The dehydration tolerance of fungal pathogen exceeds the dehydration survival limits of the host

p < 0.01
n = 20

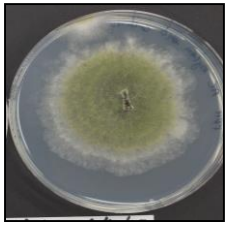


Conclusions

C1: Dieback is not caused by water stress-induced air blockage but solid blockage of xylem conduits (fungal-induced)



C2: The ultimate cause of dieback is chronic drought: the proximate cause is an opportunistic, endophytic fungus



C3: Both water starvation and carbon starvation enhance fungal growth

C4: The dehydration tolerance of the fungal pathogen exceeds the survival limits of the host

Recommendations

Reseed at Higher Elevations

- **Because limited seed transport uphill**
- **Higher elevations = higher precipitation**
- **Higher elevations are becoming warmer**

  (seedlings survive -6C; adults survive -9C)

Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). *Indicators of Climate Change in California*.

Acknowledgements

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