Progress in Anaerobic Soil Disinfestation (ASD) Research

Fumigants and non-fumigant alternatives:
Regulatory and research updates
22 April, 201. Friday, UCCE, Ventura

Carol Shennan, Joji Muramoto, Margherita Zavatta, Graeme Baird, and Lucinda Toyama, University of California, Santa Cruz

Mark Mazzola, USDA-ARS, Wenatchee, WA

Acknowledgements

We gratefully acknowledge funding and collaboration for this work from the following:

- **USDA Methyl Bromide Transition Program**
- **USDA Areawide program**
- **CDPR Pest Management Research Program**
- **California Strawberry Commission**
- **Will Doyle, WD Farm**
- **Extension and industry people who have made this work possible**

ASD Basics

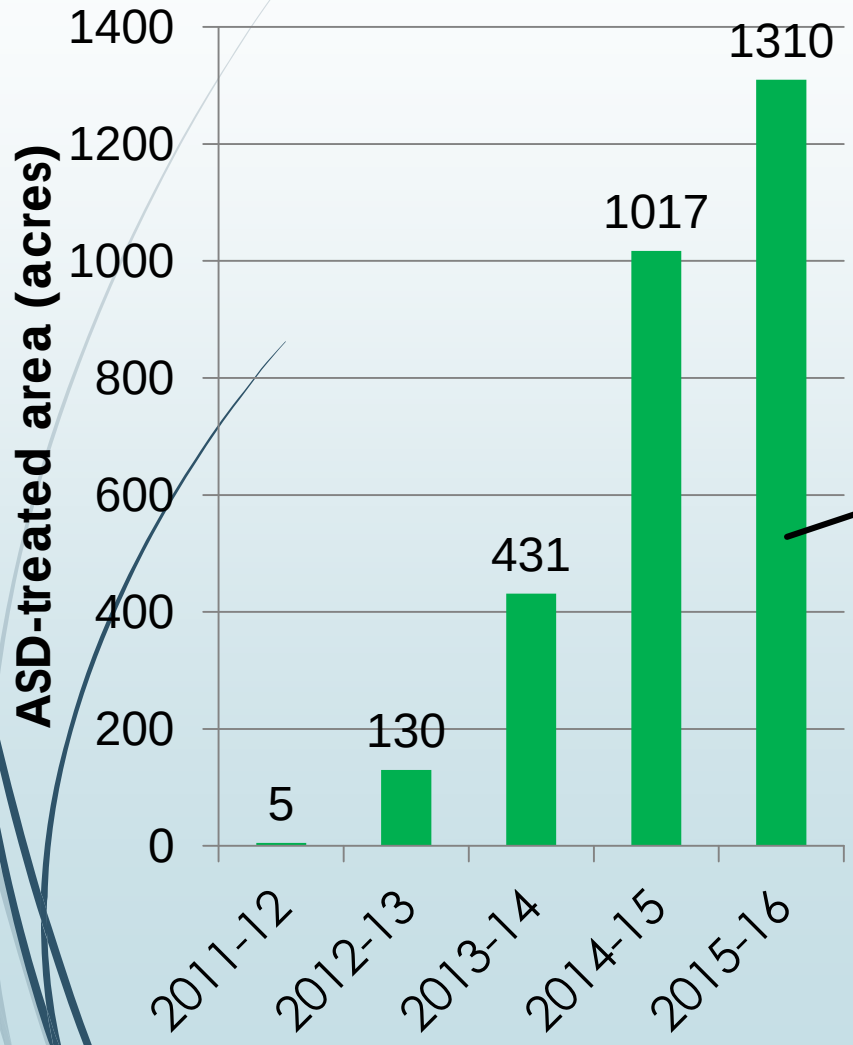
1. Incorporate readily available organic matter
   - **Provide C source for soil microbes**
2. Cover with oxygen impermeable tarp
3. Irrigate to saturate soil then to maintain field capacity
   - **Water-filled pore space**
   - **Create anaerobic conditions and stimulate anaerobic decomposition of incorporated organic material**

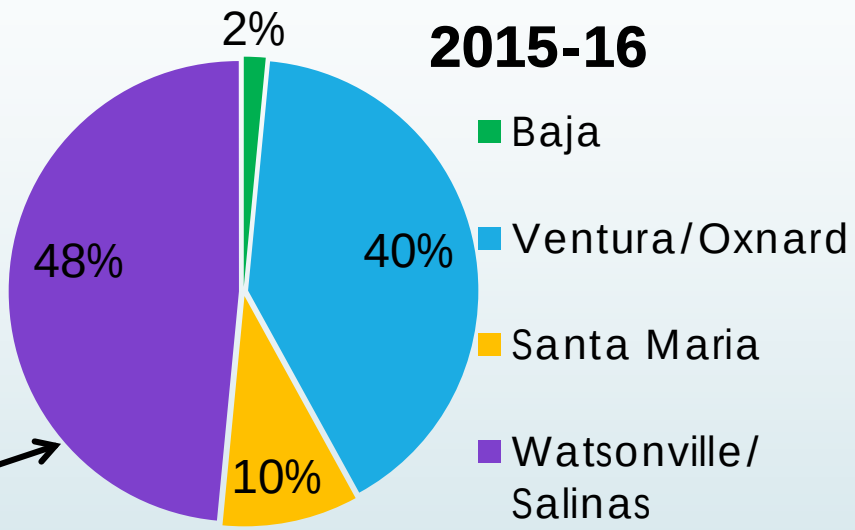
Anaerobic Soil Disinfestation (ASD)
(Shennan et al., 2007)

Principle:
Acid fermentation in anaerobic soil (Blok et al, 2000; Shinmura et al., 2000)

1. Broadcast rice bran at 9 tons/ac
2. Incorporate bran
3. List beds
4. Cover w/ plastic mulch
5. Drip irrigate total 3 ac-inches over 3 wks
6. Leave 3 wks and monitor soil Eh and temp

ASD-Treated Acreages in California and Mexico





Potential Mechanisms

- Production of organic acids toxic to some pathogens
- Production of volatiles toxic to some pathogens
- Reduction of iron and manganese – Fe^{2+} and Mn^{2+} toxic to some pathogens
- Shifts in microbial communities to create competition or antagonism that suppress pathogens
- Lack of oxygen, low pH,
- Combination of the above – all interrelated!

How are each of these processes related to suppression of specific pathogens?

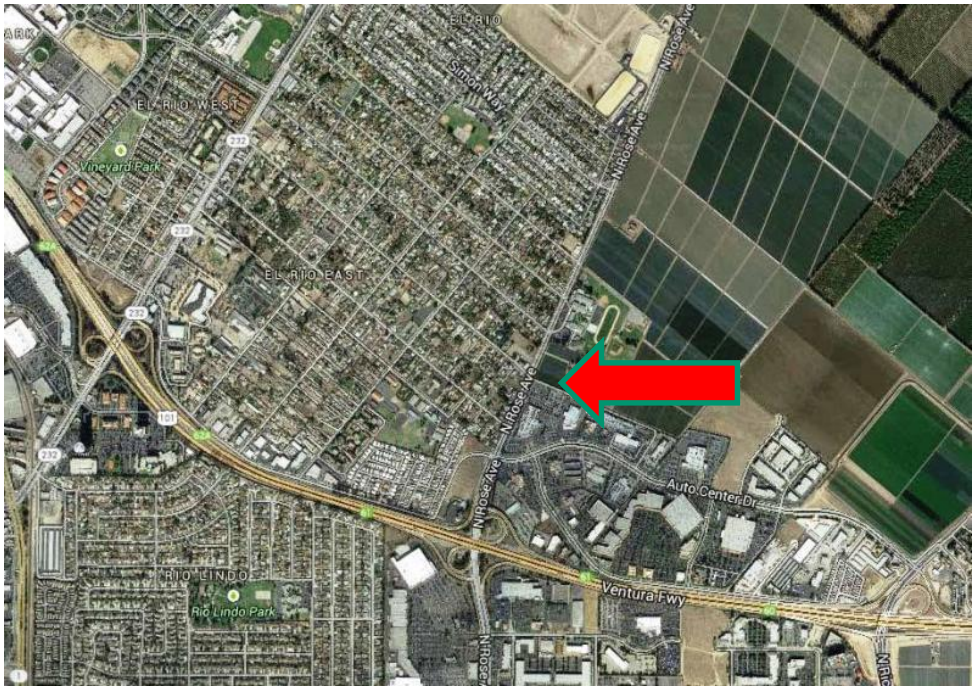
How are processes affected by C source used, soil moisture and temperature, and initial microbial community?

Summary of Findings to 2014 ~field trials~

- Good yields obtained with 9 t/ac rice bran in field trials averaged 99% (82 – 114%) of fumigant yields in 10 replicated field trials in Watsonville, Castroville, Salinas, Santa Maria, and Ventura
- Got consistently good *V. dahliae* suppression; 80 to 100% decrease in # microslerotia in soil, using 9 t/ac rice bran
- Weed suppression limited in the central coast of CA
- May not need pre-plant fertilizer with 6-9 t/ac rice bran as C-source, but probably will with lower N C-sources
- Long term suppression may be related to microbial shifts

Oxnard Trials

- 3rd year in a row of ASD-strawberry
- 8-9 yrs. Organic mngt.
- Pico sandy loam
- High soil pH (~8)
- Urbanized environment
  ….high land cost
  - Strawberry/short cover crop/strawberry rotation
- Highly infested with both *Macrophomina phaseolina* and *Fusarium oxysporum*



MSM2	ASD MSM2+RB3	ASD RB9	GS

Oxnard Demo Trial

May 29, 2014

(*Macrophomina spp.* + *Fusarium oxysporum* infested organic field)

MSM2.5*

ASD RB6*

ASD RB9*

GS

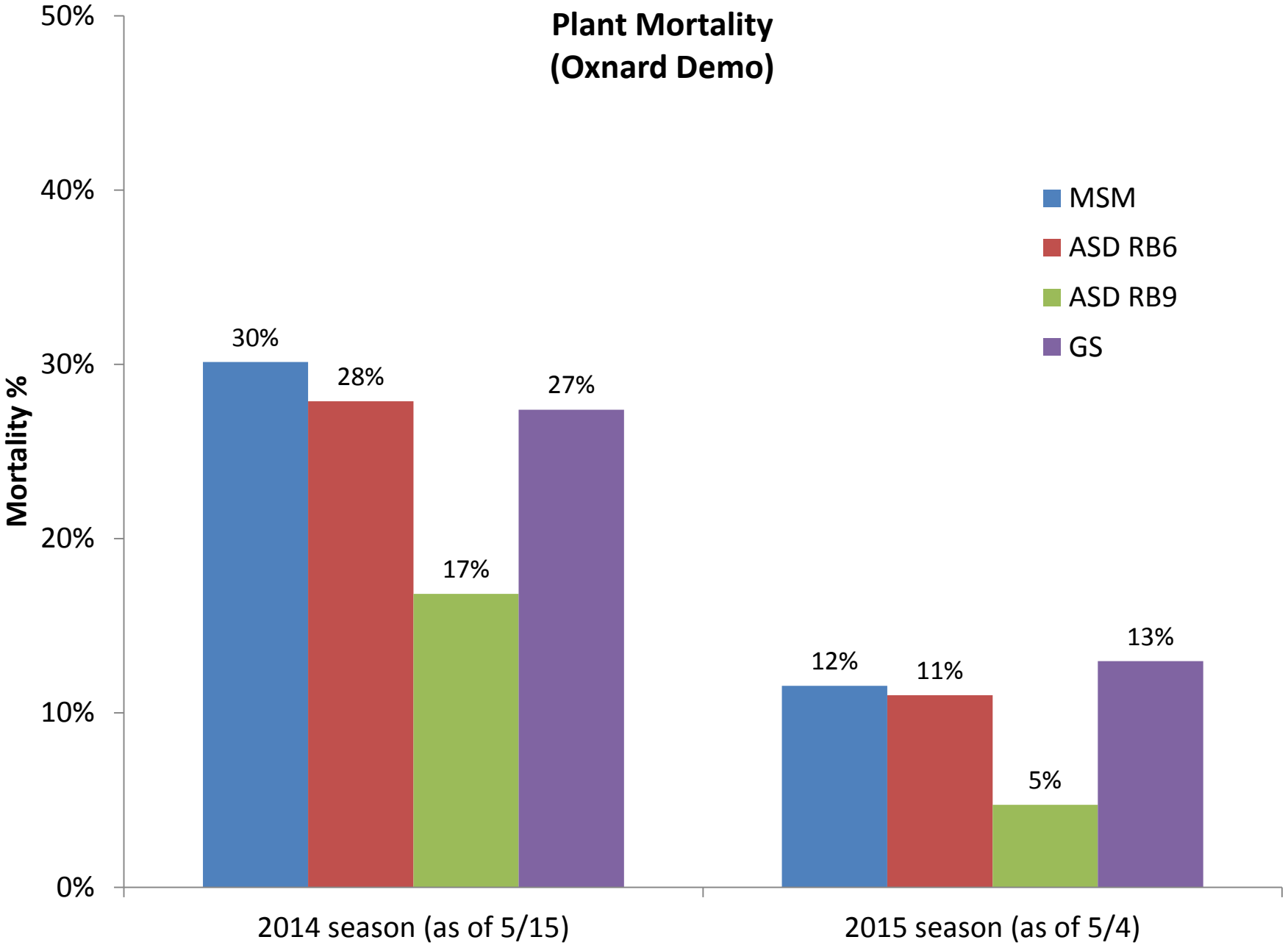
Pre-plant 10-10-2.5, 2,000 lbs/acre

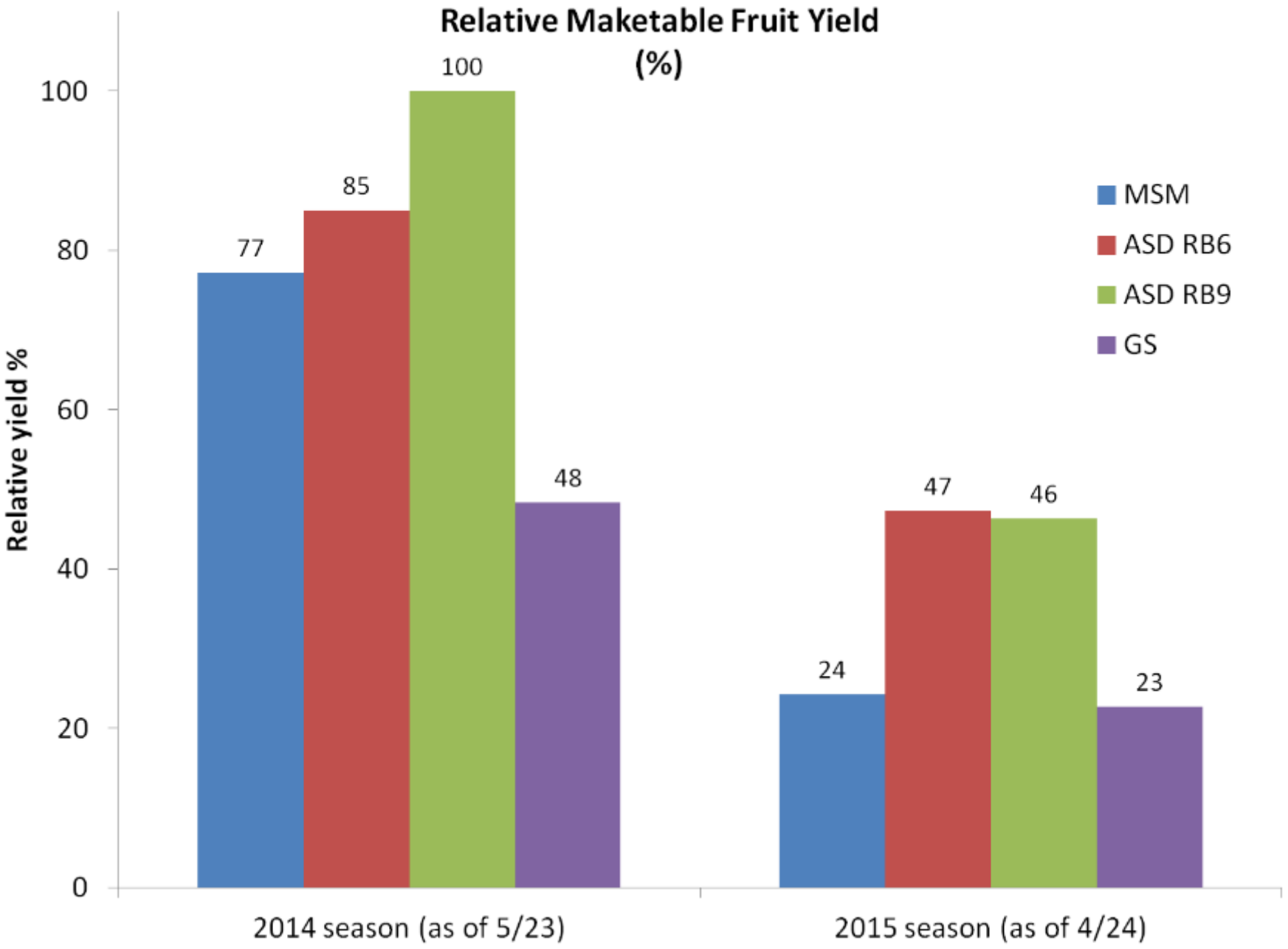
* No pre-plant fertilizer

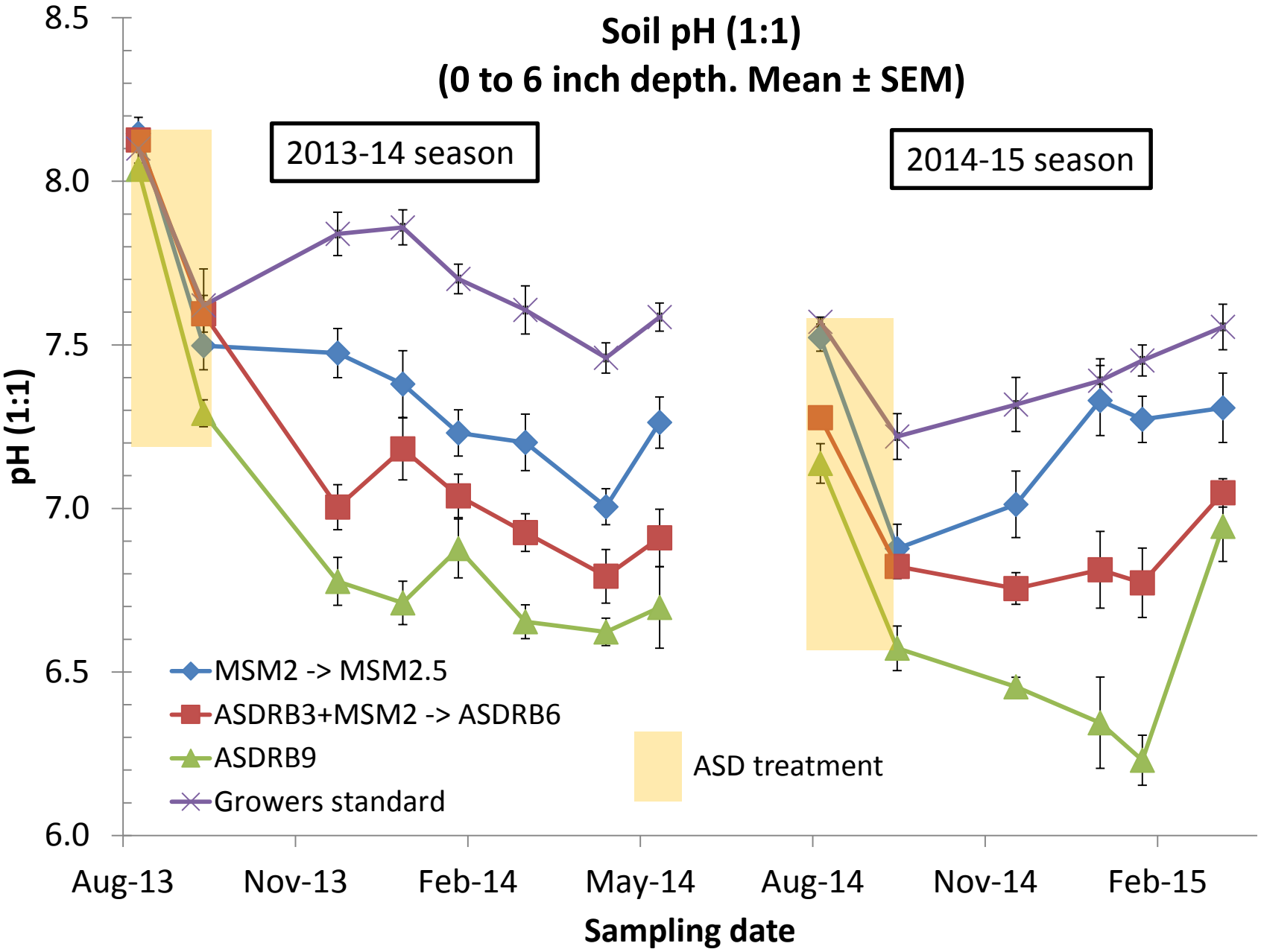
Oxnard Demo Trial

April. 23, 2015

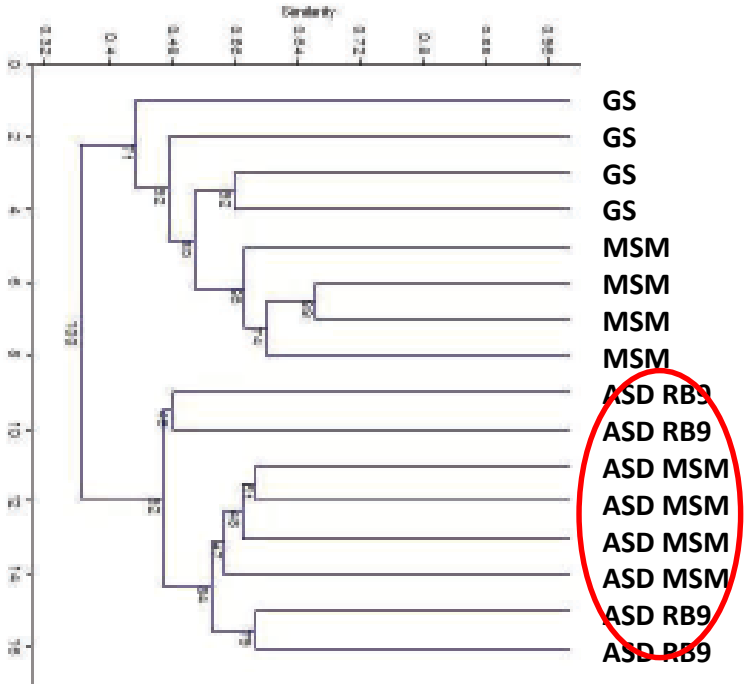
(*Macrophomina spp.* + *Fusarium oxysporum* infested organic field)


Plant Mortality
(Oxnard Demo)
50%
40%
30%
20%
10%
0%
Mortality %
MSM
ASD RB6
ASD RB9
GS
30%
28%
17%
27%
12%
11%
5%
13%
2014 season (as of 5/15)
2015 season (as of 5/4)

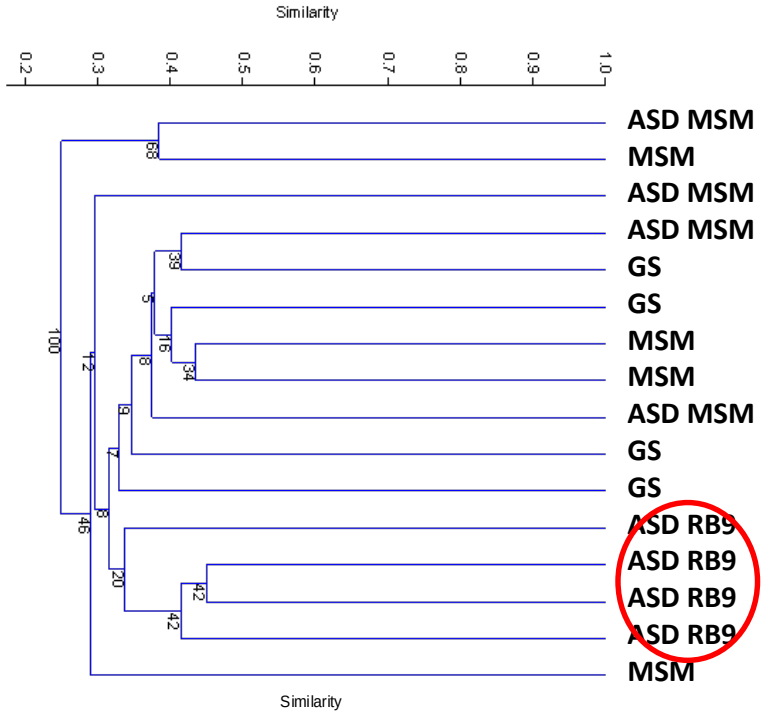

Relative Maketable Fruit Yield
(%)
Relative yield %
100
80
60
40
20
0
77
85
100
48
24
47
46
23
MSM
ASD RB6
ASD RB9
GS
2014 season (as of 5/23)
2015 season (as of 4/24)


Soil pH (1:1)
(0 to 6 inch depth. Mean ± SEM)
2013-14 season
2014-15 season
8.5
8.0
7.5
7.0
6.5
6.0
pH (1:1)
MSM2 -> MSM2.5
ASDRB3+MSM2 -> ASDRB6
ASDRB9
Growers standard
ASD treatment
Aug-13
Nov-13
Feb-14
May-14
Aug-14
Nov-14
Feb-15
Sampling date

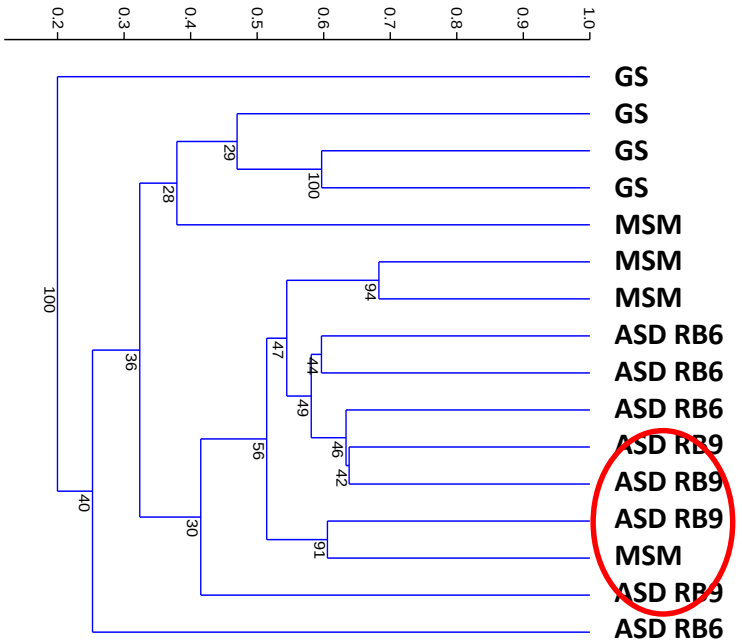
1)



2)



3)

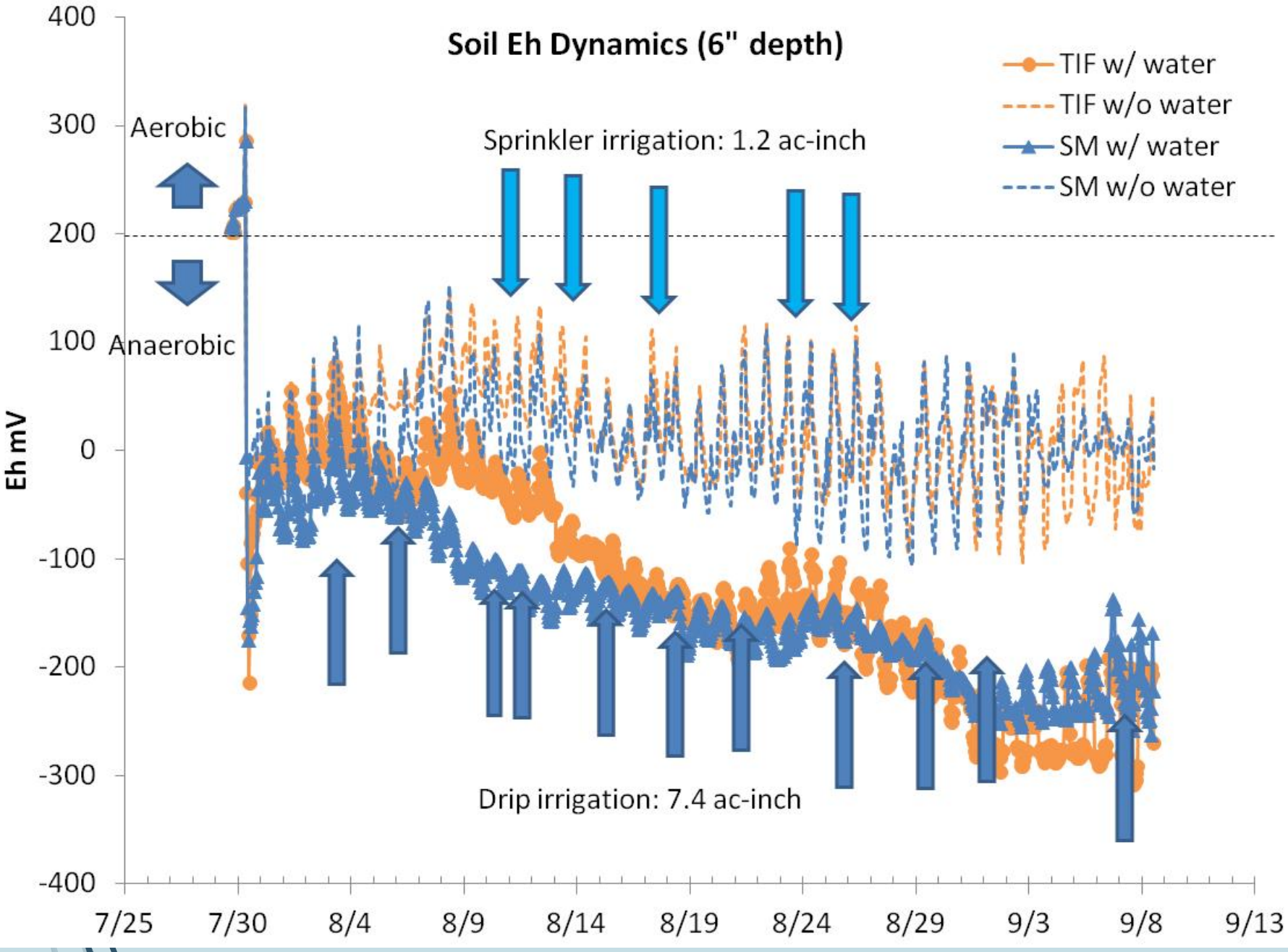


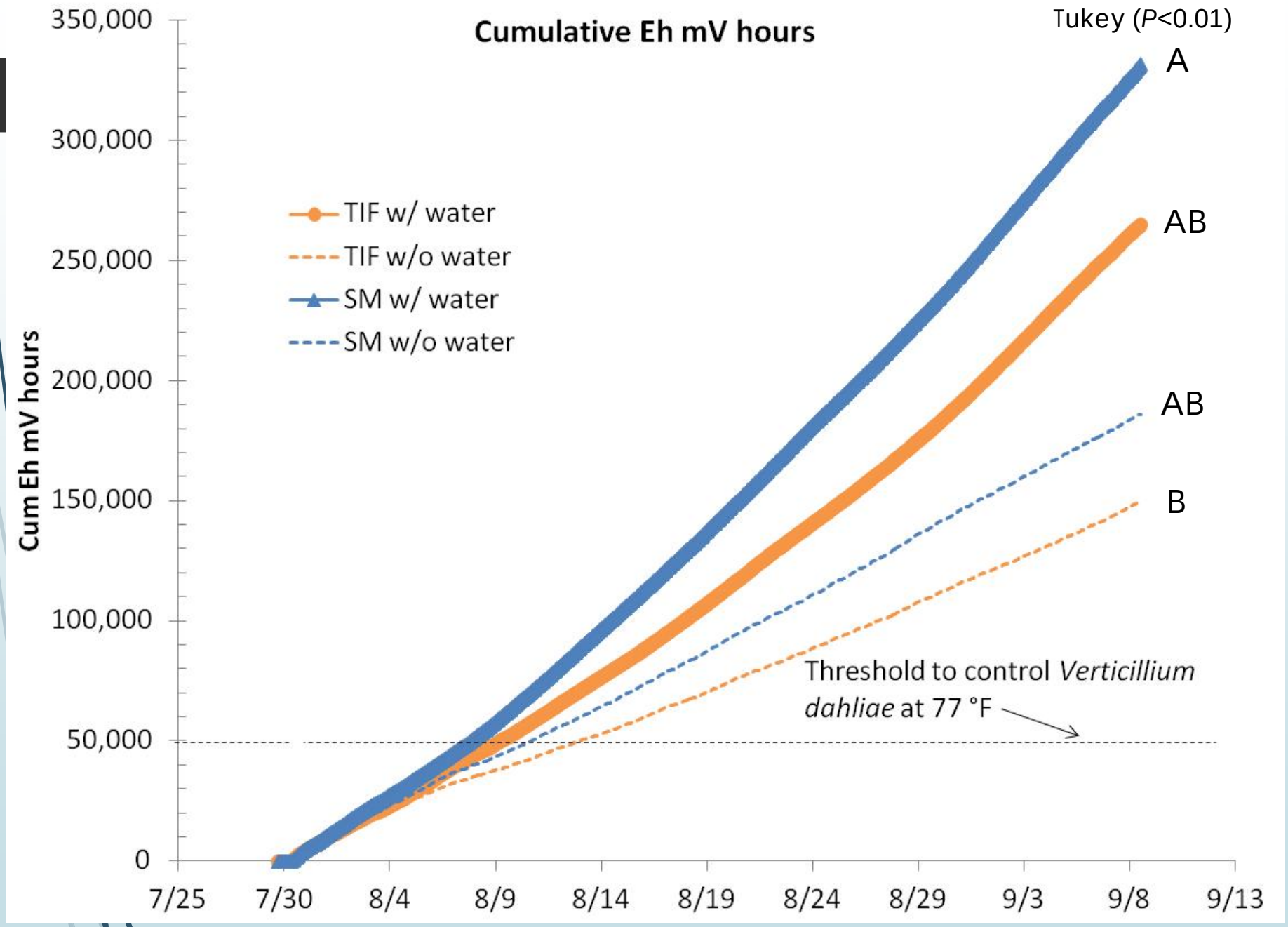
Oxnard Fungal community similarity;
ITS T-RFLP data;

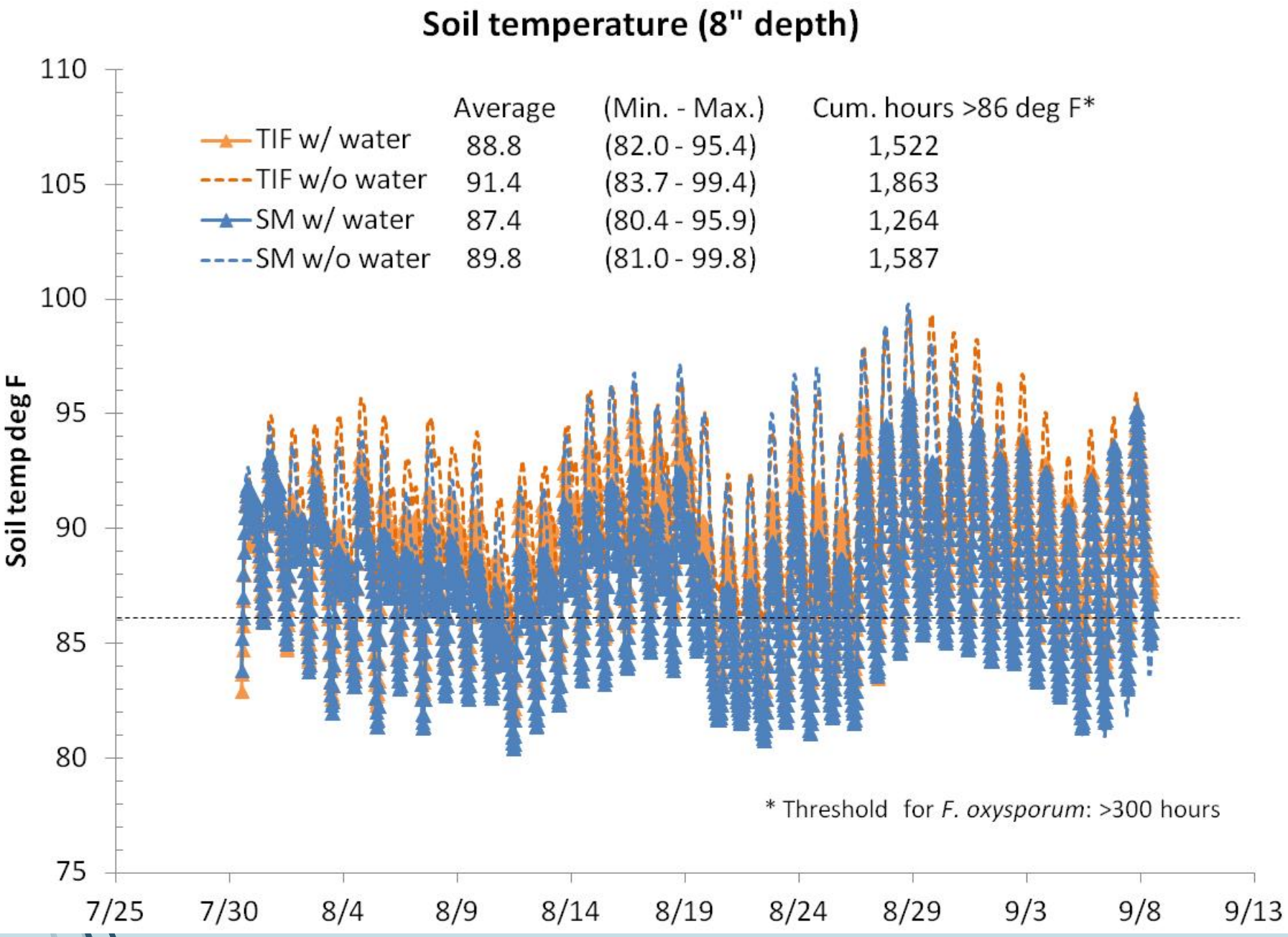
1) Oct. 2013 (post-treatment),
2) Aug. 2014 (pre-treatment), and
3) Sep. 2014 (post-treatment)

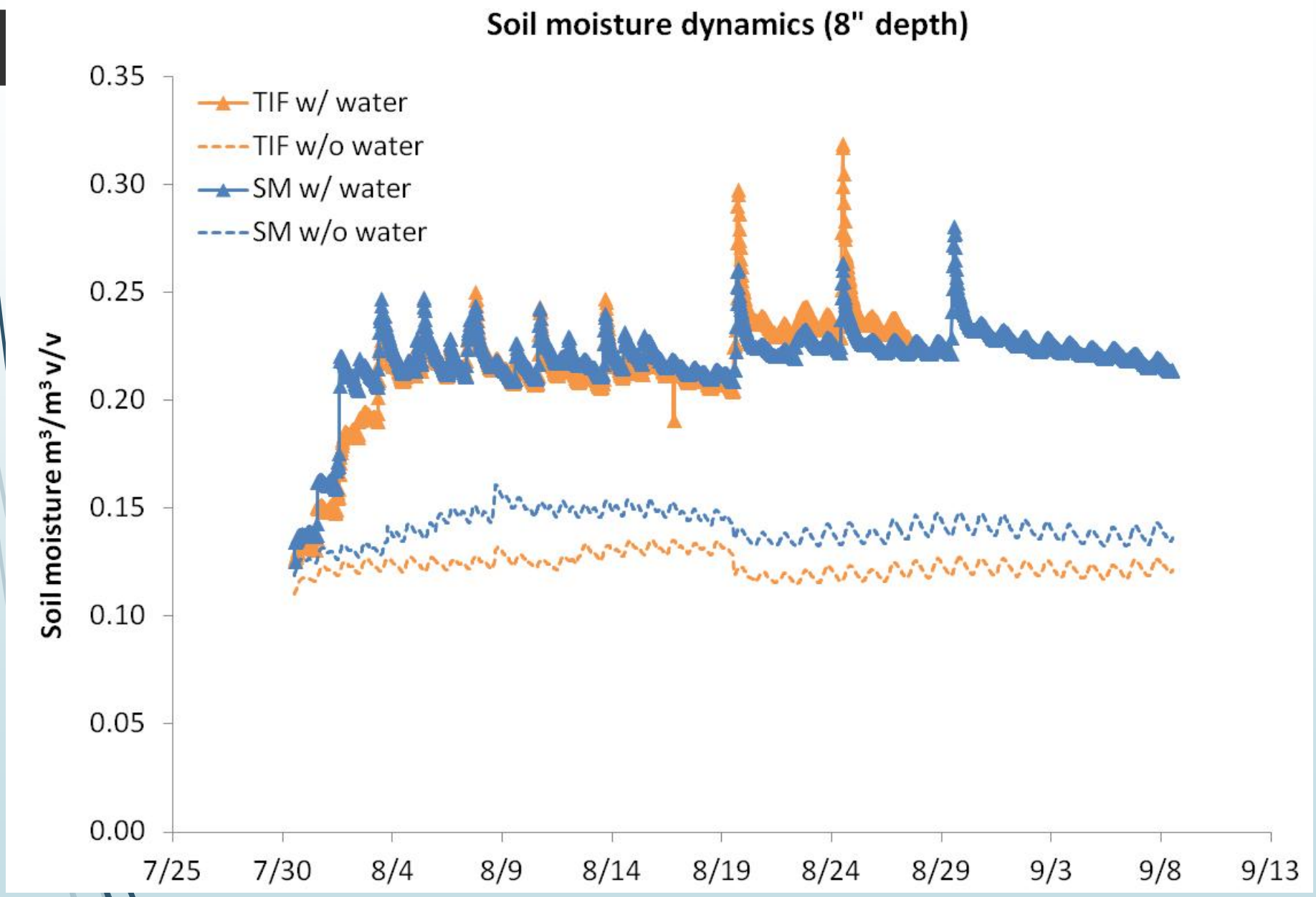
ASD: Oxnard trials 2015-16

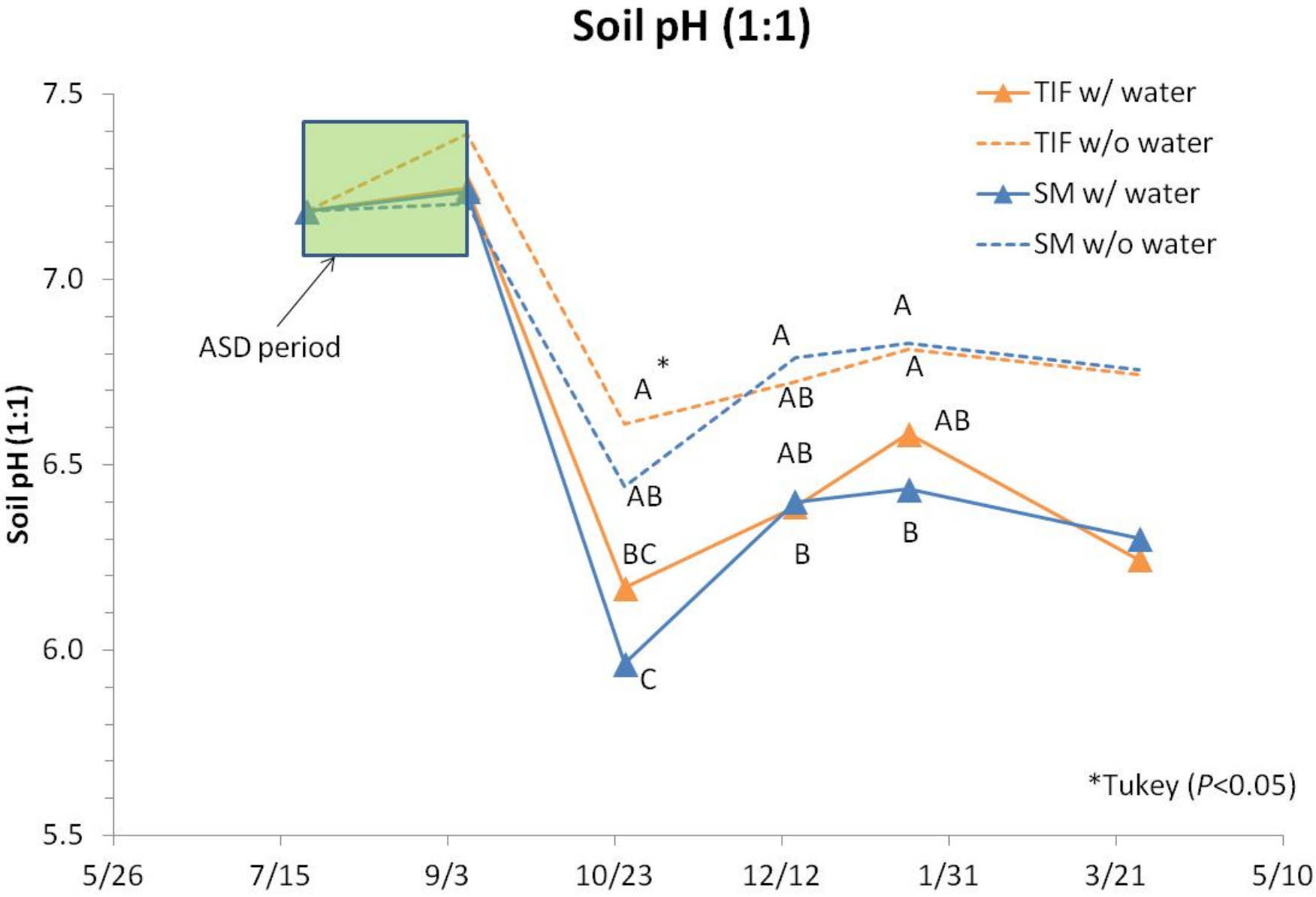
- Tarp-Water trial
  - Completely randomized block design with 5 replications
  - Type of tarp: Standard black tarp vs. TIF black
  - Water for ASD: regular vs. no water
  - 300'-476' long x 2 bed wide per plot
  - Monitoring soil Eh, temp, pH (1:1), EC (1:1), Inorganic N, soil pathogens, soil microbial community analysis (0"-6" depth soil),
  - plant mortality, plant diameter (future)

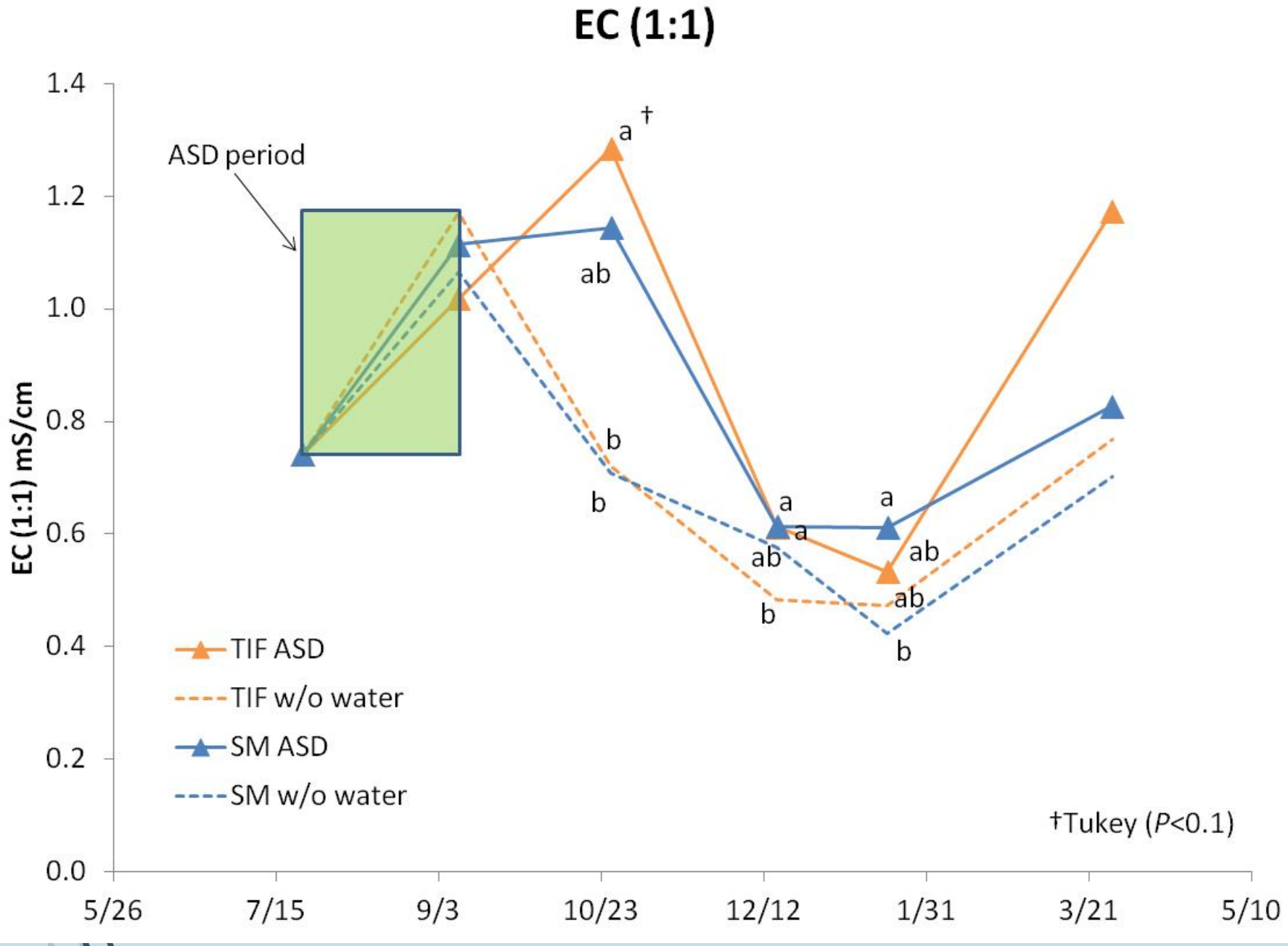

Soil Eh Dynamics (6" depth)
TIF w/ water
TIF w/o water
SM w/ water
SM w/o water
Aerobic
Anaerobic
Sprinkler irrigation: 1.2 ac-inch
Drip irrigation: 7.4 ac-inch
Eh mV
400
300
200
100
0
-100
-200
-300
-400
7/25
7/30
8/4
8/9
8/14
8/19
8/24
8/29
9/3
9/8
9/13

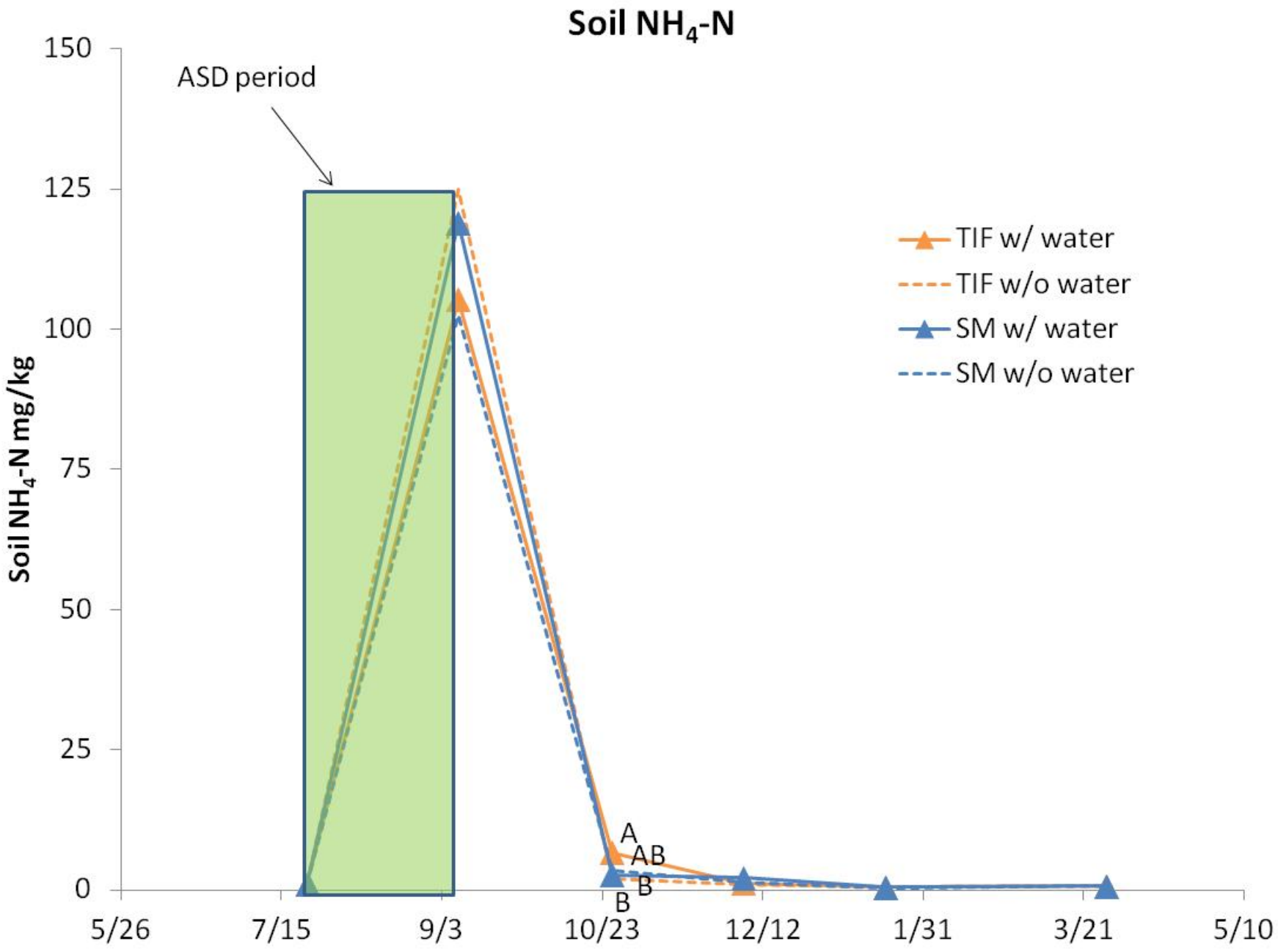

Cumulative Eh mV hours
Tukey (P<0.01)
A
AB
AB
B
TIF w/ water
TIF w/o water
SM w/ water
SM w/o water
Cum Eh mV hours
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
7/25
7/30
8/4
8/9
8/14
8/19
8/24
8/29
9/3
9/8
9/13
Threshold to control Verticillium dahliae at 77 °F

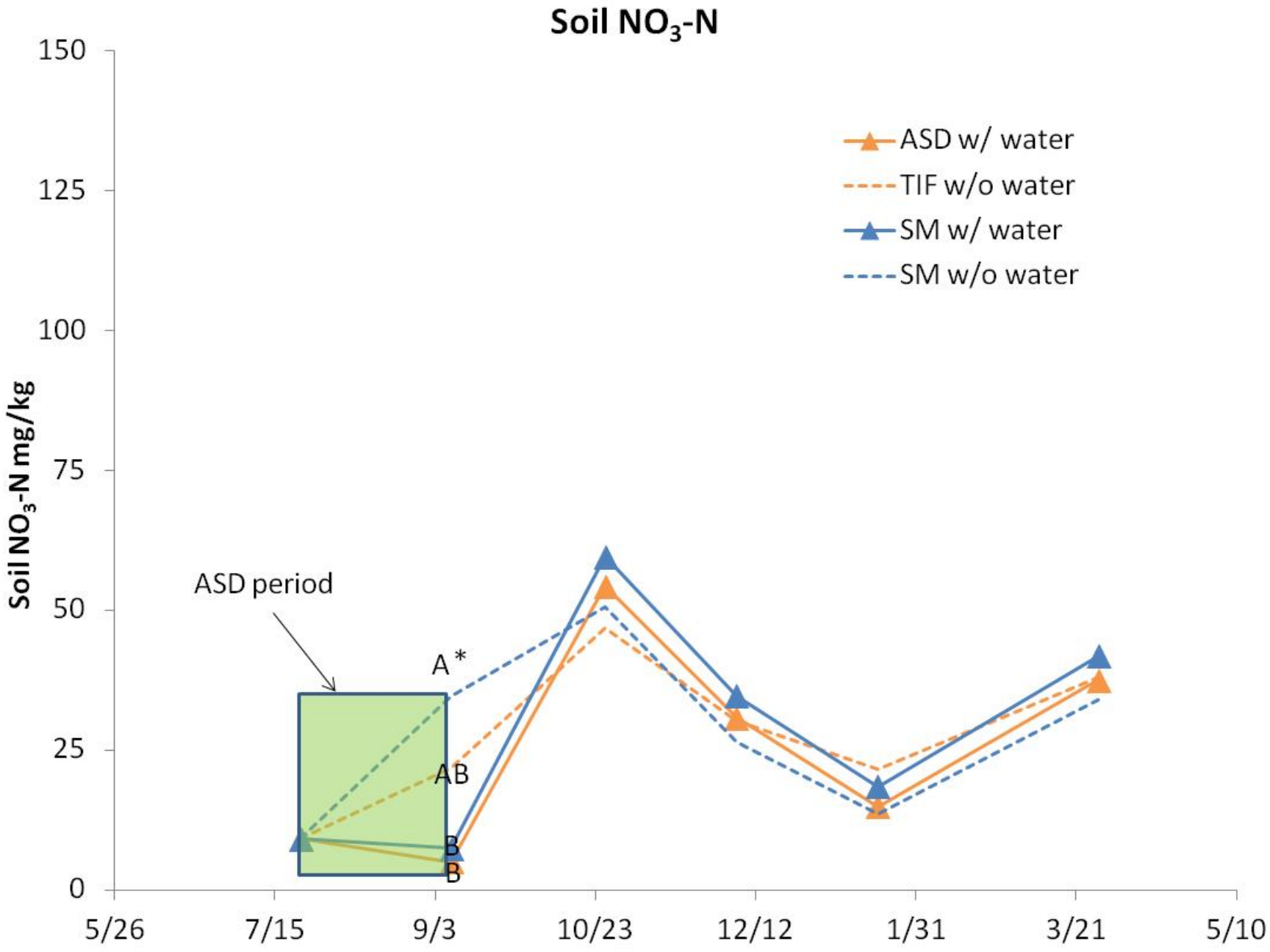

Soil temperature (8" depth)
Average
(Min. - Max.)
Cum. hours >86 deg F*
TIF w/ water 88.8 (82.0 - 95.4) 1,522
TIF w/o water 91.4 (83.7 - 99.4) 1,863
SM w/ water 87.4 (80.4 - 95.9) 1,264
SM w/o water 89.8 (81.0 - 99.8) 1,587
Soil temp deg F
110
105
100
95
90
85
80
75
7/25
7/30
8/4
8/9
8/14
8/19
8/24
8/29
9/3
9/8
9/13
* Threshold for F. oxysporum: >300 hours

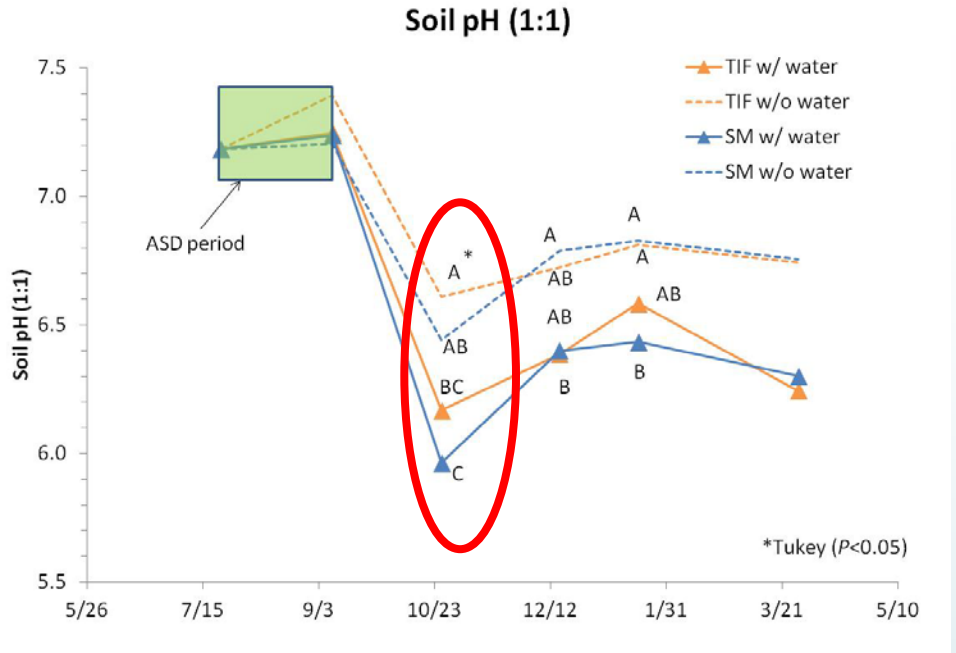

Soil moisture dynamics (8" depth)
TIF w/ water
TIF w/o water
SM w/ water
SM w/o water
Soil moisture m³/m³ v/v
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
7/25
7/30
8/4
8/9
8/14
8/19
8/24
8/29
9/3
9/8
9/13

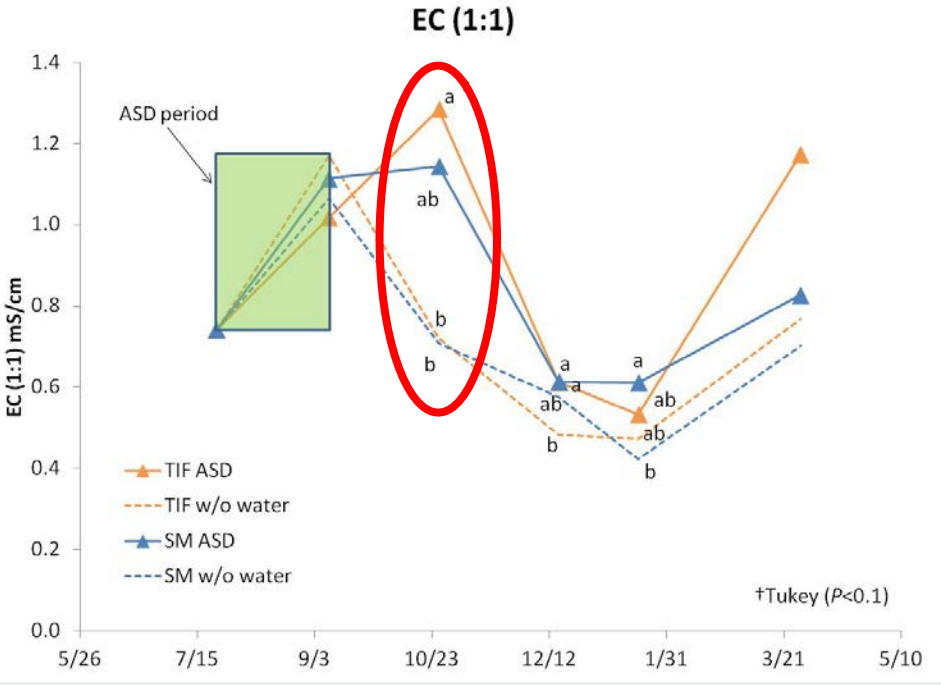

Soil pH (1:1)
TIF w/ water
TIF w/o water
SM w/ water
SM w/o water
ASD period
Soil pH (1:1)
7.5
7.0
6.5
6.0
5.5
5/26
7/15
9/3
10/23
12/12
1/31
3/21
5/10
A
*
A
AB
A
A
AB
AB
BC
B
B
C
*Tukey (P<0.05)

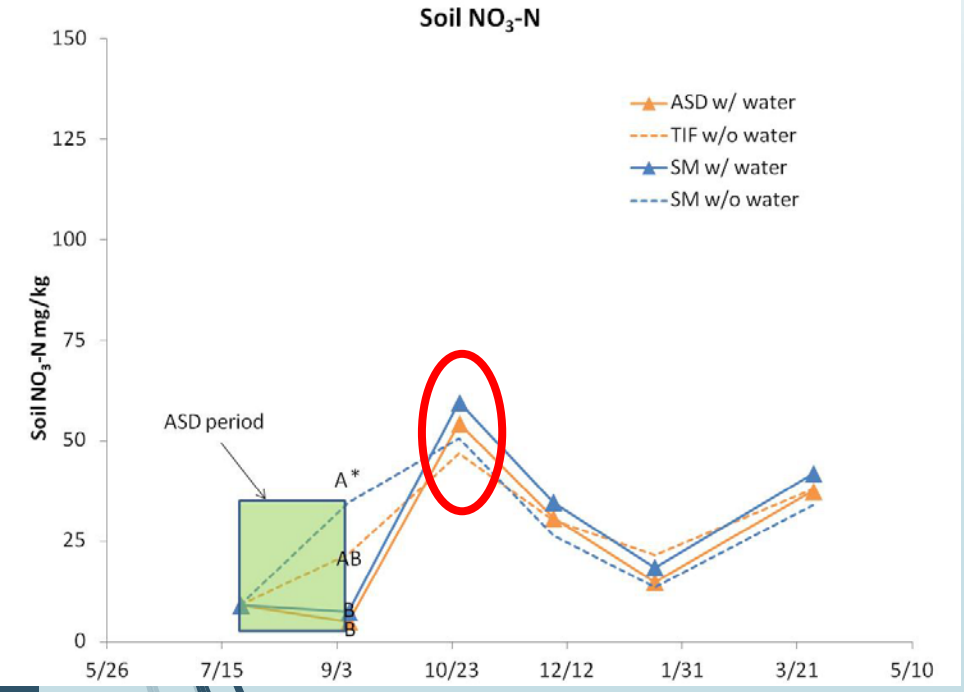

EC (1:1)
EC (1:1) mS/cm
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ASD period
a †
ab
b
b
a
a
a
ab
ab
ab
b
b
TIF ASD
TIF w/o water
SM ASD
SM w/o water
†Tukey (P<0.1)
5/26
7/15
9/3
10/23
12/12
1/31
3/21
5/10


Soil NH4-N
ASD period
150
125
100
75
50
25
0
Soil NH4-N mg/kg
TIF w/ water
TIF w/o water
SM w/ water
SM w/o water
A
AB
B
B
5/26
7/15
9/3
10/23
12/12
1/31
3/21
5/10


Soil NO3-N
Soil NO3-N mg/kg
150
125
100
75
50
25
0
5/26
7/15
9/3
10/23
12/12
1/31
3/21
5/10
ASD w/ water
TIF w/o water
SM w/ water
SM w/o water
ASD period
A *
AB
B
B







Salt = Cation (+) + Anion (-)

Cations; Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+}
Anions; SO_4^{2-}, Cl^{-}, NO_3^{-}, HCO_3^{-}

Organic acids?
CH_3COO^{-} (acetic acid)
$CH_3CH_2COO^{-}$ (propionic acid)
$CH_3CH_2CH_2COO^{-}$ (butyric acid)
$CH_3CH(OH)COO^{-}$ (lactic acid)

TIF w/ water

TIF w/o water

SM w/ water

SM w/o water

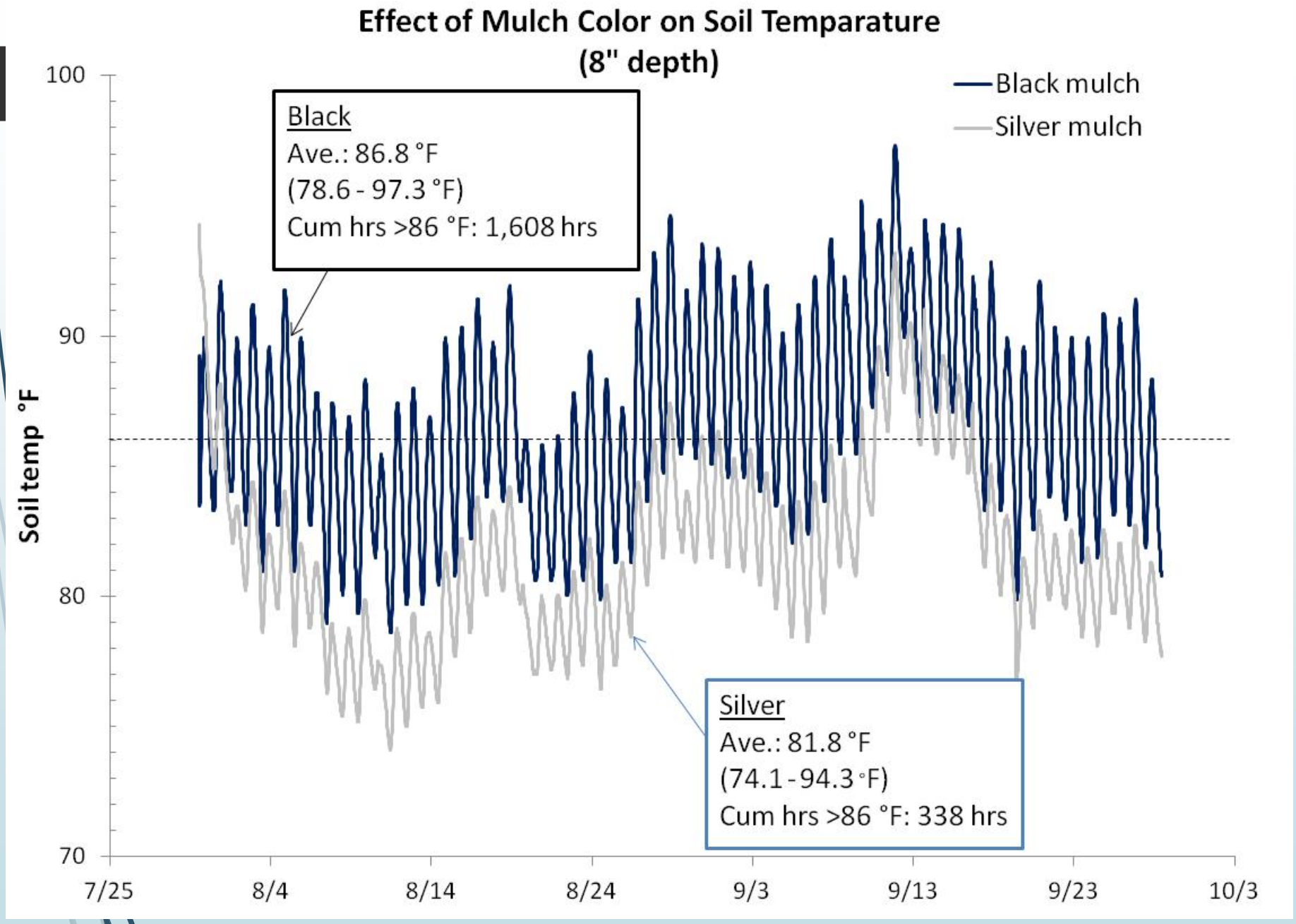
Oxnard Tarp/water experiment: Plant Growth (4/21/2016)

ASD: Oxnard trials 2015-16

- C-source trial
  - Un-replicated demonstration trial
  - C-source:

    Rice bran 9t/ac vs.

    Grape pomace 9t/ac + pre-plant fertilizer 12-12-2.5 2,000 lb/ac
    - Mulch: black vs. silver (sub-trial. Rice bran plot only)
  - 1 acre each
  - Monitoring soil Eh, temp, pH (1:1), EC (1:1), Inorganic N, soil pathogens, soil microbial community analysis, plant mortality, plant diameter


Effect of Mulch Color on Soil Temparature
(8" depth)
Black mulch
Silver mulch
Black
Ave.: 86.8 °F
(78.6 - 97.3 °F)
Cum hrs >86 °F: 1,608 hrs
Silver
Ave.: 81.8 °F
(74.1 - 94.3 °F)
Cum hrs >86 °F: 338 hrs
Soil temp °F
100
90
80
70
7/25
8/4
8/14
8/24
9/3
9/13
9/23
10/3

Black mulch
ASD rice bran 9t/ac

Silver mulch
ASD rice bran 9t/ac

(4/21/2016)

ASD 2.0-Future studies and challenges-

- **Controlling Fusarium wilt and Macrophomina charcoal rot**
  - Fall planting in Watsonville/Salinas area with low temperature
- **Reduced water use**
  - From ~3 acre-inches to <1.5 acre-inches by conserving soil moisture at bed listing
  - Depending on soil type---even sandy loam soil can work!
- **Evaluate the environmental impacts**
  - N_2O emission and NO_3 leaching ….depending on soil residual NO_3 level
  - Recycling by summer cover crop, immobilization by high C/N organic amendment application
- **New C-source recipes**
  - Grape pomace, almond hull, grass hey, summer cover crop (Sudan grass), wheat bran, rice bran…..in combination
  - Reduced costs and improved consistency
- **Understanding mechanisms**
  - Chemical, **biological**, physical

Questions?

joji@ucsc.edu