Anaerobic Soil Disinfestation (ASD)

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Outline

1. Background
2. Mechanisms
3. Project goal
4. Approach
5. Results from lab studies and three on-farm trials

ASD: Background

- Developed as ecological alternative to methyl bromide fumigation in Netherlands (Blok et al., 2000; Doug et al., 2004) and Japan (Shinmura and Sakamoto, 1998; Shinmura, 2000 , 2004)
- Integrates principles of solarization and flooding
  - Can be used where solarization or flooding is not feasible
- Controls a range of soilborne pathogens and nematodes across a range of crops
- In Japan, it is used by hundreds of farmers in greenhouse production (small scale)

ASD: Target Pests and Crops

- *Soil-borne pathogen*
  - *Verticillium dahliae*[1,2]
  - *Fusarium oxysporum*[1,2]
  - *Fusarium redolens*[2]
  - *Ralstonia solanacearum*[2]
  - *Rhizoctonia solani*[1]
- *Nematode*
  - *Meloidogyne incognita*[1]
  - *Pratylenchus fallax*[2]
- *Weed*
  - *Nutsedge*[3]

- Crops tested
  - Welsh onion[2]
  - Tomatoes[2]
  - Strawberries[2]
  - Eggplant[2, 3]
  - Spinach[2]
  - Peppers[3]
  - Maple[1]
  - Catalpa[1]

[1]: Dutch studies [2]: Japanese studies [3]: Florida studies

ASD: Three Steps

1. Incorporate organic material

   → **Provide C source for soil microorganisms**

2. Irrigation

   → **Saturate soil pores with water**

3. Cover with plastic mulch

   → **Limit O_2 supply, and maintain the soil water condition above the field capacity and anaerobic decomposition in the soil**

ASD: Recipe for Success
(Shinmura 2004)

- Soil temp: at or above 30 °C (= 86 F)
- Incorporate 4.5 tons/acre of rice (or wheat) bran thoroughly into the soil
- Cover the soil surface with plastic tarp
- Retain soil water content above the field capacity during the treatment (no flooding)

ASD: Mechanisms (1)

- Accumulation of toxic products under anaerobic decomposition (e.g. organic acids, volatiles)
  - After 72 hours of ASD, 12 mM of acetic acid

    → Exceeding LC50 of acetic acid *(5.6 mM)* on *Meloidogyne incognita*

    (Katase et al., 2009)

ASD: Mechanisms (2)

- Biocontrol by anaerobic microorganisms
- Low pH
- Lack of oxygen
- Combination of all of these
- Biochemical (not physical)

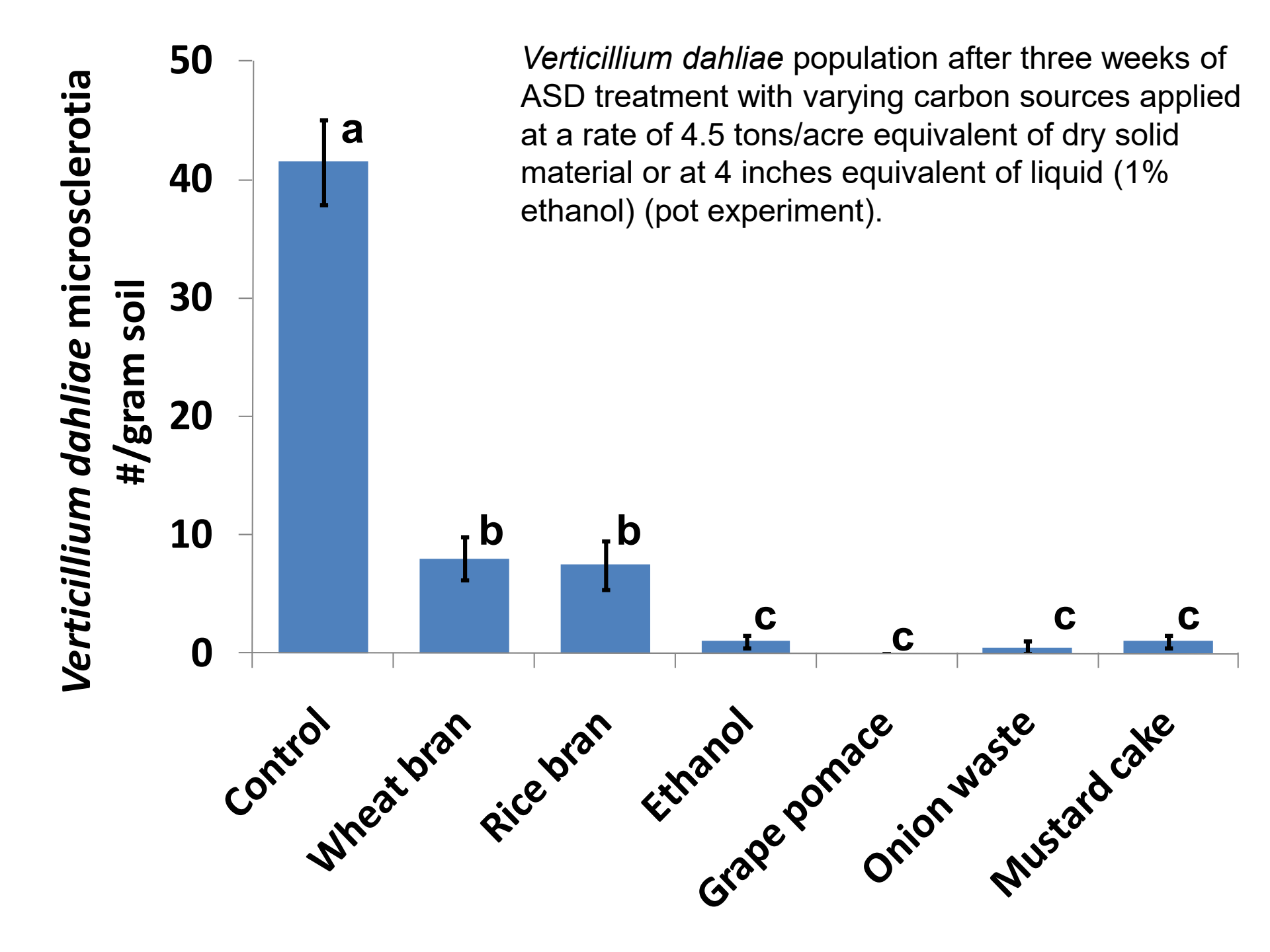
ASD: Project Goal

- To optimize **ASD** as an **economic alternative to MeBr** for **strawberry growers on coastal California**

  - 2007-2009: optimization
  - 2009-2010: optimization and evaluation (comparison with MeBr. in progress)

ASD: Approach

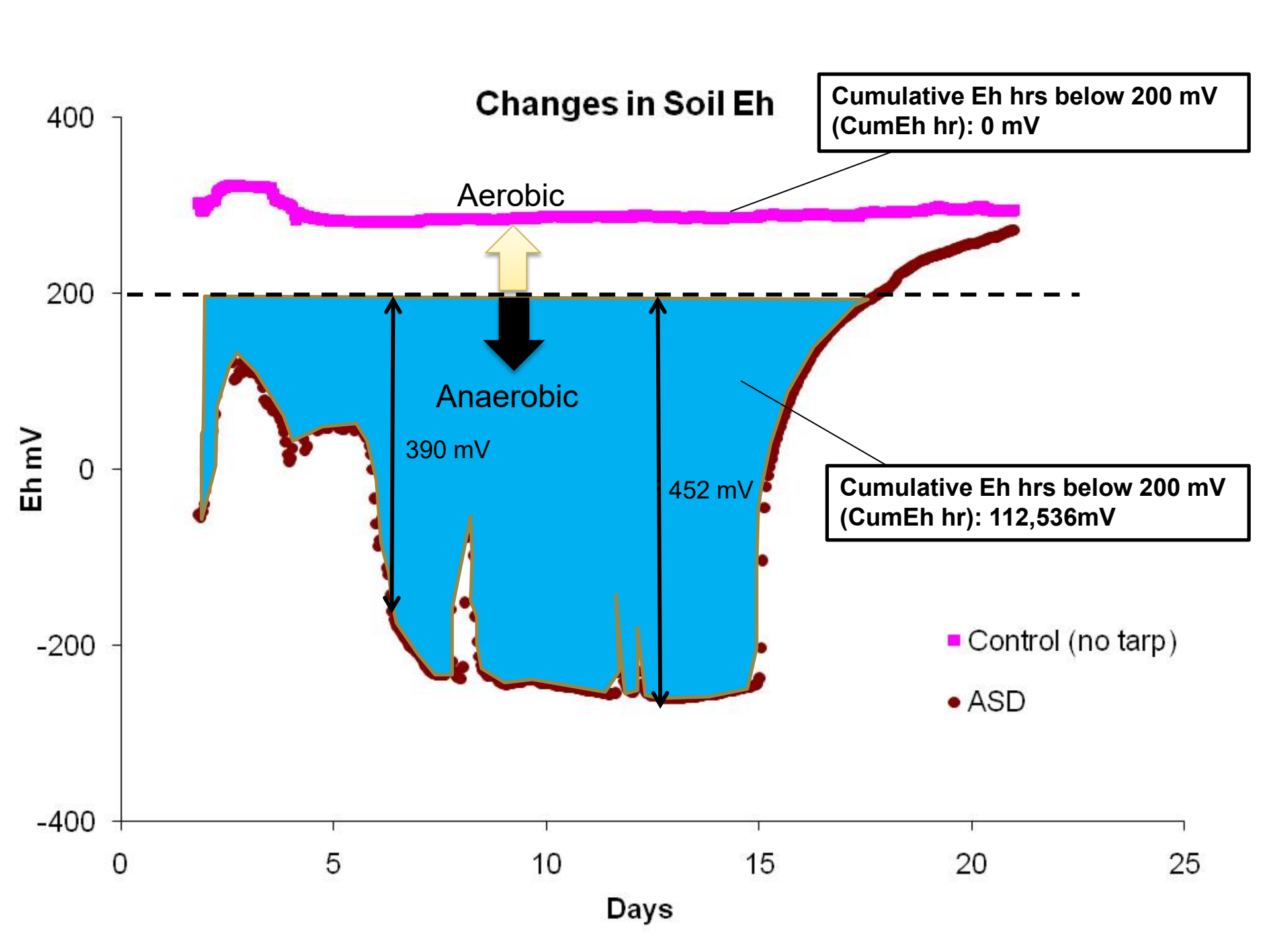
- Bed treatment (rather than flat treatment)
  - Easier to fit to current strawberry systems
  - Less use of plastic
- *Verticillium dahliae* as a target pest
  - The key pathogen for strawberries in coastal CA
- A series of pot experiments, and on-farm trials in Watsonville, Salinas, and Ventura
  - C-sources, irrigation scheme, tarp type
  - Soil temp, Eh, water content, fruit yield, weed biomass

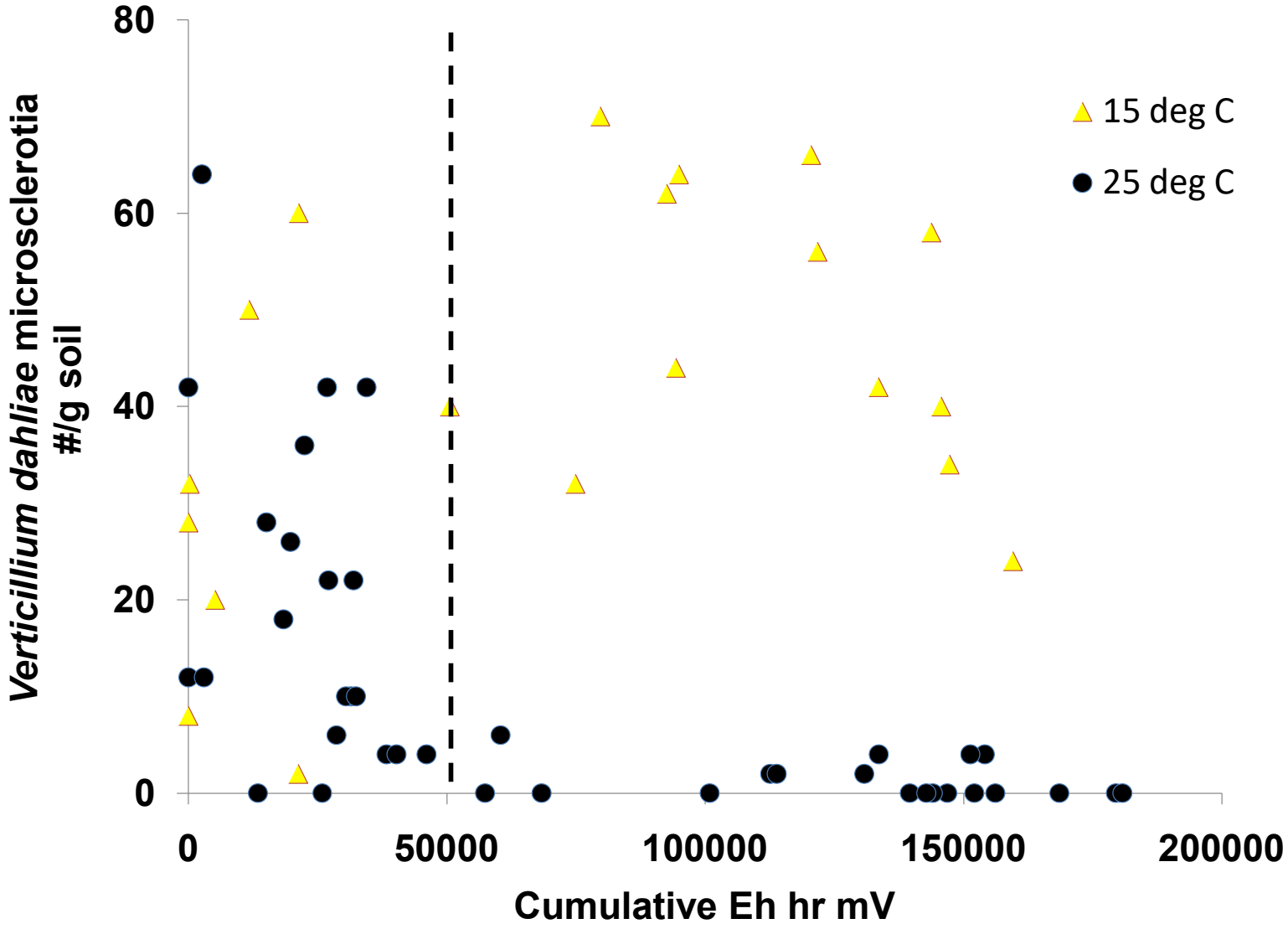

Verticillium dahliae population after three weeks of ASD treatment with varying carbon sources applied at a rate of 4.5 tons/acre equivalent of dry solid material or at 4 inches equivalent of liquid (1% ethanol) (pot experiment).
Verticillium dahliae microsclerotia #/gram soil
50
40
30
20
10
0
a
b
b
c
c
c
c
Control
Wheat bran
Rice bran
Ethanol
Grape pomace
Onion waste
Mustard cake

Cost of organic materials for anaerobic soil disinfection

Organic material	Local price $/ton	Amount tons/acre	Cost $/acre
Rice bran (CA)*	$120	4.5 – 9.0	$540 - 980
Mustard cake (CA)**	$1,600	1	$1,600
Molasses (FL)	$115	5.4	$617
Cover crop seeds (FL, TN)	~$1/lbs	33 - 78 lbs/acre	$33 -78
c.f. MeBr fumigation	-	-	$2,500-3,000

* Approximately 75,000 tons of rice bran is available annually in CA.
** Locally available in Watsonville, CA.


Changes in Soil Eh
Cumulative Eh hrs below 200 mV (CumEh hr): 0 mV
Aerobic
Anaerobic
390 mV
452 mV
Cumulative Eh hrs below 200 mV (CumEh hr): 112,536mV
Control (no tarp)
ASD
Eh mV
400
200
0
-200
-400
0
5
10
15
20
25
Days



Correlation between *Verticillium dahliae* population after three weeks of ASD treatment and cumulative Eh hr below 200 mV during the entire incubation period at 25 °C and 15°C (pot experiment).

On-Farm Trial in Salinas, CA (2008-09)

- **Clay loam soil** with **native *V. dahliae*: 20/gram soil**
- Randomized complete block design with 4 reps.

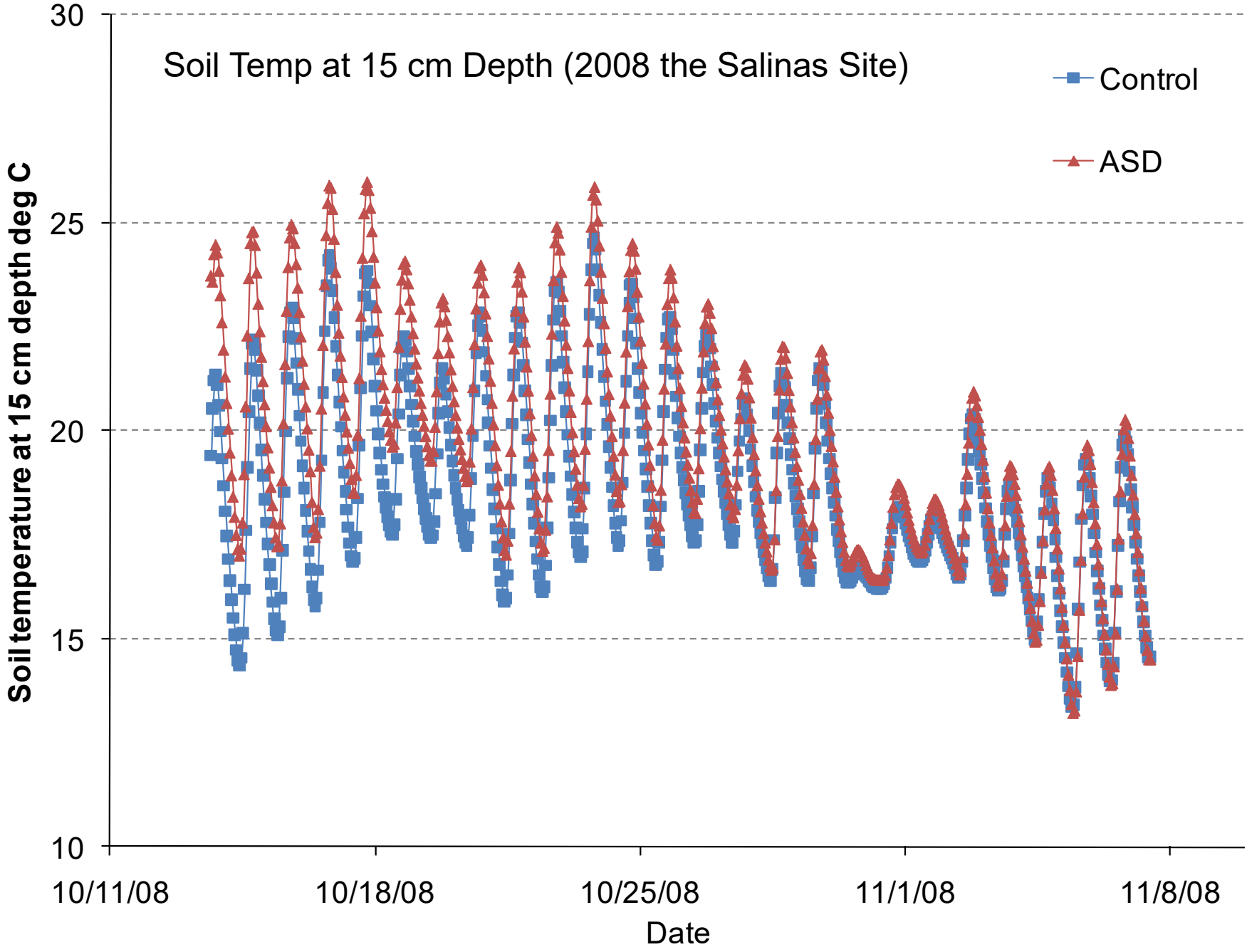
  Control (No C-source) and ASD (rice bran 4.5 tons/acre)
- Standard green plastic mulch (1.25 mil)
- **Irrigation: 11.5 acre-inches** intermittently applied
- **ASD treatment: 10/14/08 - 11/4/08 (3 weeks)**

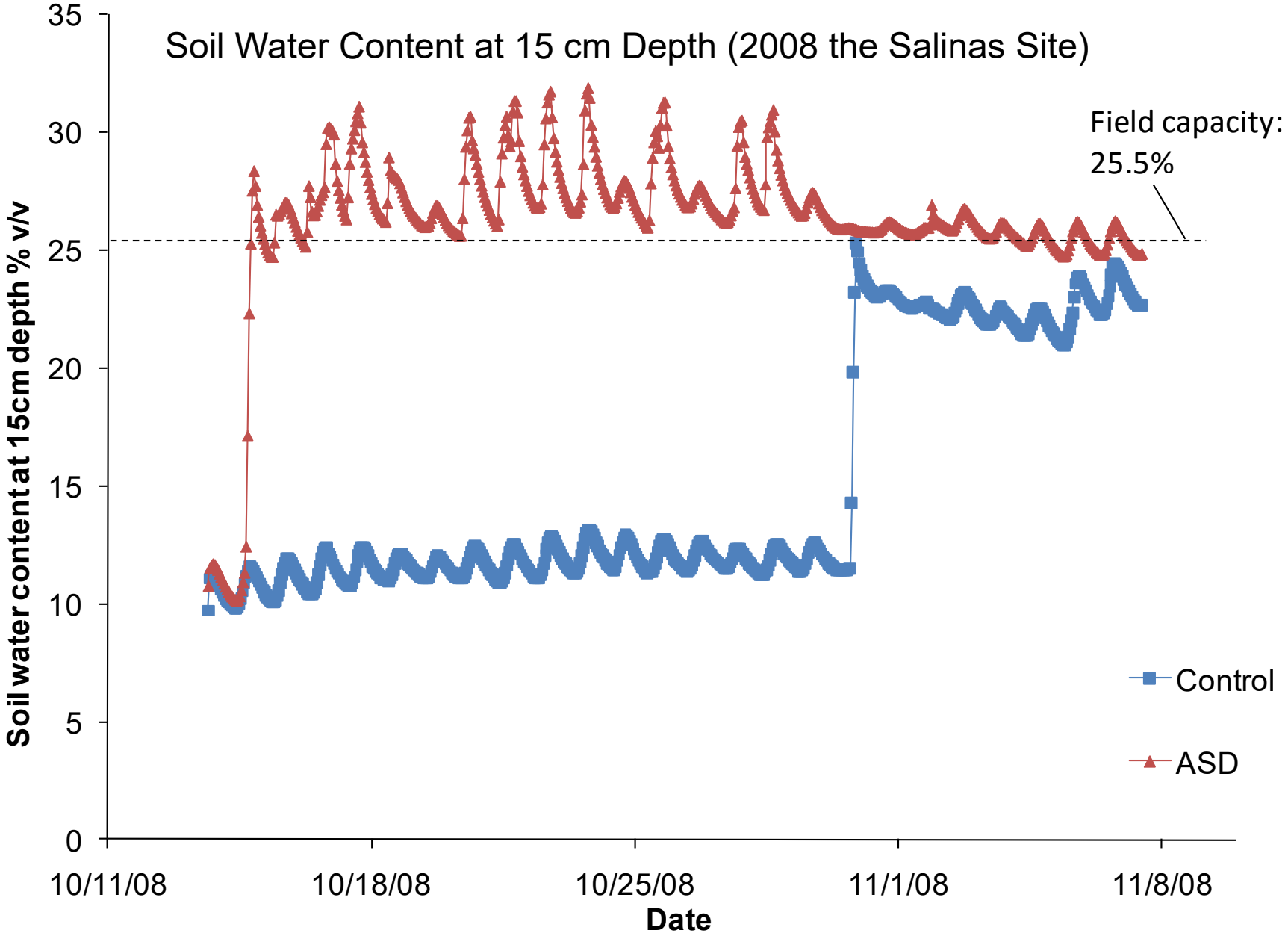

10/10/2008

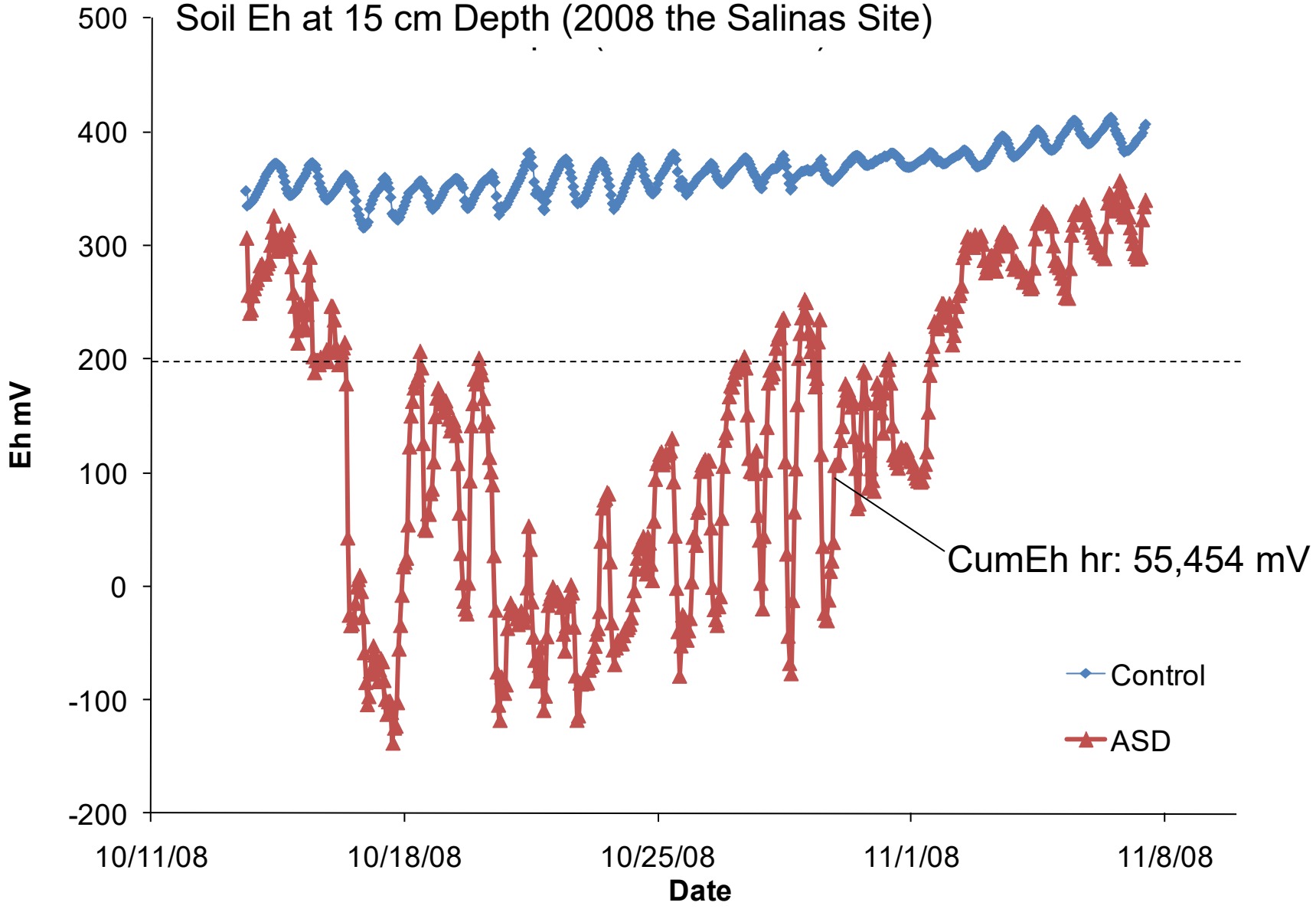

10/10/2008

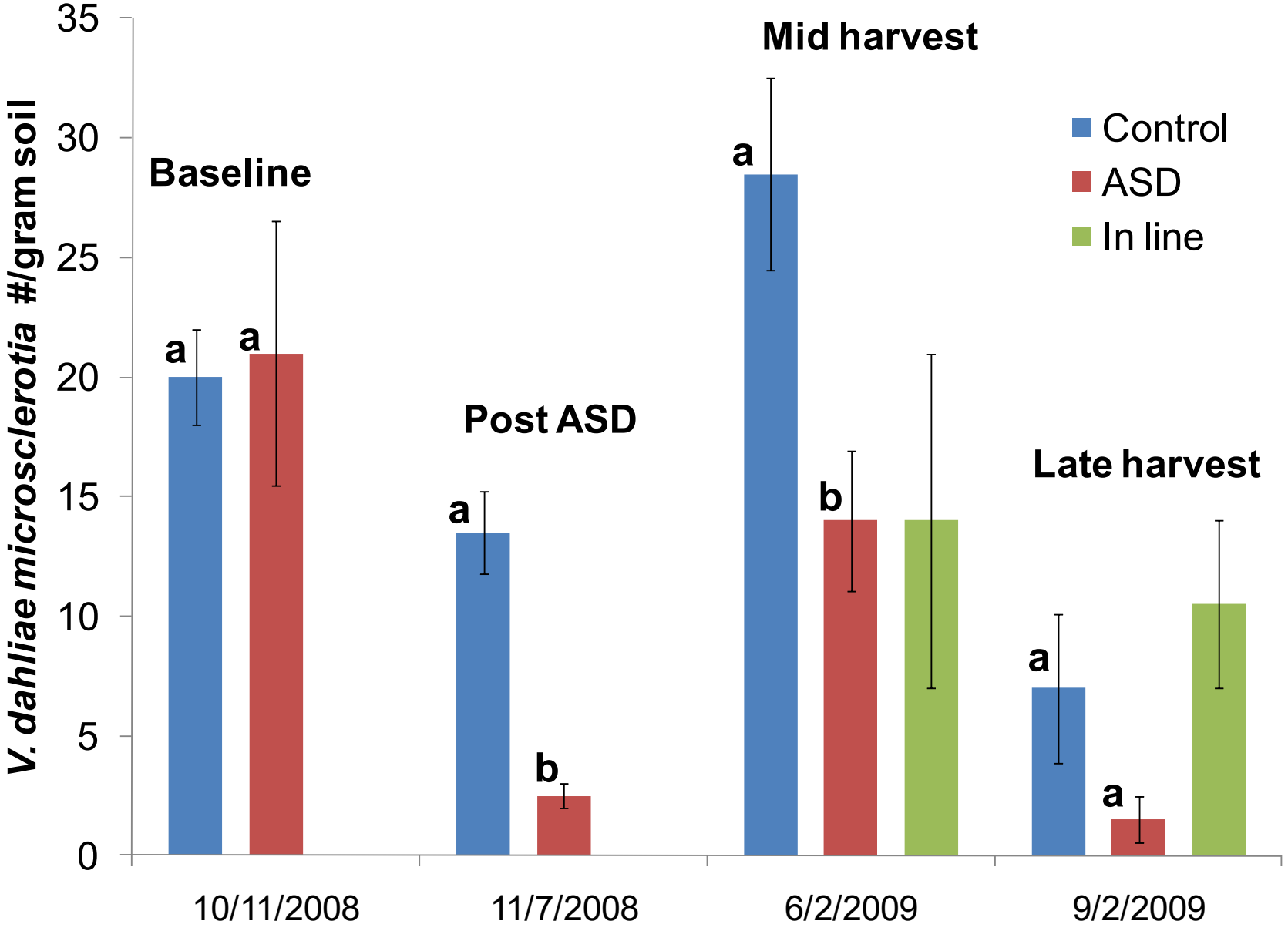

CATERPILLAR
10/11/2008


11/7/2008

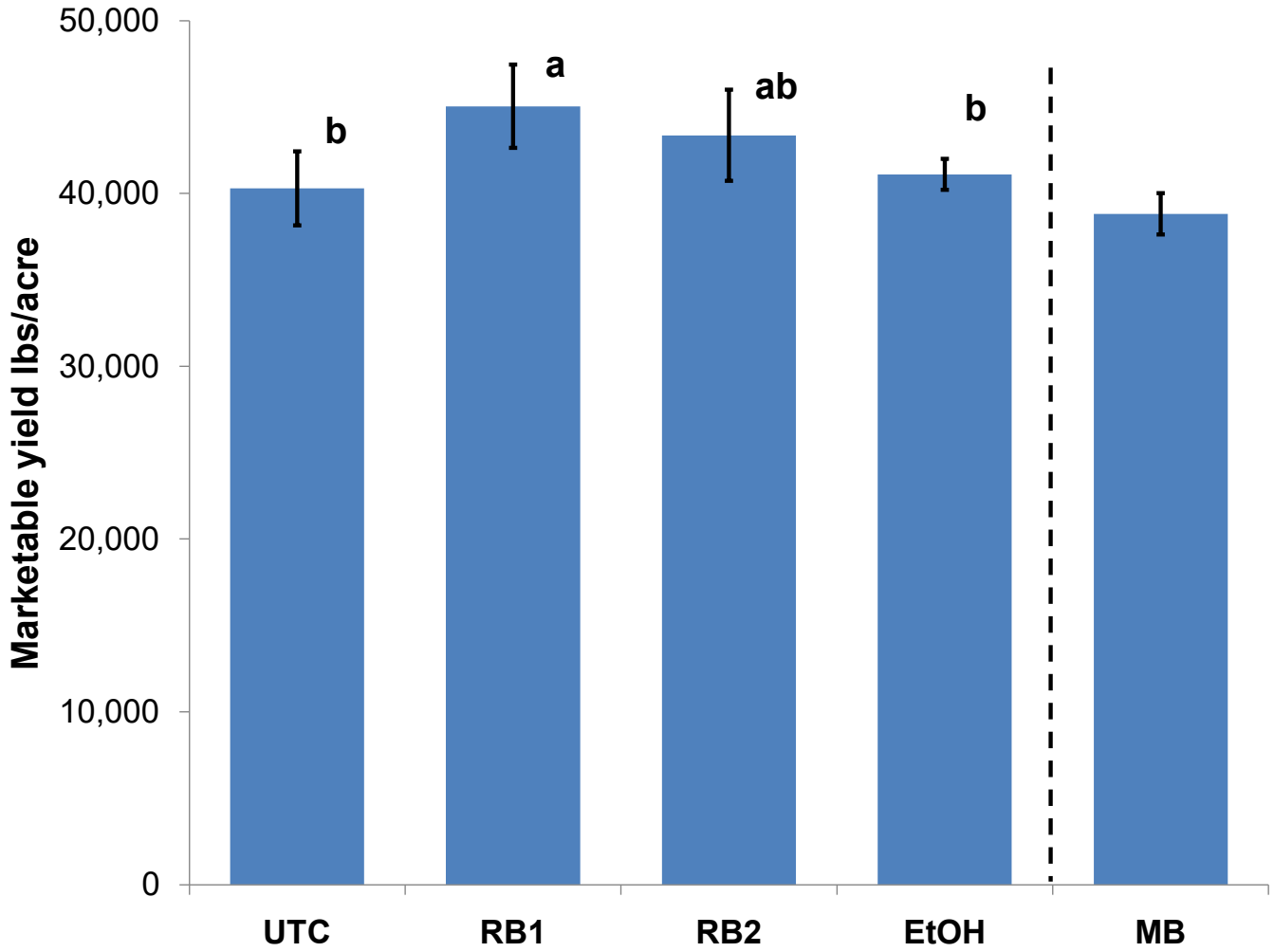

Soil Temp at 15 cm Depth (2008 the Salinas Site)
Control
ASD
Soil temperature at 15 cm depth deg C
30
25
20
15
10
10/11/08
10/18/08
10/25/08
11/1/08
11/8/08
Date


Soil Water Content at 15 cm Depth (2008 the Salinas Site)
Field capacity:
25.5%
Soil water content at 15cm depth % v/v
35
30
25
20
15
10
5
0
10/11/08
10/18/08
10/25/08
11/1/08
11/8/08
Date
Control
ASD


Soil Eh at 15 cm Depth (2008 the Salinas Site)
500
400
300
200
100
0
-100
-200
Eh mV
10/11/08
10/18/08
10/25/08
11/1/08
11/8/08
Date
CumEh hr: 55,454 mV
Control
ASD



Effect of ASD on native *Verticillium dahliae* population in soils in Salinas trial (2008-09). On 6/2/09 and 9/2/09, soils from surrounding In Line-treated field were also analyzed for *V. dahliae* population and data are shown for comparison.



Marketable fruit yield of strawberries from ASD experiment at the Moss Landing site (cultivar Anita. 2008-09). UTC: untreated check. RB1: rice bran 4.5 tons/acre, RB2: rice bran 9 tons/acre, and EtOH: Ethanol 1% 4 acre-inches equivalent. Data from surrounding methyl bromide fumigated area (MB. n=4) are shown for comparison. MB area has slightly clayey soil compared to the experimental site (sandy loam). Verticillium population in the soil was very low in this entire field.

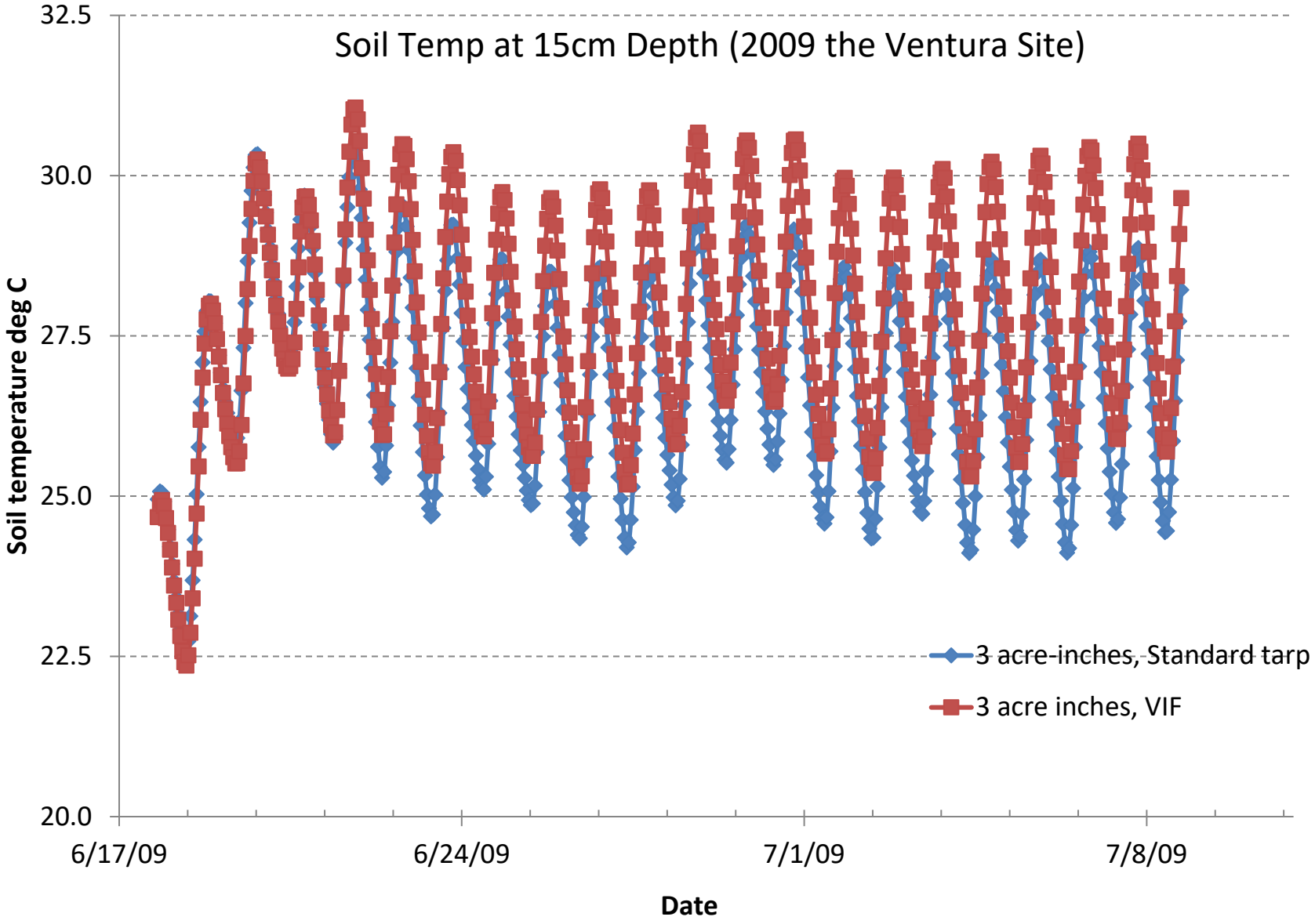
On-Farm Trial in Ventura, CA (2009)

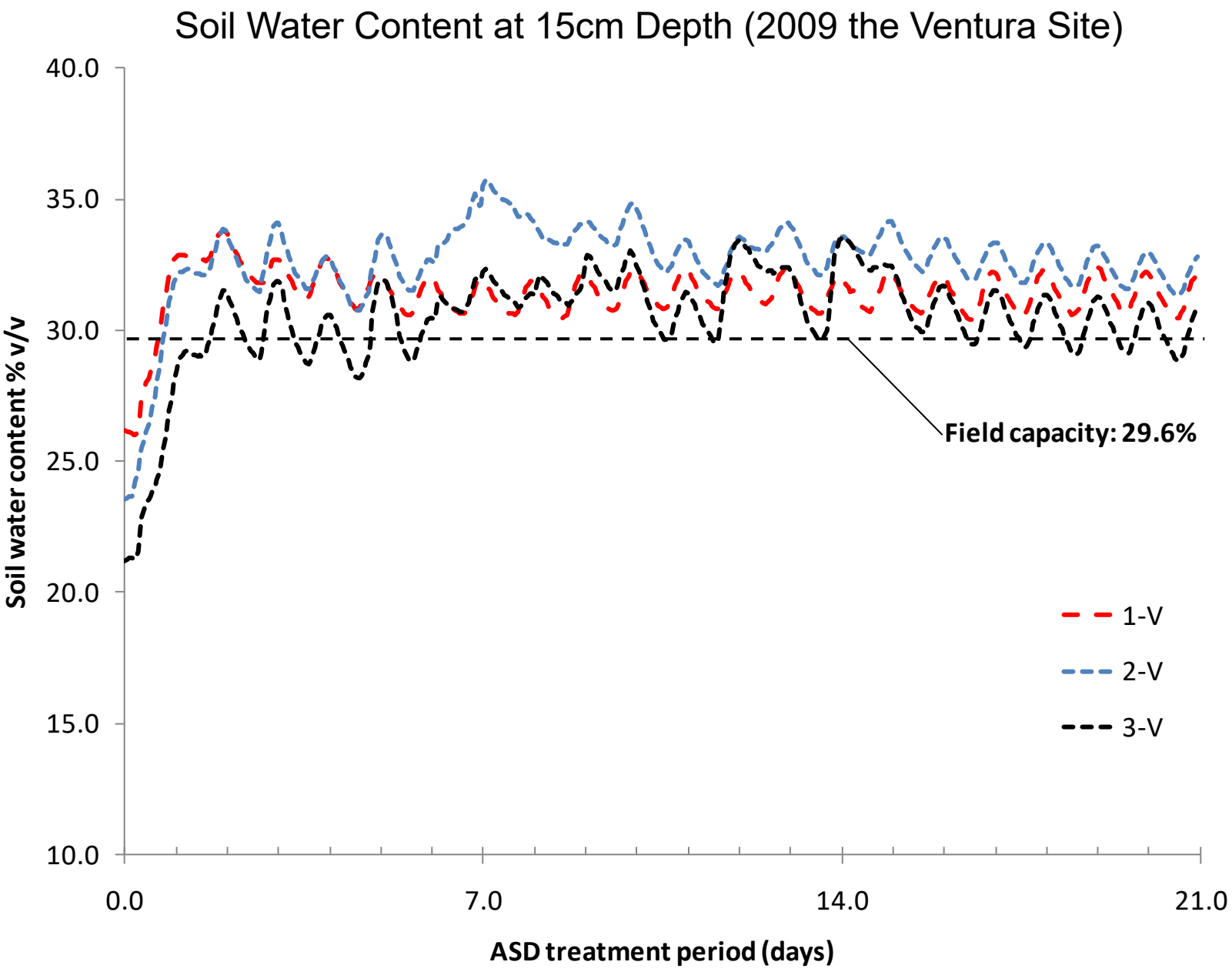
- UC Hansen Agricultural Center, Santa Paula.
- Silty clay loam soil with native *V. dahliae*: 33 /gram soil (a range of 19 – 43)
- Randomized block split design with 5 reps.

  Main plot: Irrigation rate (3, 8, and 16 acre inches)

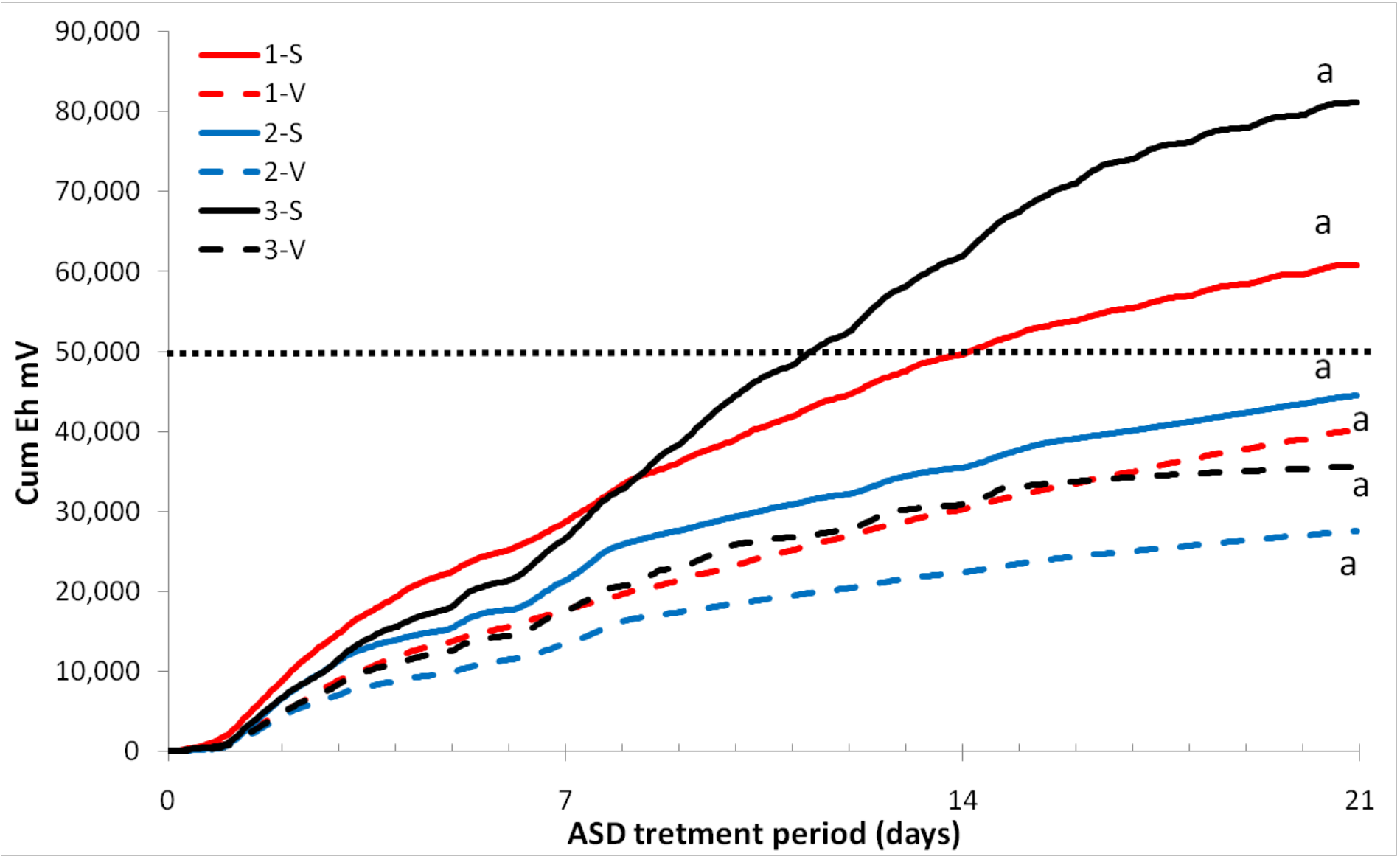
  Split plot: type of tarp (standard black 1.5 mil, and black VIF 1.25 mil)
- Rice bran 9 tons/acre at all plots.
- ASD treatment: 6/17/09 – 7/8/09 (3 weeks)

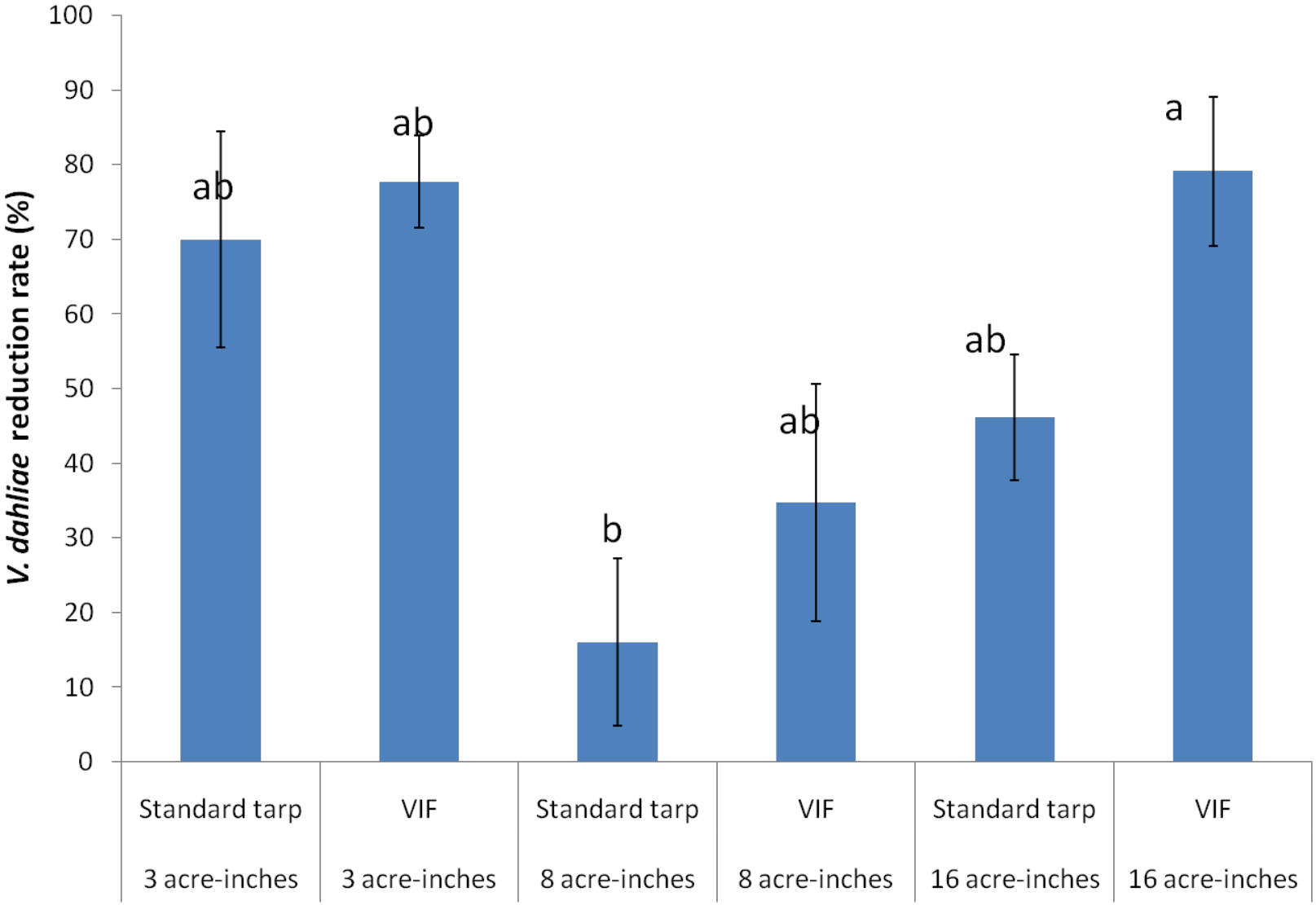

6/17/2009


Soil Temp at 15cm Depth (2009 the Ventura Site)
32.5
30.0
27.5
25.0
22.5
20.0
Soil temperature deg C
6/17/09
6/24/09
7/1/09
7/8/09
Date
3 acre-inches, Standard tarp
3 acre inches, VIF

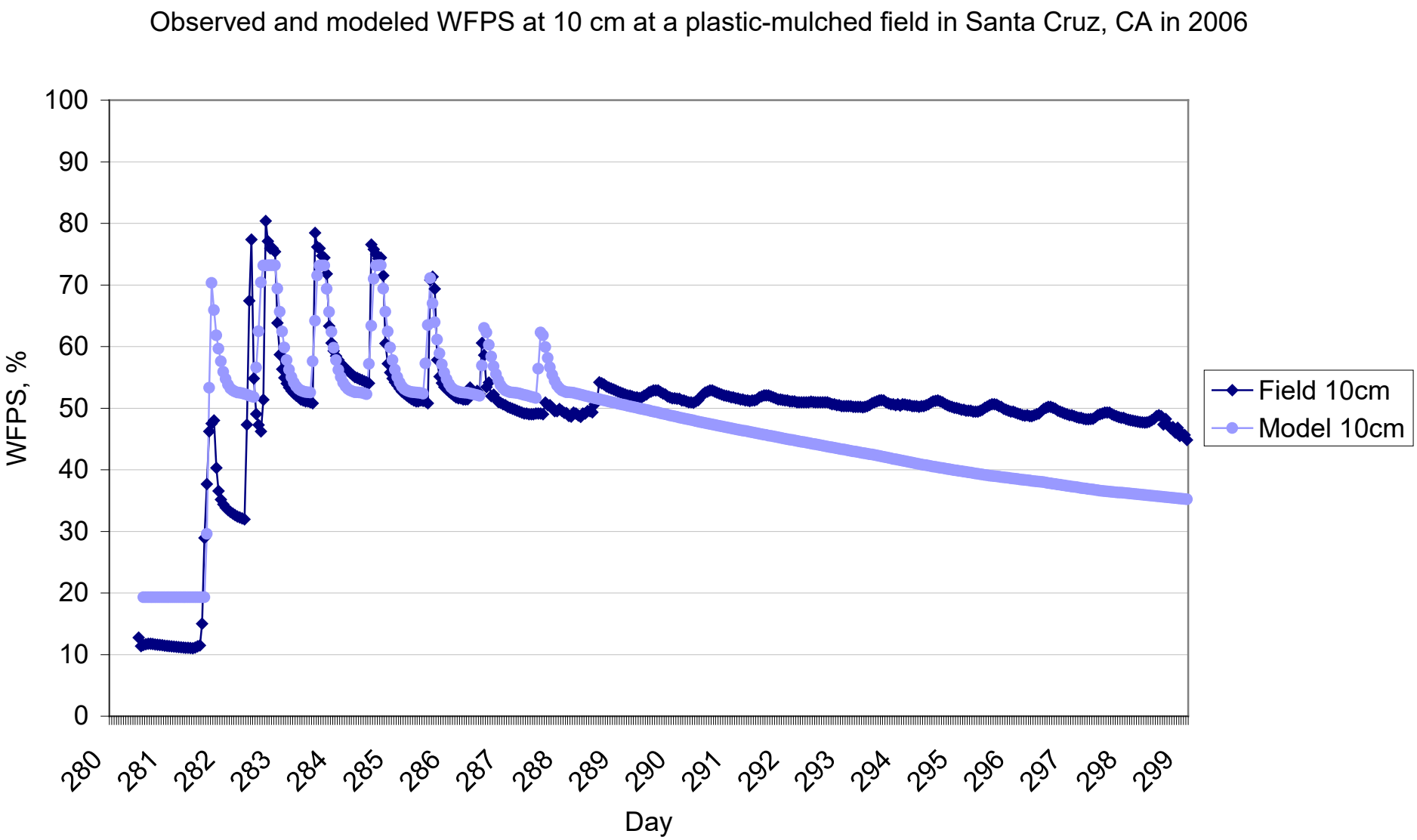

Soil Water Content at 15cm Depth (2009 the Ventura Site)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
Soil water content % v/v
0.0
7.0
14.0
21.0
ASD treatment period (days)
Field capacity: 29.6%
1-V
2-V
3-V

Cumulative Eh hr at 15 cm Depth (2009 the Ventura Site)





Effect of ASD on reduction rate of native *Verticillium dahliae* in soils in Ventura trial (2009). Baseline *V. dahliae* population in the soil at each treatment varied from 15 to 45 microsclerotia/gram soil.


Observed and modeled WFPS at 10 cm at a plastic-mulched field in Santa Cruz, CA in 2006
WFPS, %
100
90
80
70
60
50
40
30
20
10
0
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
Day
Field 10cm
Model 10cm

On-Farm Trial in Watsonville, CA (2009-10)

- Loam soil with native *V. dahliae*: 0 /gram soil
- Randomized block split design with 4 reps.

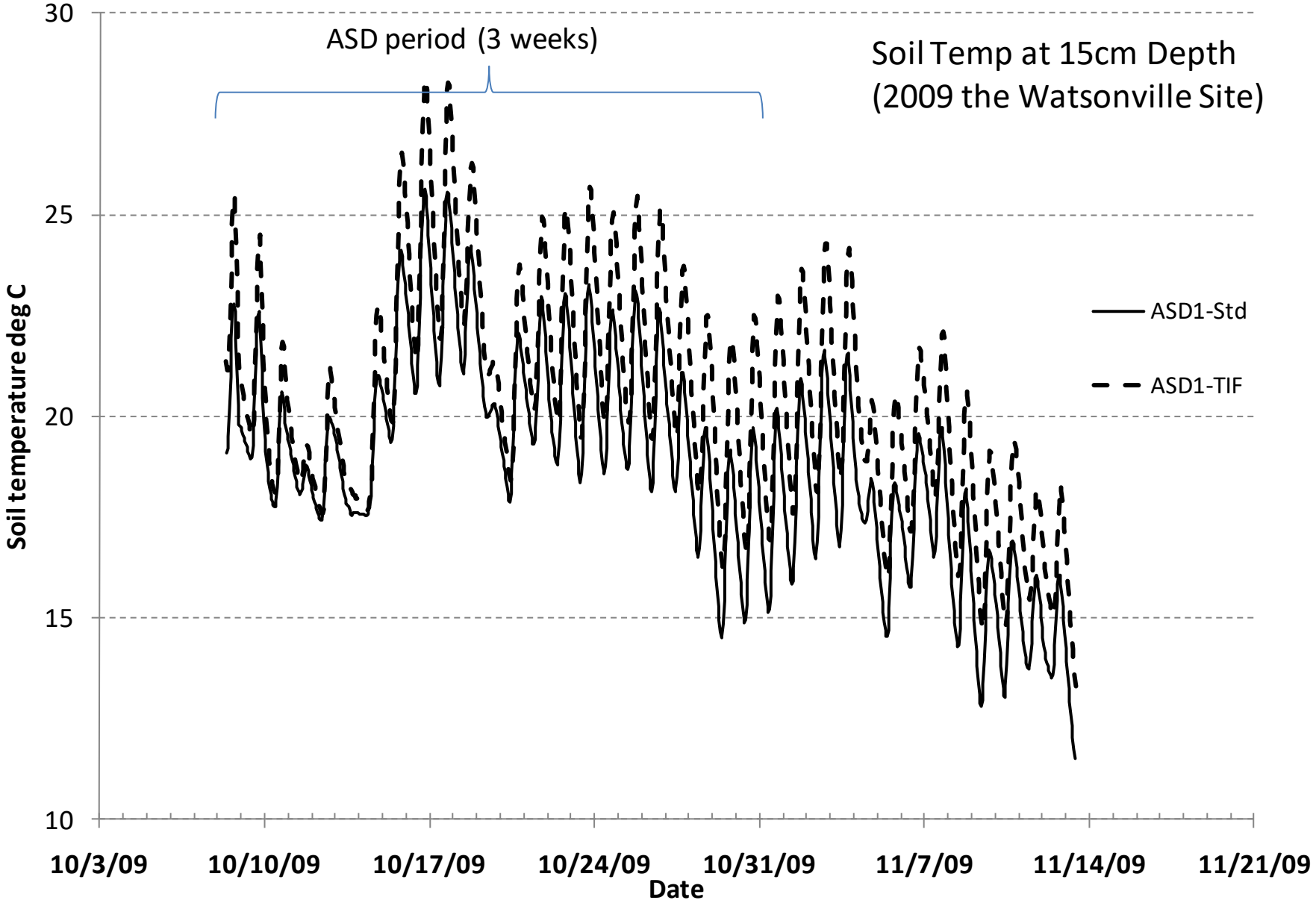
  Main plot:

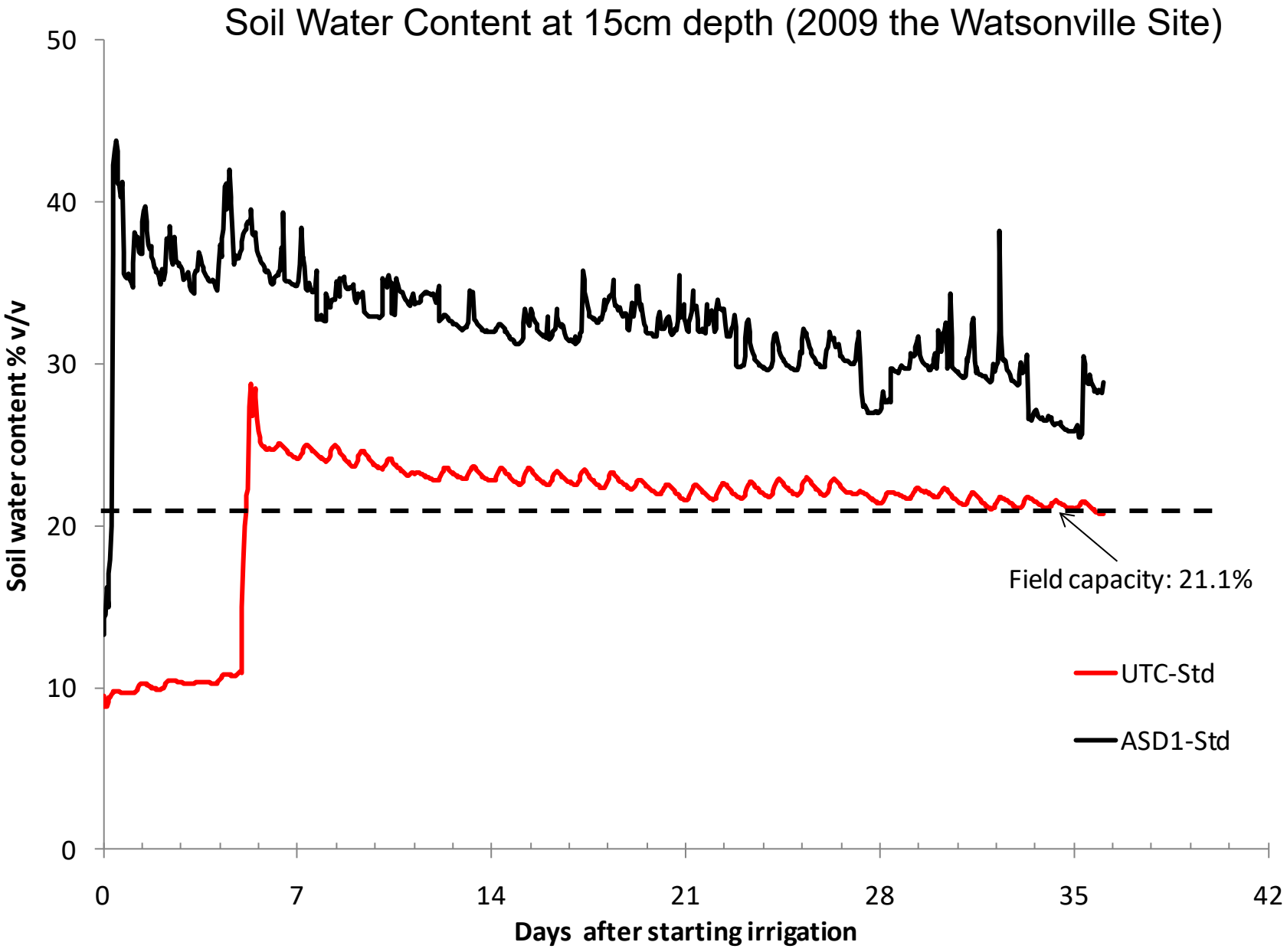
  - UTC (Untreated check)
  - ASD 1 (rice bran 4.5 tons/a)
  - ASD 2 (rice bran 9.0 tons/a)
  - ASD 3 (rice bran 8.0 tons/a + mustard cake 1.0 ton/a)
  - Methyl bromide + Chloropicrin

  Split plot:

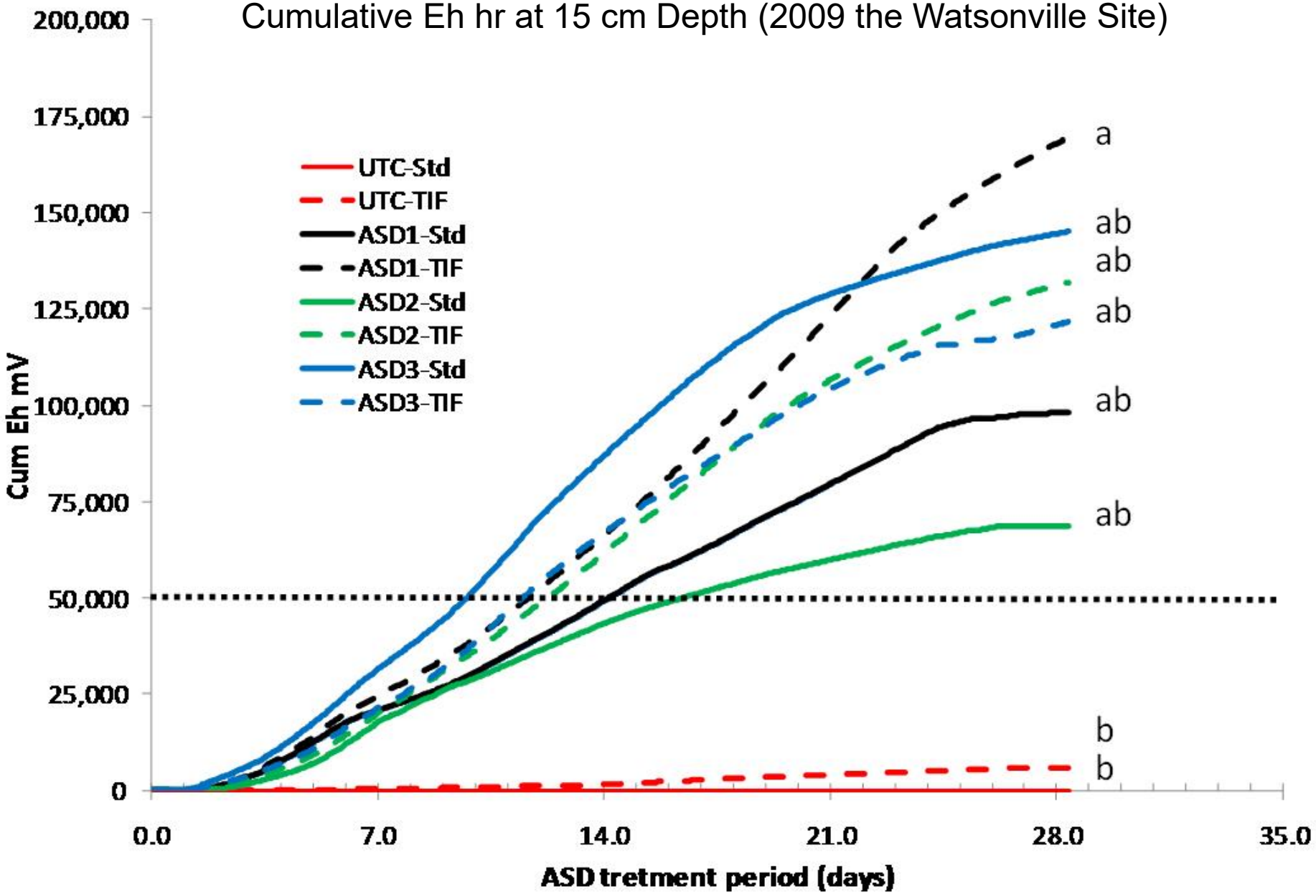
  - Standard tarp (1.25 mil green), TIF (1.2 mil clear)
- Irrigation: 4 acre-inches intermittently applied
- ASD treatment: 10/8/09 – 11/4/09


9/30/2009

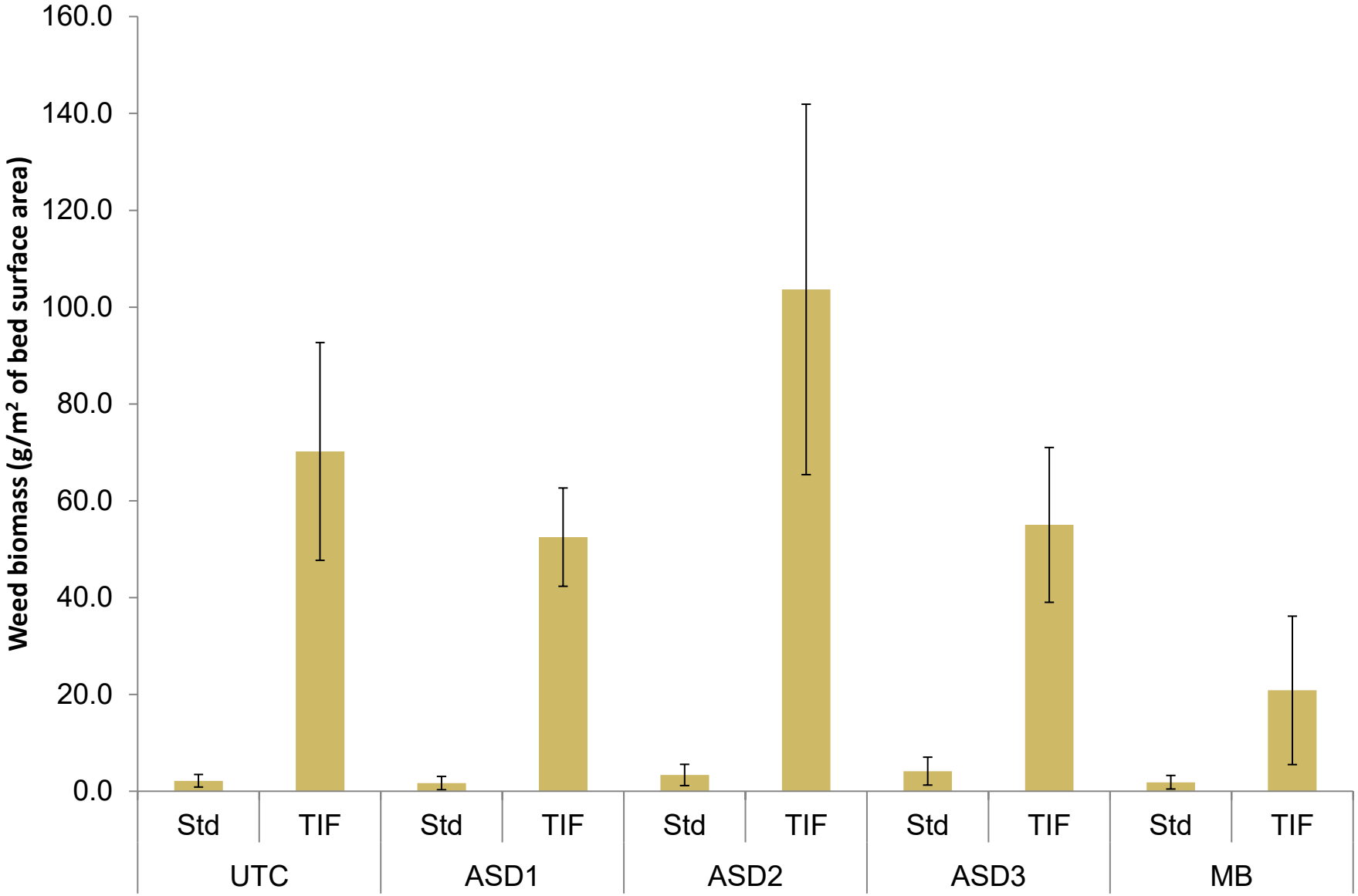

ASD period (3 weeks)
Soil Temp at 15cm Depth
(2009 the Watsonville Site)
ASD1-Std
ASD1-TIF
Soil temperature deg C
30
25
20
15
10
10/3/09
10/10/09
10/17/09
10/24/09
10/31/09
11/7/09
11/14/09
11/21/09
Date

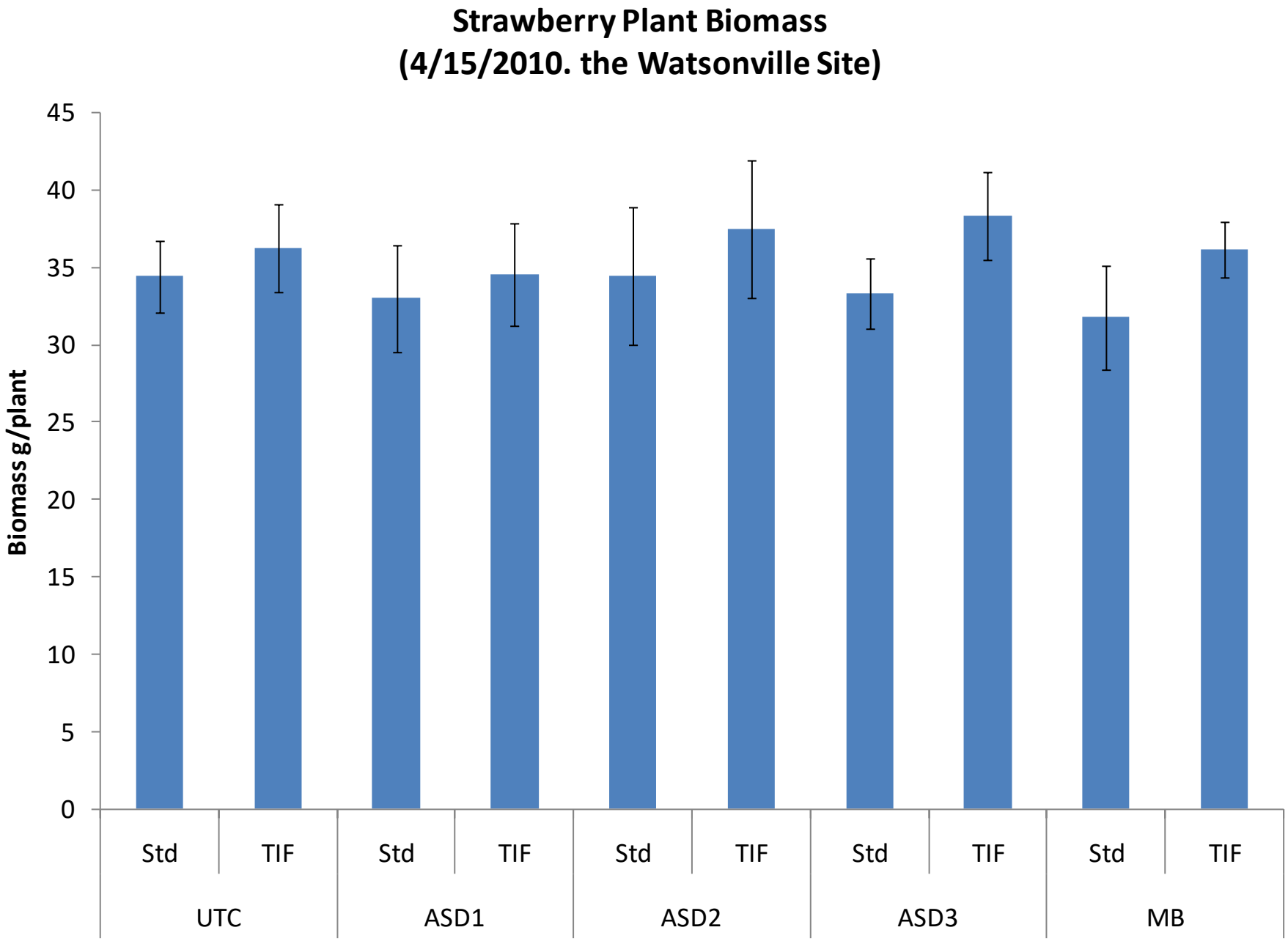

Soil Water Content at 15cm depth (2009 the Watsonville Site)
Soil water content % v/v
50
40
30
20
10
0
0
7
14
21
28
35
42
Days after starting irrigation
Field capacity: 21.1%
UTC-Std
ASD1-Std

Cumulative Eh hr at 15 cm Depth (2009 the Watsonville Site)



Total Weed Biomass
(as of 3/22/2010. the Watsonville Site)

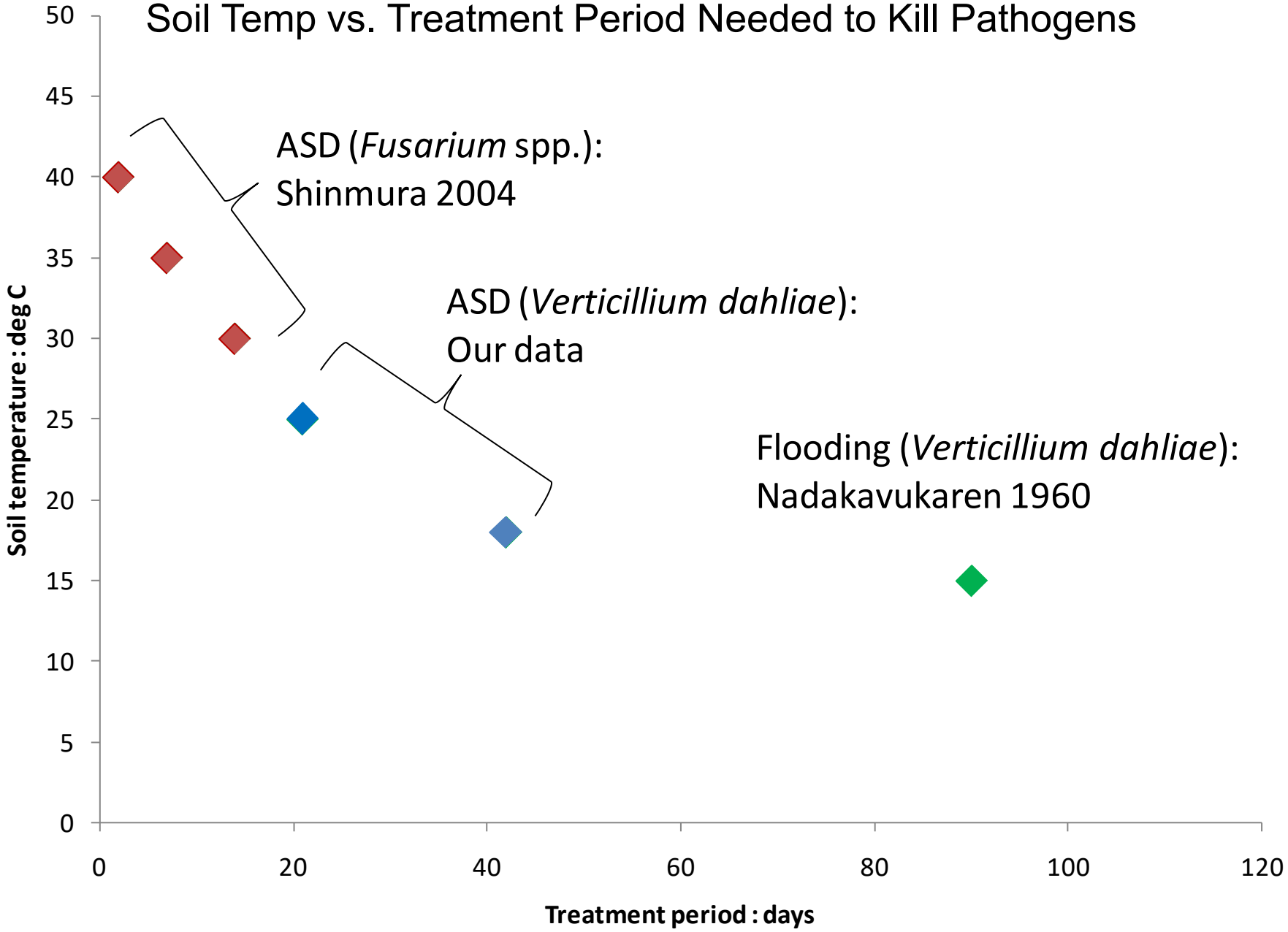


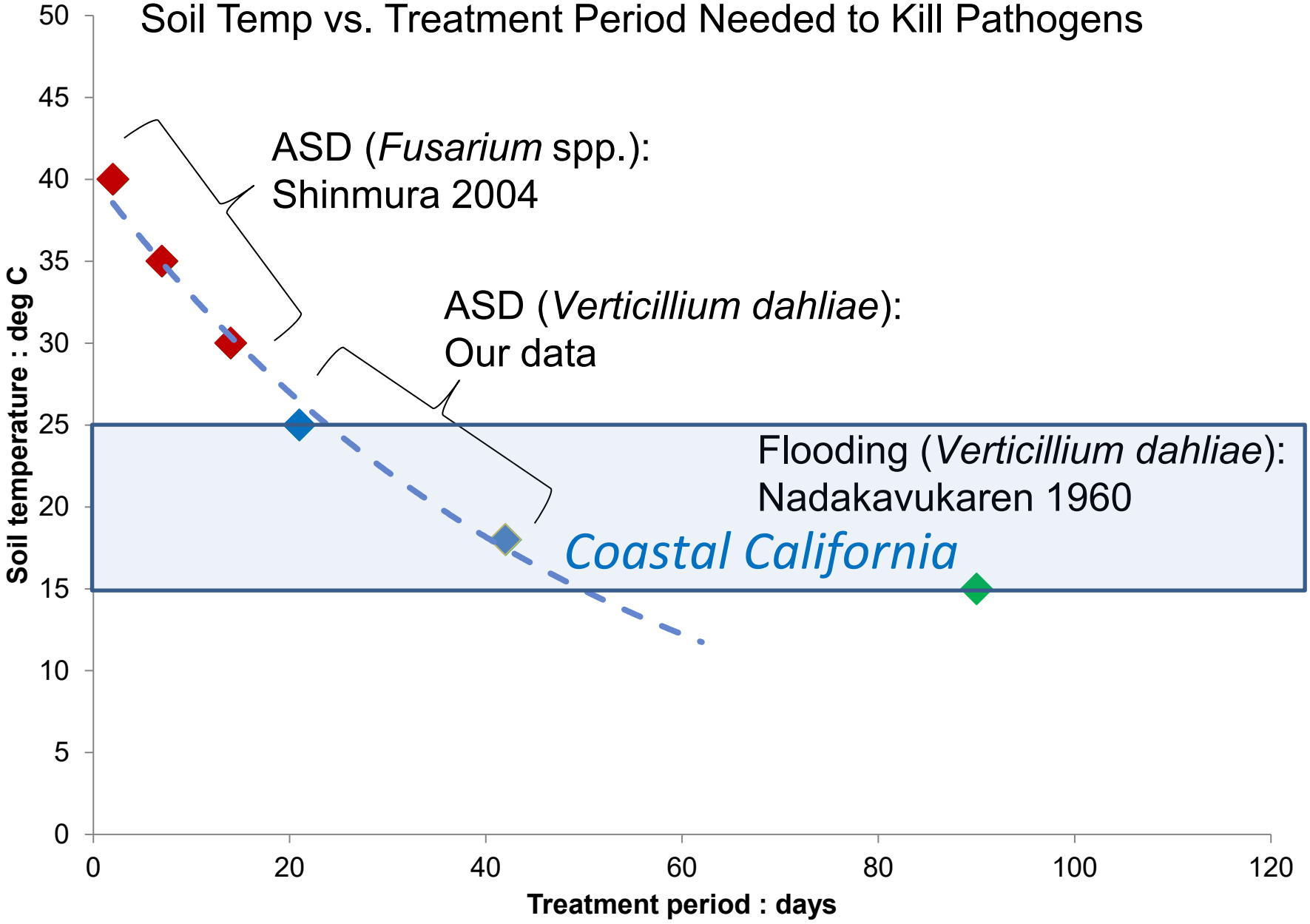

Strawberry Plant Biomass
(4/15/2010. the Watsonville Site)
Biomass g/plant
45
40
35
30
25
20
15
10
5
0
Std
TIF
Std
TIF
Std
TIF
Std
TIF
Std
TIF
UTC
ASD1
ASD2
ASD3
MB

Summary

1. **Type of C-sources….rice bran 4.5 – 9 tons/acre plus mustard cake 1 ton/acre?**
2. **Soil types….Loam – Siltyclayloam**
3. **Irrigation….3 to 6 acre inches (use of model)**
4. **Type of plastic tarps….Clear TIF vs. regular green?**
5. **Soil temperature ….15 – 30 °C**
6. **Anaerobic condition….50,000 CumEhhr at 25 °C**

   At 15 to 20 °C?
7. **Treatment period ?**


Soil Temp vs. Treatment Period Needed to Kill Pathogens
ASD (*Fusarium* spp.):
Shinmura 2004
ASD (*Verticillium dahliae*):
Our data
Flooding (*Verticillium dahliae*):
Nadakavukaren 1960
Soil temperature : deg C
Treatment period : days
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120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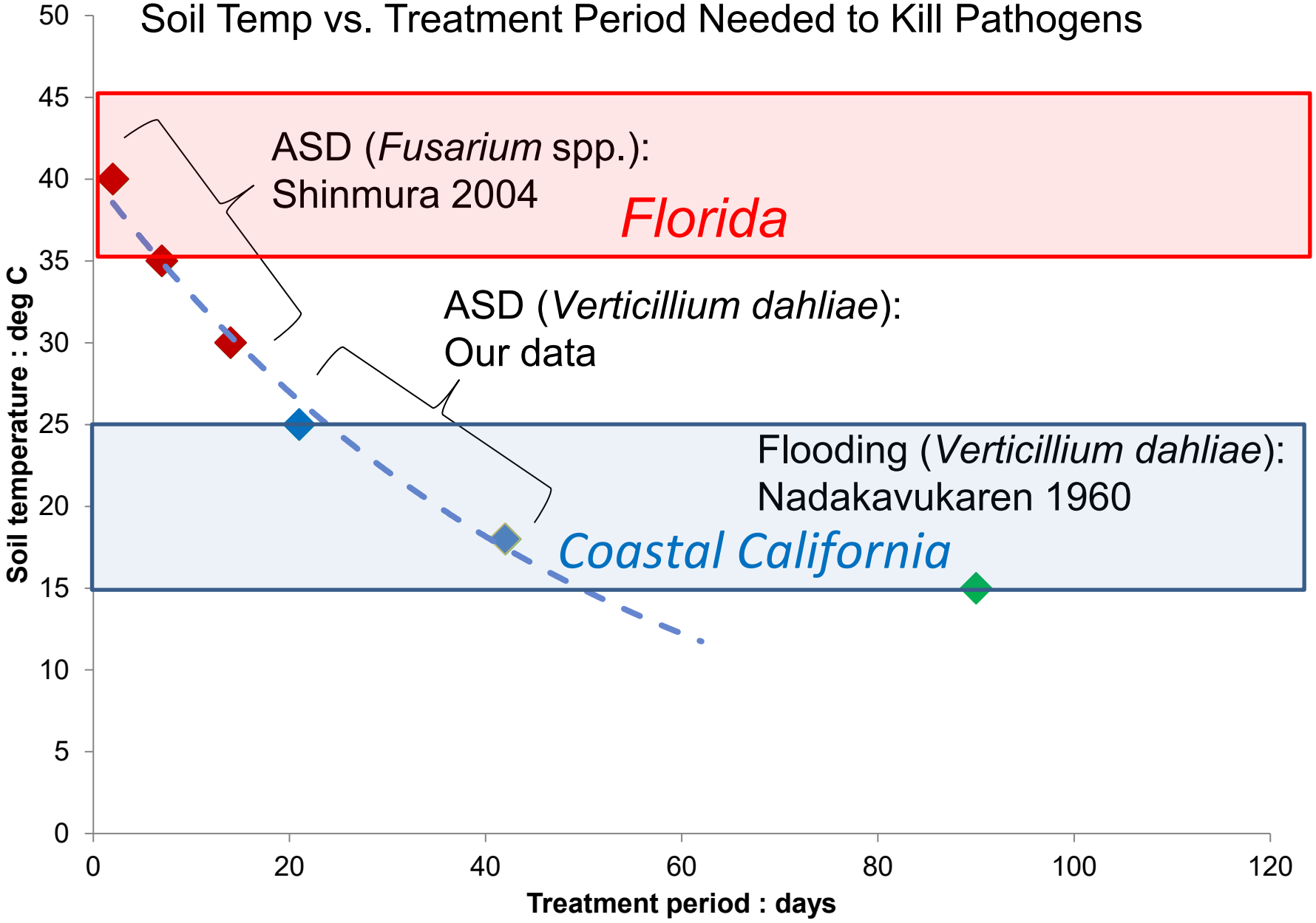
ASD (*Verticillium dahliae*):
Our data
Flooding (*Verticillium dahliae*):
Nadakavukaren 1960
Coastal California
Soil temperature : deg C
Treatment period : days
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120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ASD (Fusarium spp.):
Shinmura 2004
Florida
ASD (Verticillium dahliae):
Our data
Flooding (Verticillium dahliae):
Nadakavukaren 1960
Coastal California
Soil temperature : deg C
Treatment period : days
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120

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