Progress in Anaerobic Soil Disinfestation (ASD) Research

Fumigants and non-fumigant alternatives:
Regulatory and research updates
23 April, Thursday, UCCE, Ventura

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

Mark Mazzola, USDA-ARS, Wenatchee, WA

Steven Koike, UC Cooperative Extension, Salinas, CA

Acknowledgements

We gratefully acknowledge funding for this work from the following:

- USDA NIFA MBTP Award # 2012-51102-20294
- USDA NIFA MBTP Award # 2010-51102-21707
- USDA CSREES MBTP Award # 2007-51102-03854
- California Strawberry Commission Grants ST13-25, ST13-12, ST12-10, ST11-10, ST10-61, ST09-61, and ST08-61
- USDA WSARE Award # SW11-116
- Organic Farming Research Foundation

- And the many growers, extension and industry people who have made this work possible

ASD Basics

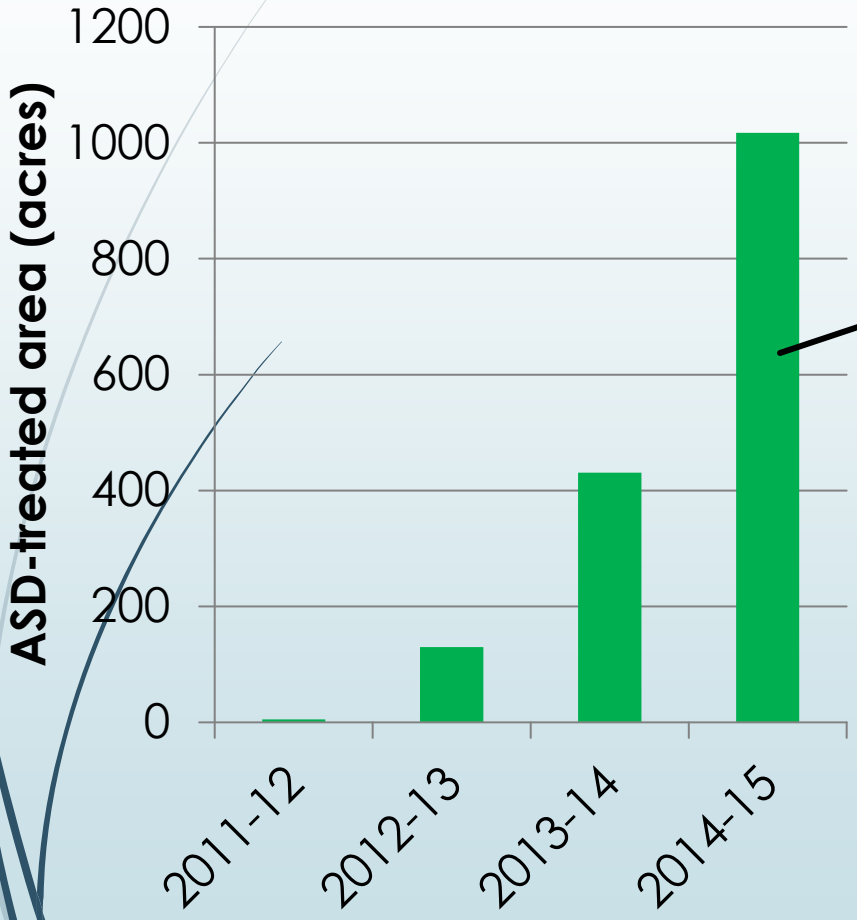
1. Incorporate readily available organic matter
   - **Provide C source for soil microbes**
2. Cover with oxygen impermeable tarp
3. Irrigate to saturate soil then to maintain field capacity
   - **Water-filled pore space**
   - **Create anaerobic conditions and stimulate anaerobic decomposition of incorporated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

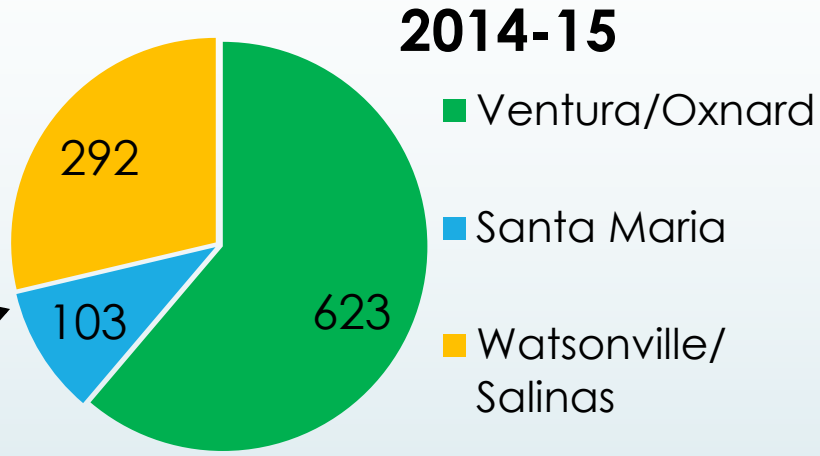
Anaerobic Soil Disinfestation (ASD)
(Shennan et al., 2007)

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 Fields in California





- 80% organic sites
- 20% conventional sites

- ~20% of CA organic strawberry acreages
- ~2.5% of CA total strawberry acreages

(Farm Fuel Inc. Personal communication)

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

Exp. 1: Carbon source trial (PSI, Watsonville)

- Rhizoctonia-infested field
- RB split plot. 4 reps

Main plots:

- ASD RB 9 t/ac
- ASD RB 6 t/ac
- ASD ground dry grape pomace (GP) 9 t/ac
- Methyl bromide/chloropicrin (50:50) 400 lbs/acre
- UTC

Split plots:

- With and with pre-plant fertilizer (PPF. 650 lb/ac of 6-month slow-release 18-6-12)

- In-season fertilizer (all plots)
  March-Aug. 45-19-51 lbs/ac

Bed top application!

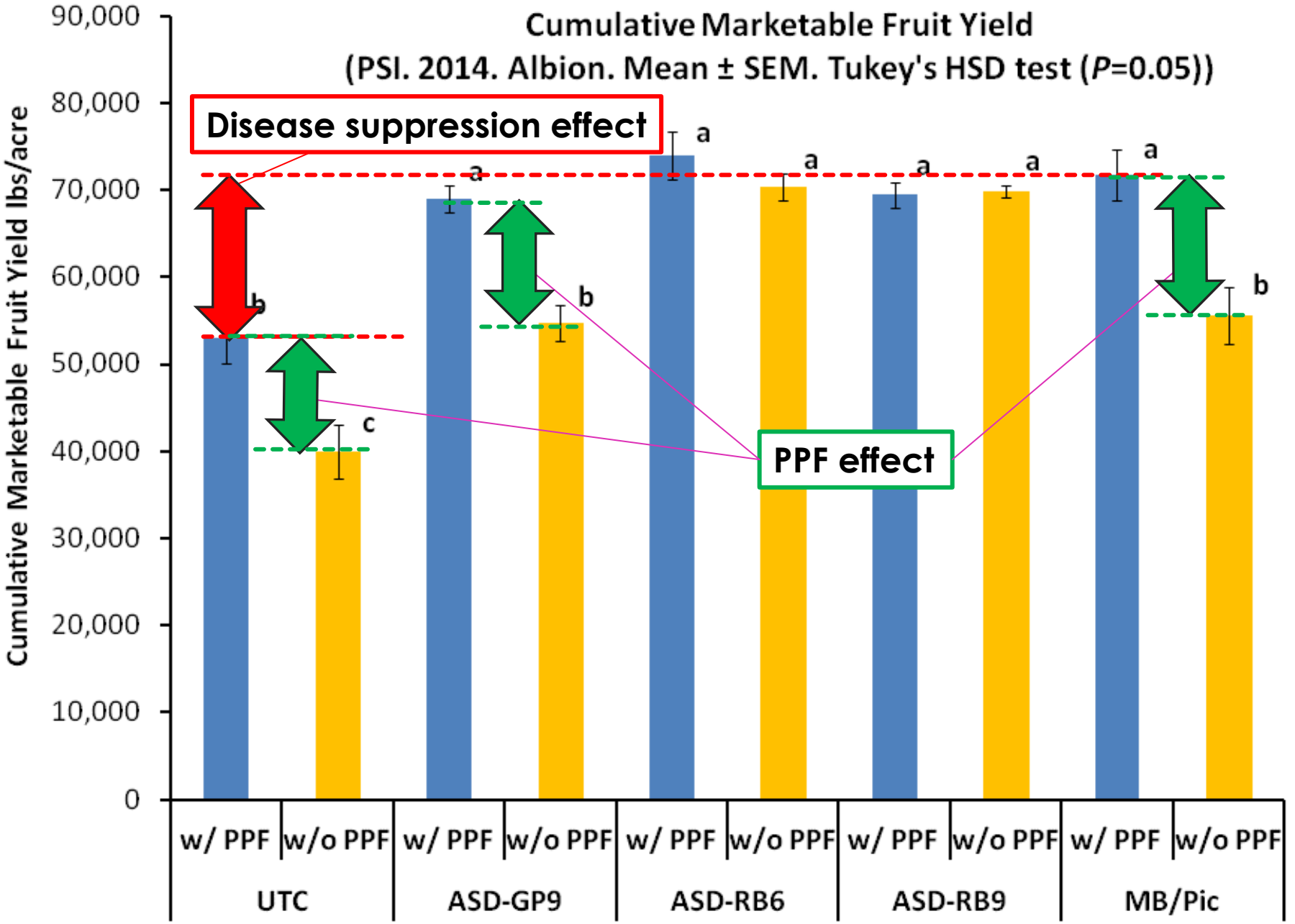
Albion plants

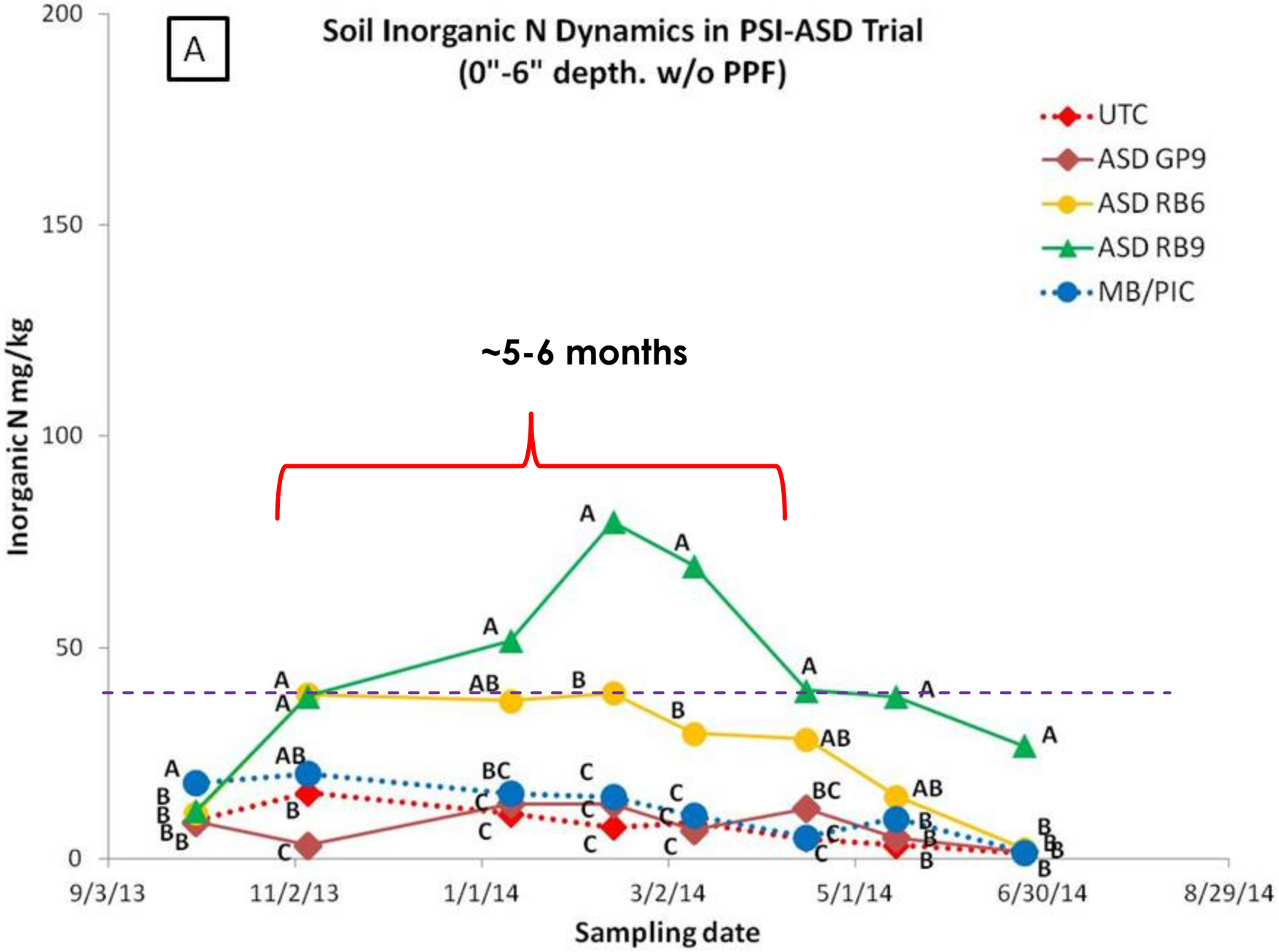
Ground Dry Grape Pomace (grape skin + seeds)

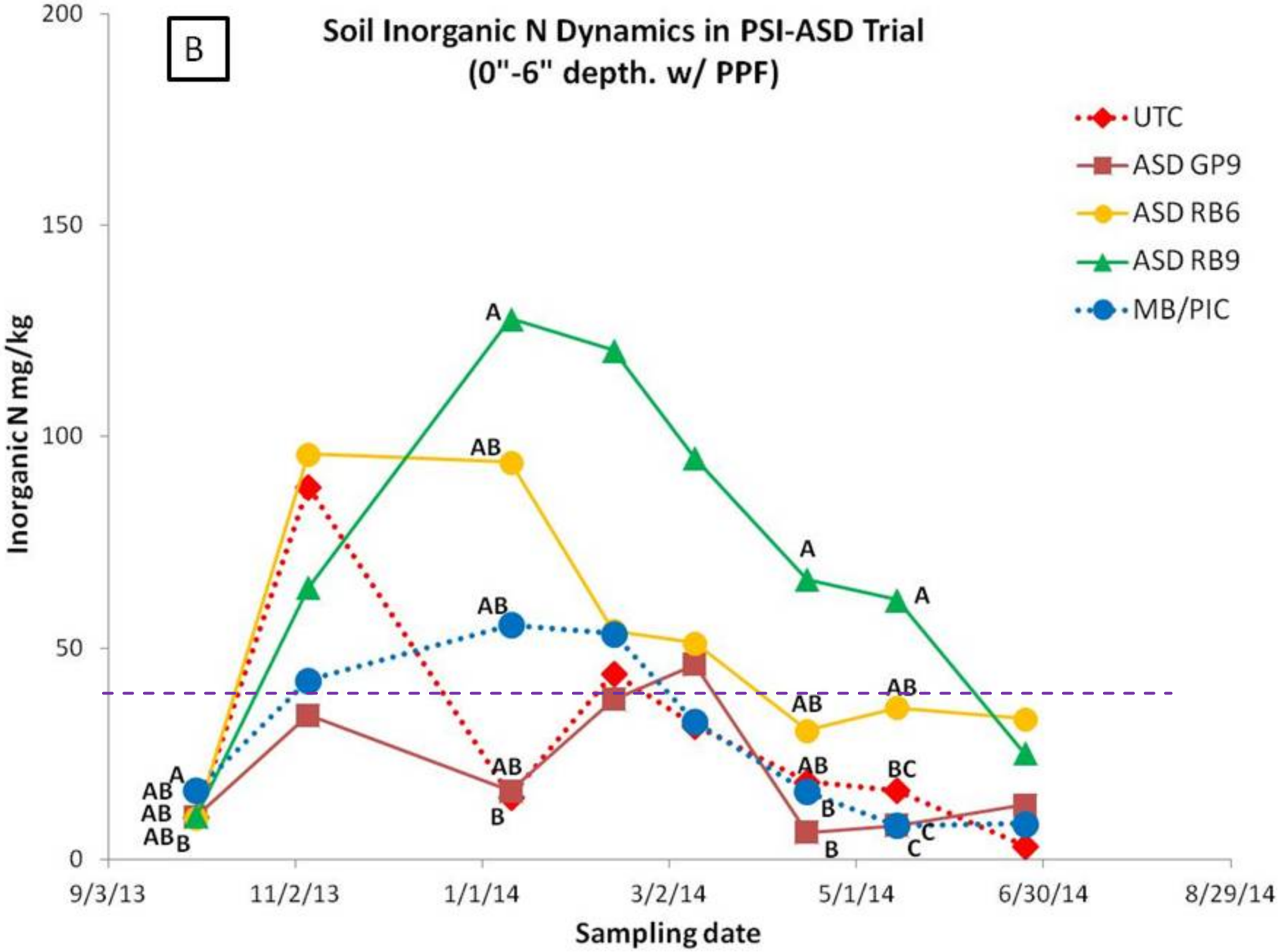
N:2.1%, C:49%, C/N:23

Rice Bran

N:2.3%, C:41%, C/N:18


Cumulative Marketable Fruit Yield
(PSI. 2014. Albion. Mean ± SEM. Tukey's HSD test (P=0.05))
Cumulative Marketable Fruit Yield lbs/acre
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Disease suppression effect
PPF effect
a
b
c
w/ PPF
w/o PPF
UTC
ASD-GP9
ASD-RB6
ASD-RB9
MB/Pic


A
Soil Inorganic N Dynamics in PSI-ASD Trial
(0"-6" depth. w/o PPF)
UTC
ASD GP9
ASD RB6
ASD RB9
MB/PIC
~5-6 months
Inorganic N mg/kg
200
150
100
50
0
9/3/13
11/2/13
1/1/14
3/2/14
5/1/14
6/30/14
8/29/14
Sampling date

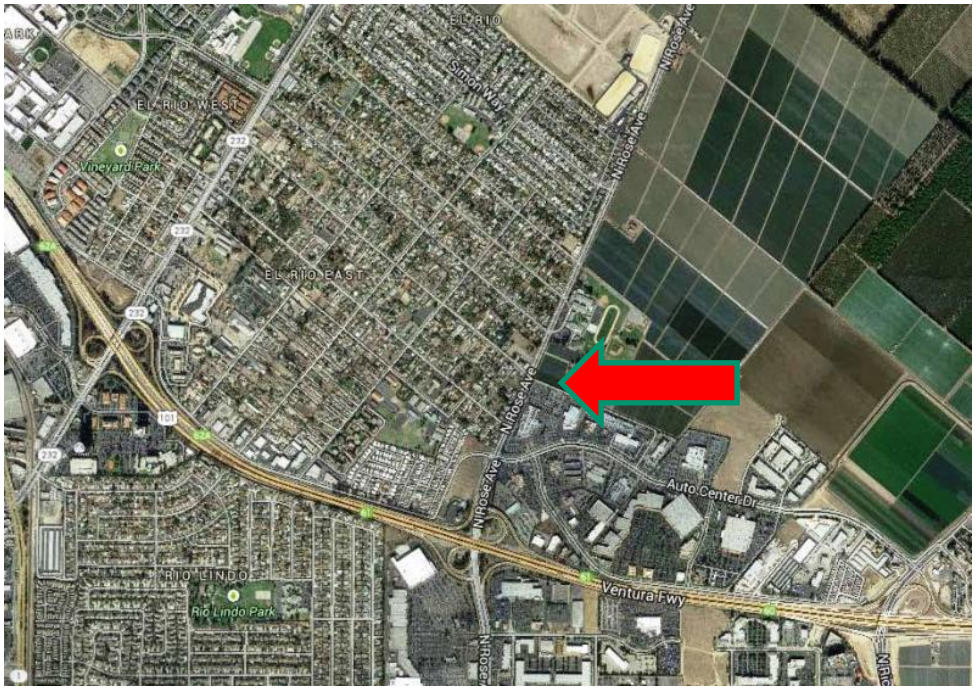

B
Soil Inorganic N Dynamics in PSI-ASD Trial
(0"-6" depth. w/ PPF)
UTC
ASD GP9
ASD RB6
ASD RB9
MB/PIC
Inorganic N mg/kg
200
150
100
50
0
9/3/13
11/2/13
1/1/14
3/2/14
5/1/14
6/30/14
8/29/14
Sampling date
A
AB
AB
AB
B
AB
A
AB
AB
B
A
A
AB
AB
AB
B
BC
B
C
C

Summary

- ASD with rice bran 6 t/ac worked well without sacrificing fruit yield and having excess soil inorganic N
- Ground dry grape pomace 9 t/ac worked but only with pre-plant fertilizer
- Pre-plant fertilizer was not necessary when rice bran 6 to 9 tons/ac was used
- All above have to be examined in broadcast application/incorporation systems
- ~40 mg/kg of soil inorganic N (0”-6” depth) until April to May was sufficient to achieve the highest yield

Exp. 2 Oxnard Demonstration Trial

- 1 acre/plot, non-replicated
- 7-8 yr. 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*
- ASD and MSM, two years in a row (2013-14, 2014-15)



- Field Day…..May 8th (F)

2013-14 Rice Bran Application/Incorporation

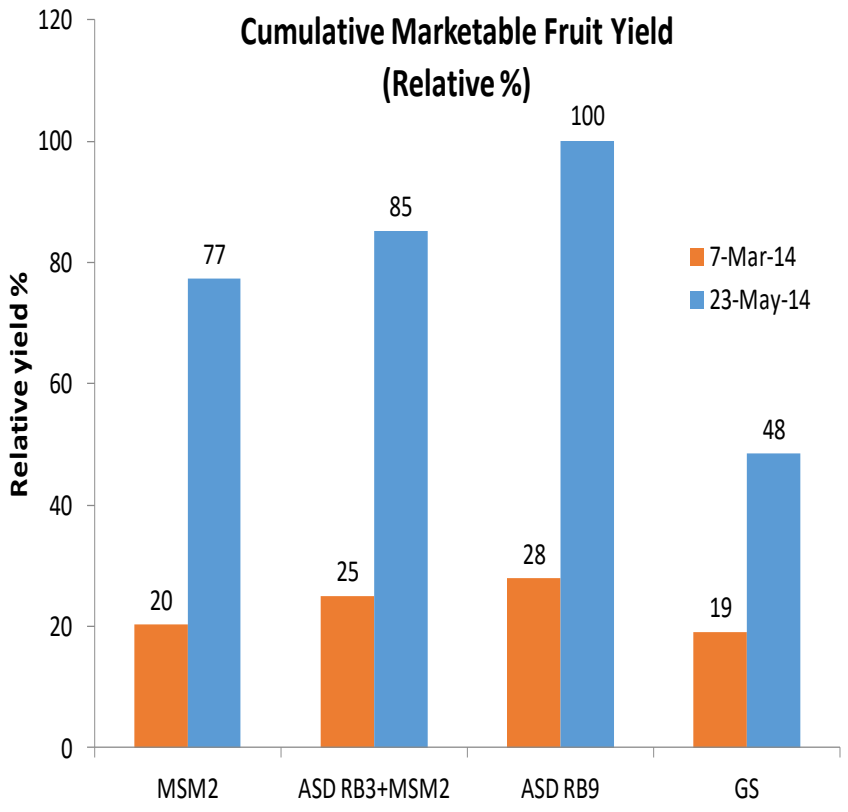

GS
ASD RB9
ASD MSM2
+RB3
MSM2

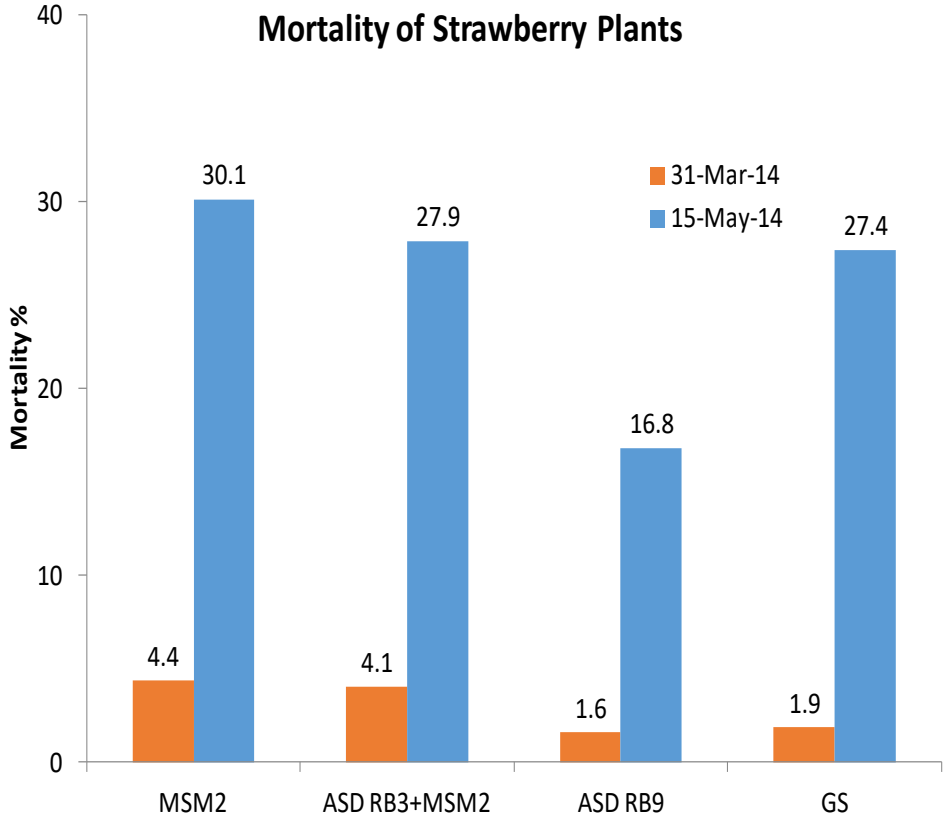
MSM2	ASD MSM2+RB3	ASD RB9	GS

Oxnard Demo Trial

May 29, 2014

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





Oxnard Demo Trial (2013-14 Season)

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

2014-15 Rice Bran Incorporation

Photos by Mark Edsall

MSM2.5*

ASD RB6*

ASD RB9*

GS

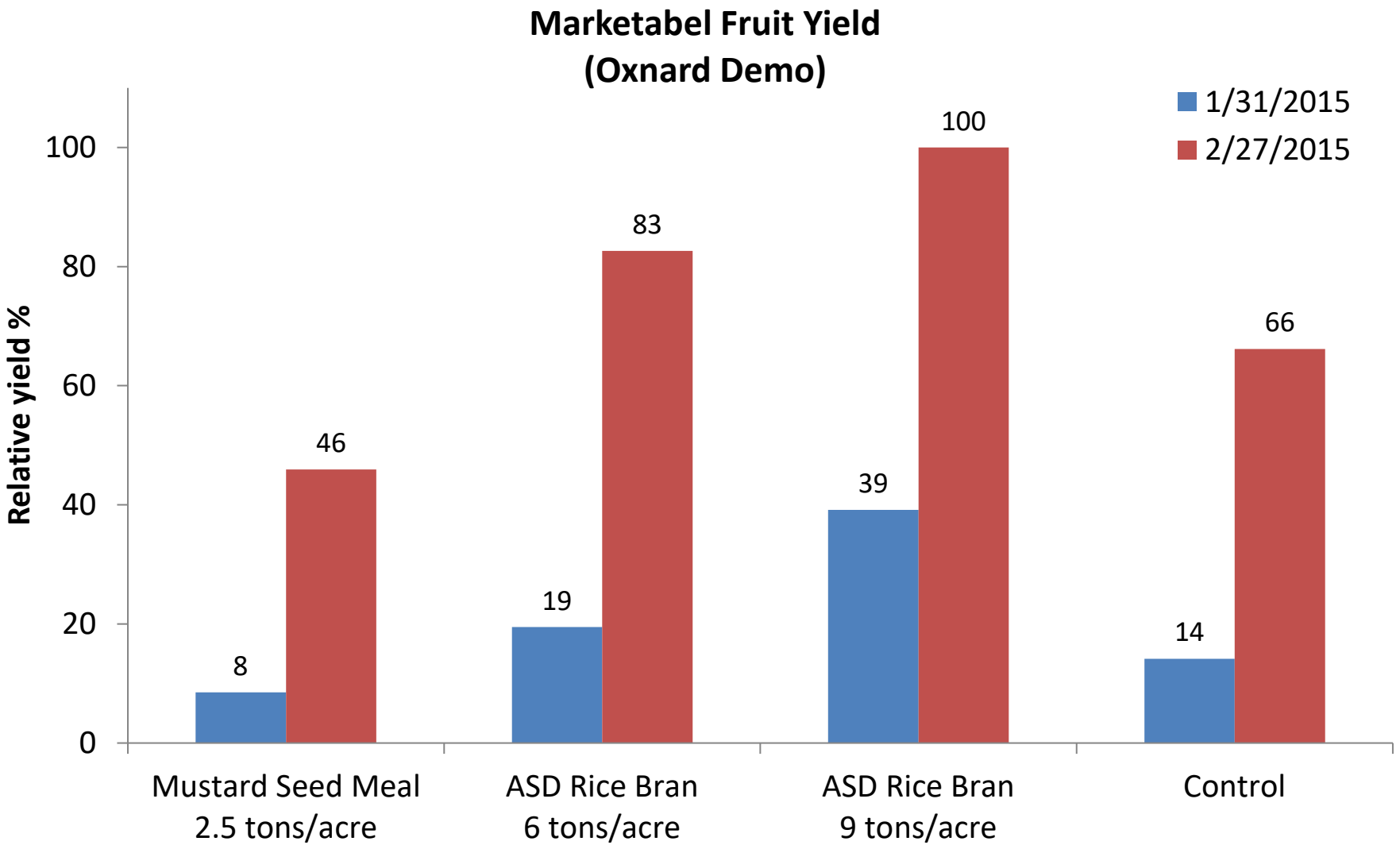
Pre-plant 10-10-2.5, 2,000 lbs/acre

* No pre-plant fertilizer

Oxnard Demo Trial

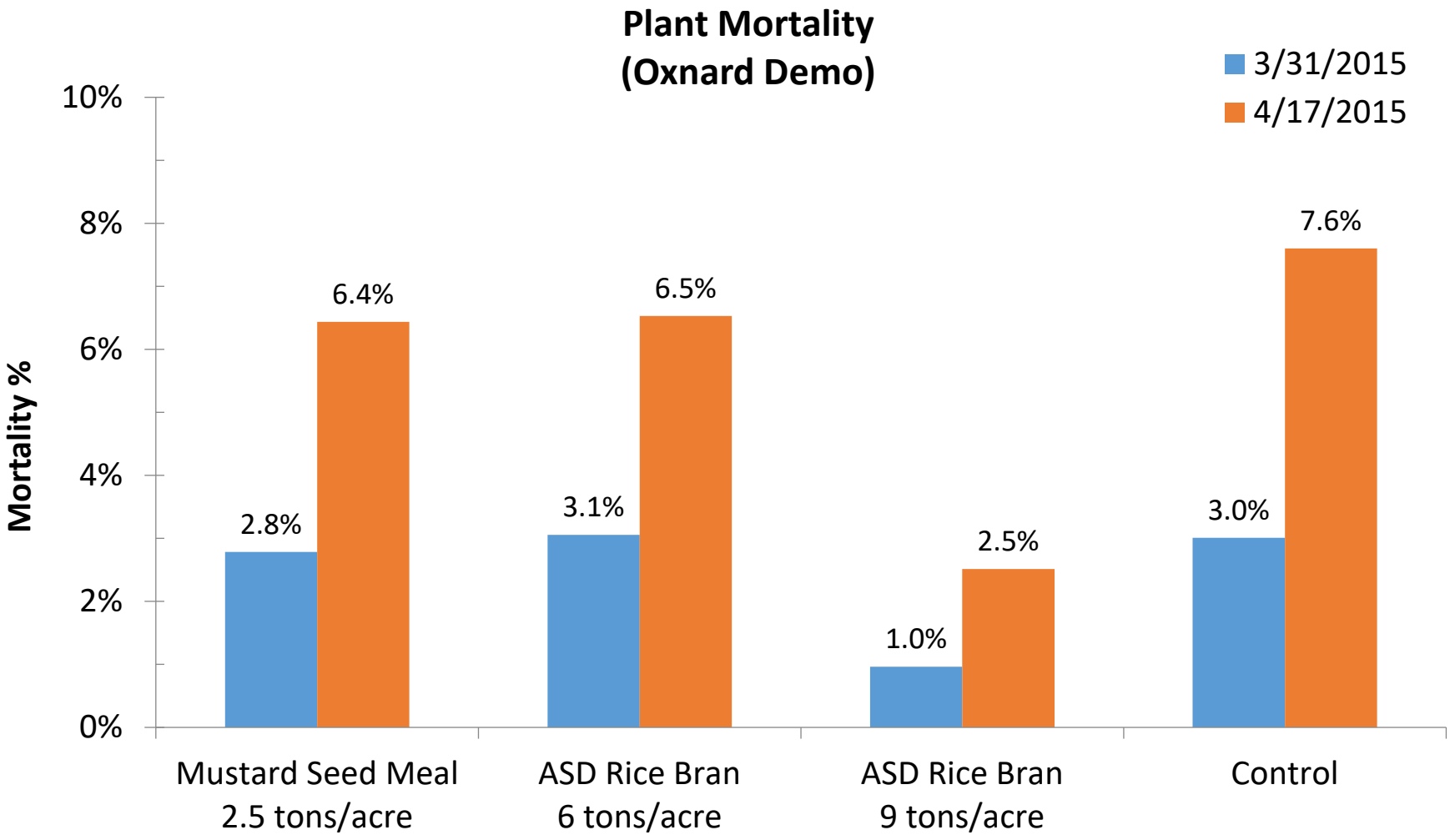
Feb. 5, 2015

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



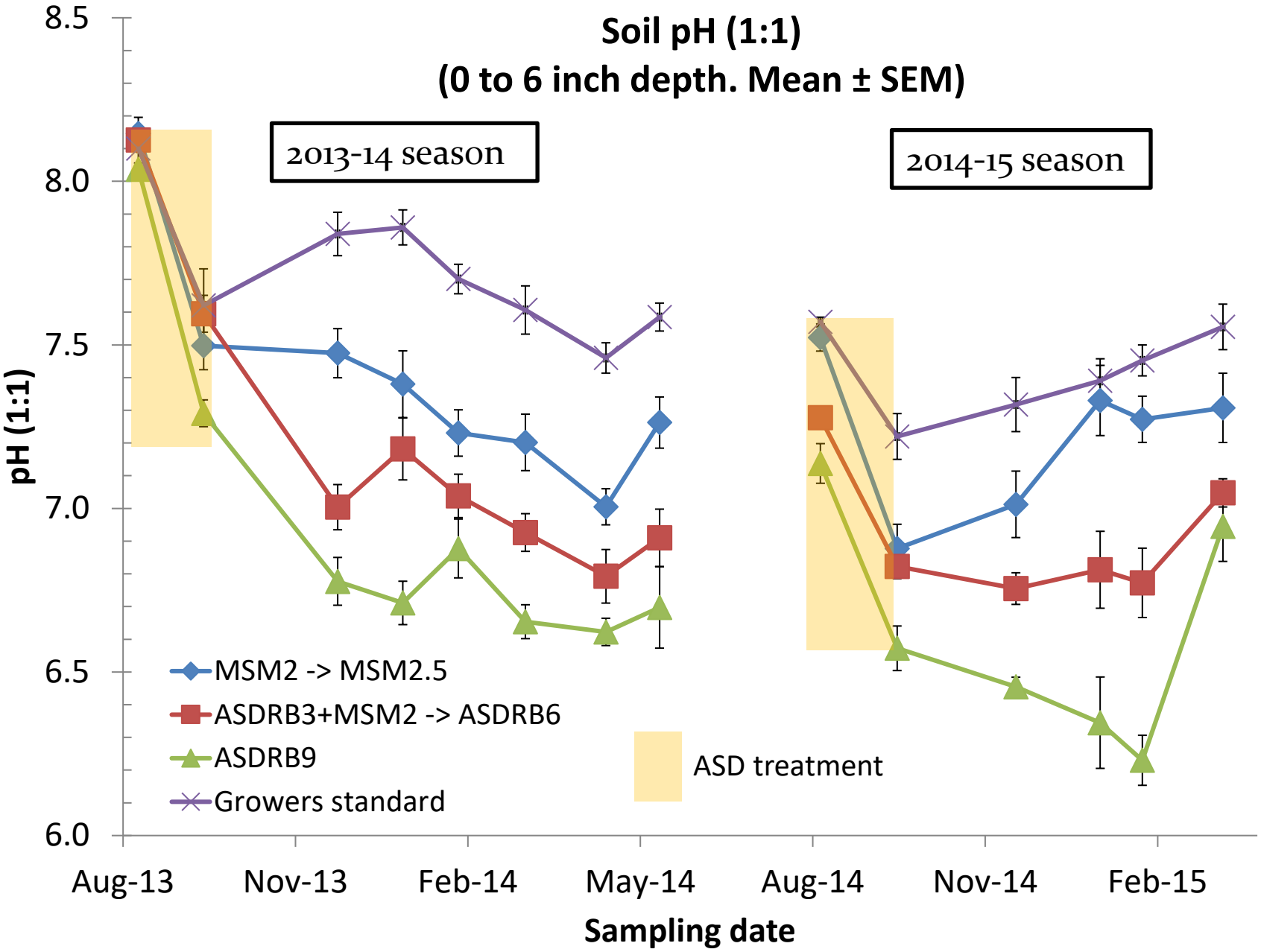
Oxnard Demo Trial (2014-15 season)

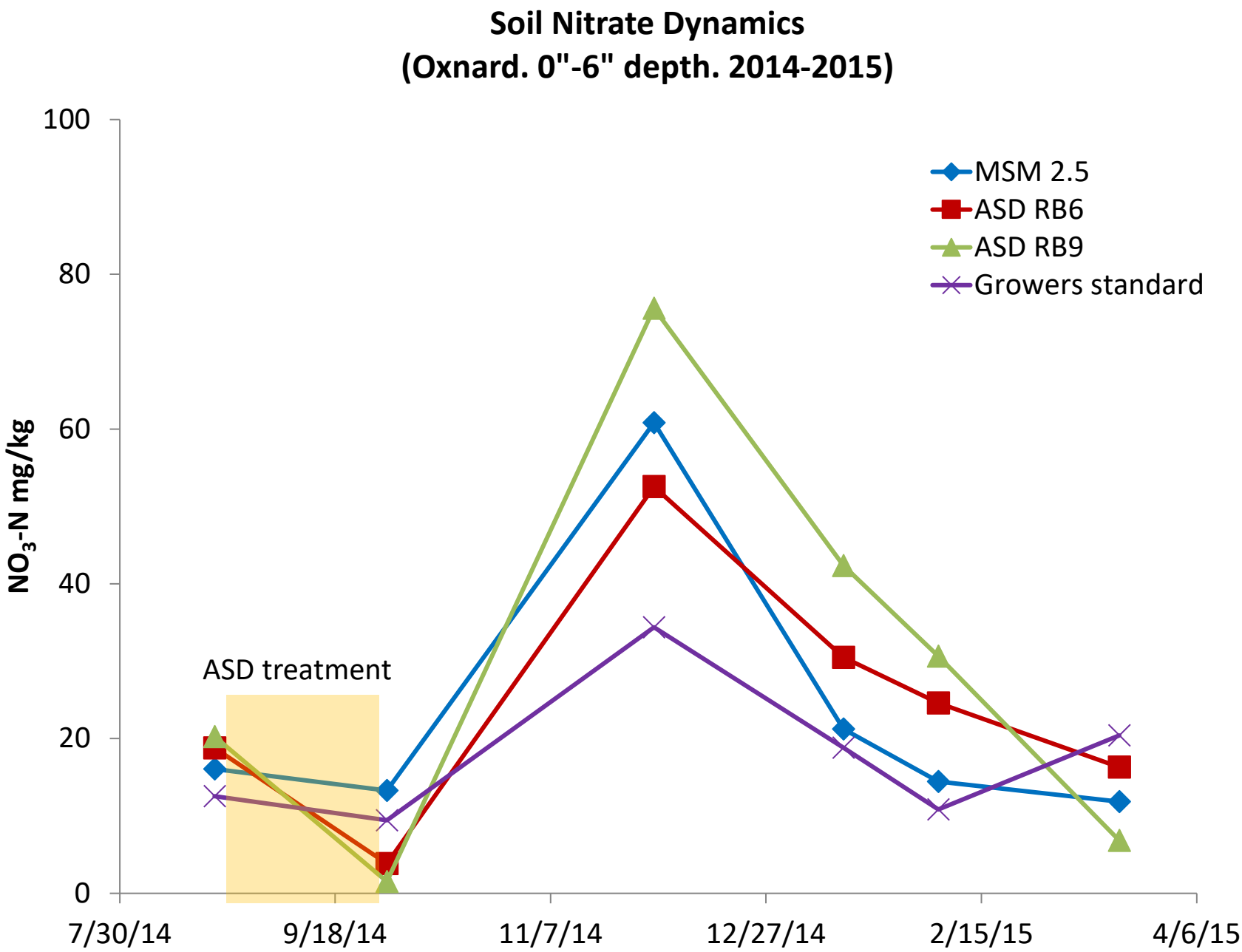
(*Macrophomina spp.* + *Fusarium oxysporum*-infested organic field)



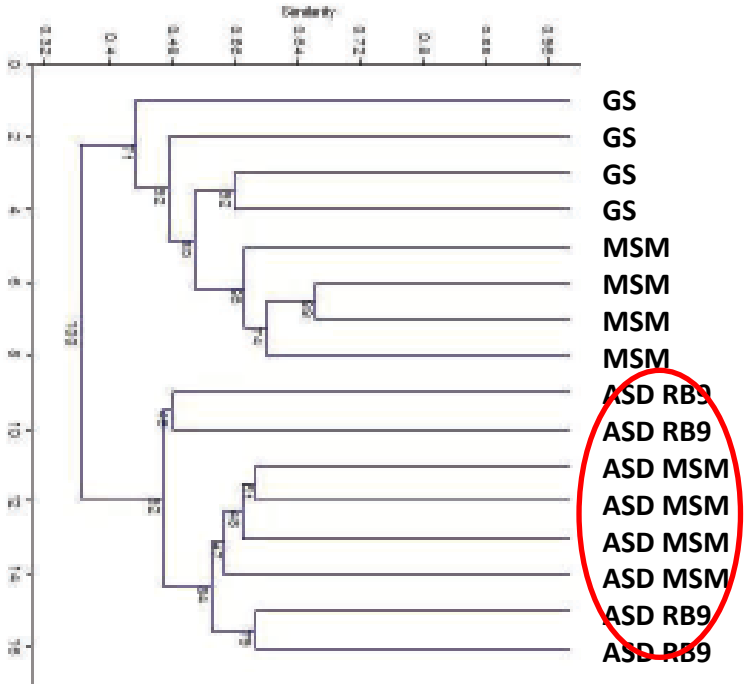
Oxnard Demo Trial (2014-15 season)

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

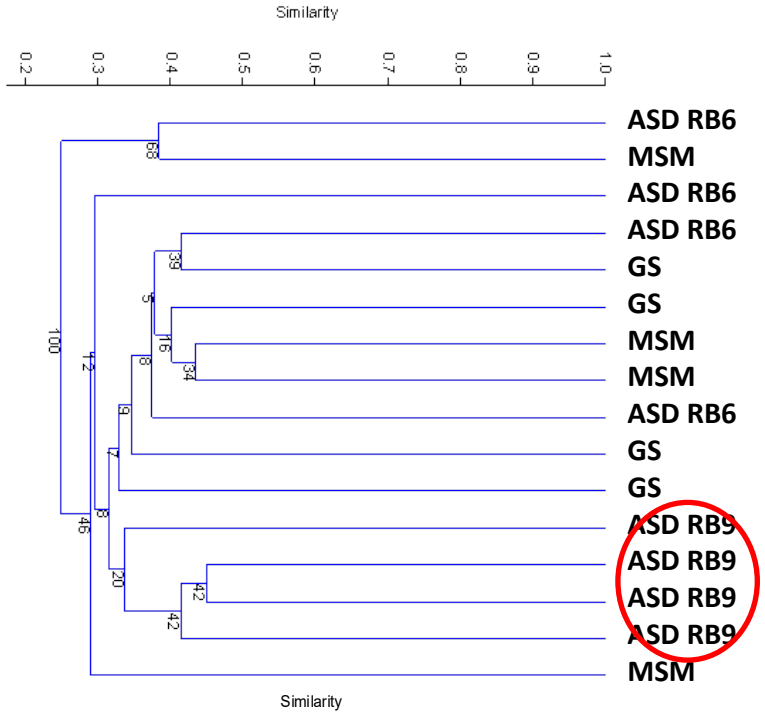

Soil pH (1:1)
(0 to 6 inch depth. Mean ± SEM)
2013-14 season
2014-15 season
8.5
8.0
7.5
7.0
6.5
6.0
pH (1:1)
MSM2 -> MSM2.5
ASDRB3+MSM2 -> ASDRB6
ASDRB9
Growers standard
ASD treatment
Aug-13
Nov-13
Feb-14
May-14
Aug-14
Nov-14
Feb-15
Sampling date


Soil Nitrate Dynamics
(Oxnard. 0"-6" depth. 2014-2015)
100
80
60
40
20
0
NO_3-N mg/kg
MSM 2.5
ASD RB6
ASD RB9
Growers standard
ASD treatment
7/30/14
9/18/14
11/7/14
12/27/14
2/15/15
4/6/15

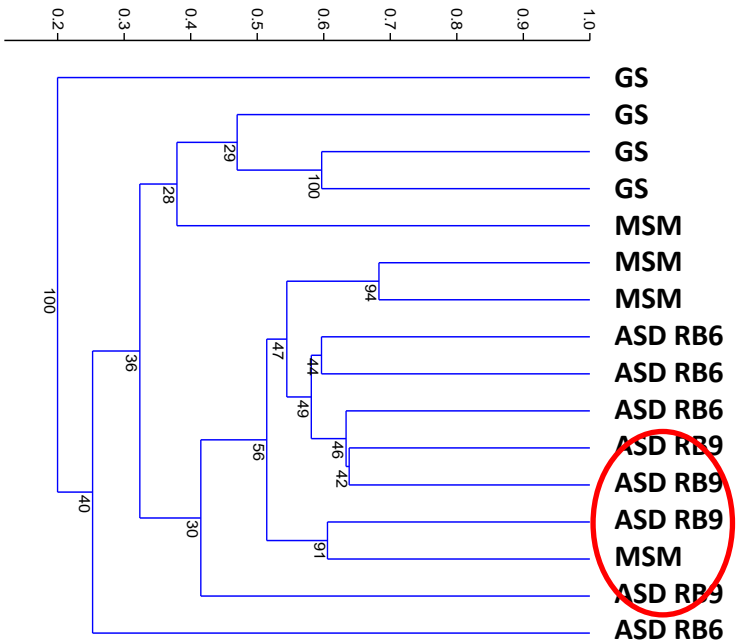
1)



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: On-going Studies/Challenges

- Controlling emerging diseases caused by *Fusarium oxysporum* and *Macrophomina phaseolina*
  - Can we improve on 50% Macrophomina/Fusarium control?
- Reducing N input from C-sources
  - Grape pomace
  - Cover crop + Low rate of rice bran
- Evaluating environmental impacts
  - Greenhouse gas emission, nitrate leaching, phosphorus accumulation
- Ineffective in heavy soils?
  - Large clods in beds prevent development of anaerobic condition
- Understanding biological mechanisms
  - Changes in functional diversity of soil microorganisms?
- Growth enhancement vs. disease control?

Questions?

joji@ucsc.edu