History and Principles of Anaerobic Soil Disinfestation

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ASD: Background

What is Anaerobic Soil Disinfestation?

known also as **Biological Soil Disinfestation** (Blok et al. 2000) or as **Reductive Soil Disinfestation** (Shinmura et al. 1999),

ASD is considered one of the most promising **non-chemical methods** for the (*simultaneous*) control of soil-borne pathogens, plant-parasitic nematodes and weeds

ASD: Background

- Developed as an alternative to **methyl bromide** and other soil **chemical fumigants** independently in **Japan** (Shinmura & Sakamoto, 1998; Shinmura, 2000) and in **The Netherlands** (Blok et al., 2000)

  ASD has proved to be effective against several soil-borne **fungal** and **bacterial** plant diseases, plant-parasitic **nematodes** and **weeds**, across a wide range of **crops** and **environments** (Momma, 2008; Shennan et al., 2014)

ASD: target crops and phytosanitary issues

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Crops tested

Onion[2]

Tomatoes[2,3]

Strawberries[2,3,4]

Eggplant[2, 3]

Spinach[2]

Peppers[3]

Cut flowers[3]

Cucurbits[3]

Banana[5]

Asparagus[1]

Soil-borne pathogens

Verticillium dahliae[1,2,4]
Fusarium oxysporum[1,2.3]
Fusarium redolens[2]
Ralstonia solanacearum[2,3]
Rhizoctonia solani[1]
Sclerotium rolsfii[3]

Nematodes

Meloidogyne incognita[1,3]
Pratylenchus fallax[2]

Weeds

Nutsedge[3]
Grasses[3]

Studies: [1]Dutch; [2]Japanese; [3]**Florida**; [4]California; [5]China

ASD: in The Netherlands

How ASD was developed?

1944-45 Wieringermeer flood (Hoes et al. 2013)

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ASD: in The Netherlands

Bulb growers saw flooding controlled soil-borne diseases

ASD: in The Netherlands

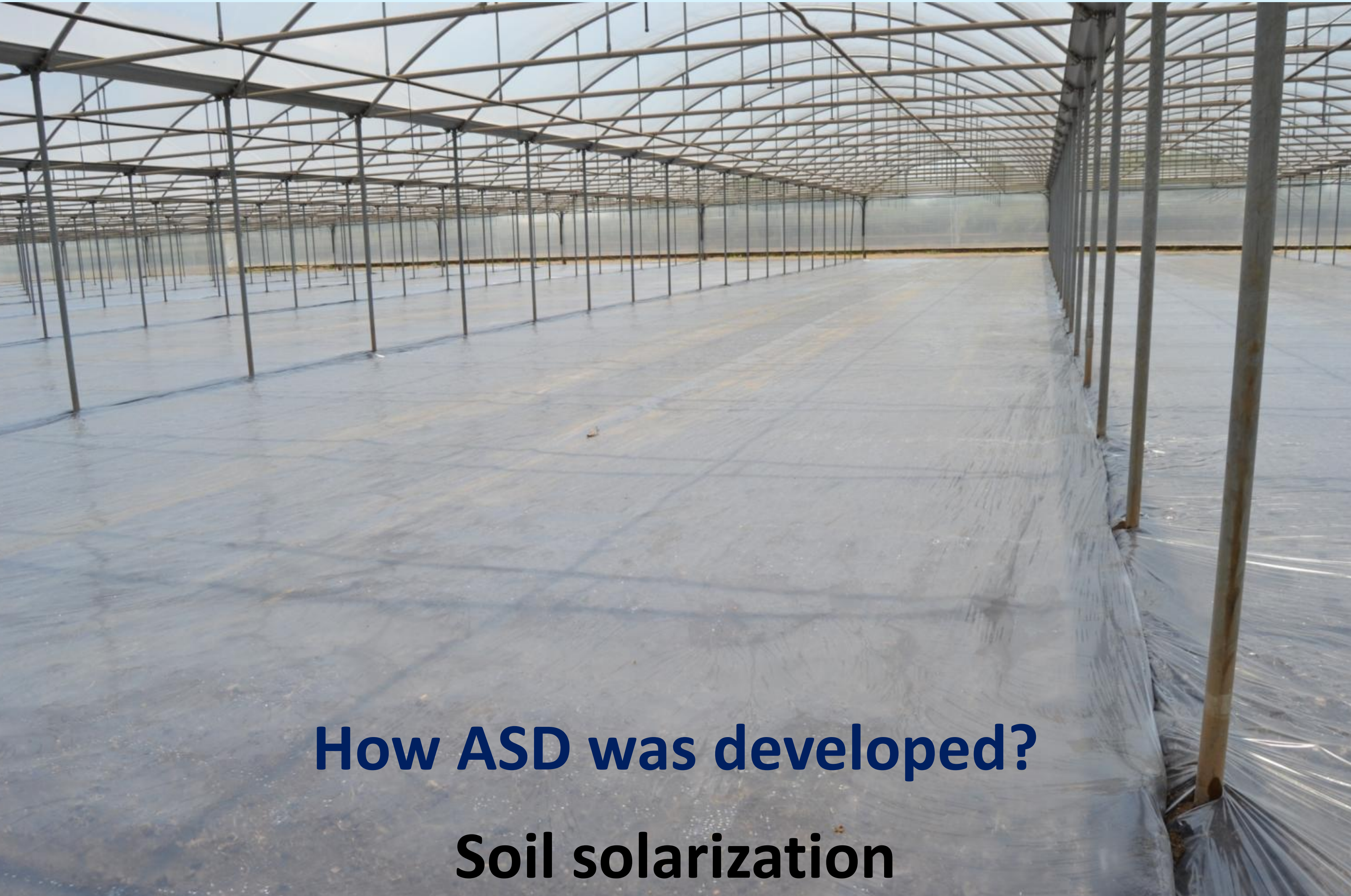
Nematode control with 8-12 weeks of flooding

How ASD was developed?

Photo credits
Noriaki Momma

Paddy-upland field rotation system

ASD: in Japan



How ASD was developed?

Soil solarization

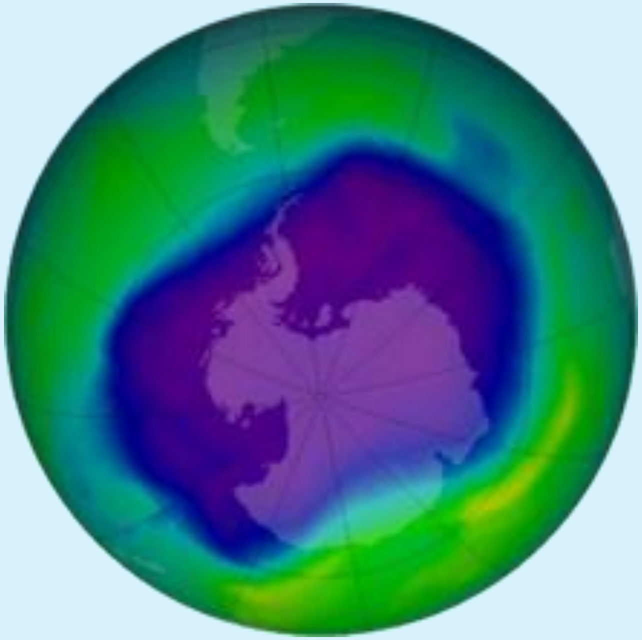
How ASD was developed?

- **Flooding** and **Soil solarization** efficacy was facilitated by **organic amendments** inducing activation of soil microbes and accumulation of volatile compounds (Momma et al.2013)

- Until **methyl bromide** was available **non-chemical** disease-controlling methods received little attention and were not developed

How ASD was developed?

- After Montreal and Kyoto protocol and with the increasing concern about human health and environmental sustainability, **Shinmura** (2000) combined the classical flooding and soil solarization technique with organic amendment developing the **reductive soil disinfestation** method



Antarctic ozone hole (NASA – NOAA, 2006)

How ASD was developed?

- The **reductive soil disinfestation** method developed by Shinmura consists of:

  1) incorporation of organic matter (wheat bran, rice bran, molasses, …)

  2) irrigation to soil saturation

  3) covering the soil with plastic film

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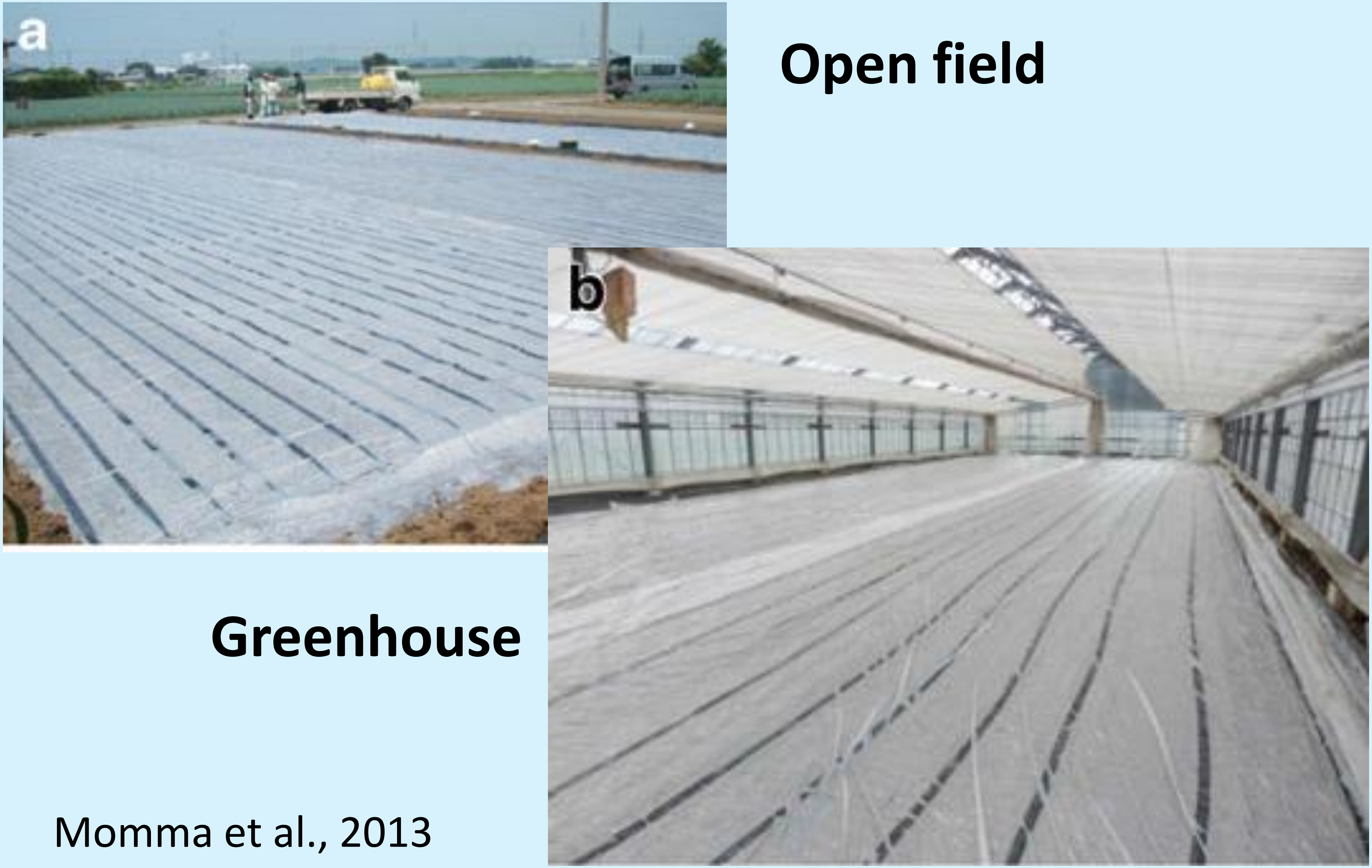
ASD: Background

- Today ASD is applied at commercial level
in both **open field** and **greenhouse**,
in **organic** and **conventional** farms,
in **Japan** in 33 prefectures out of 47
(Momma 2015, personal communication),
in **The Netherlands**,
in **USA** (California) on about **1,000** acres,
and is gaining large interest in **China**,
Europe and other Countries.

ASD: in Japan



Open field

Greenhouse

Momma et al., 2013

ASD: in Japan

ASD is applied even in soilless systems

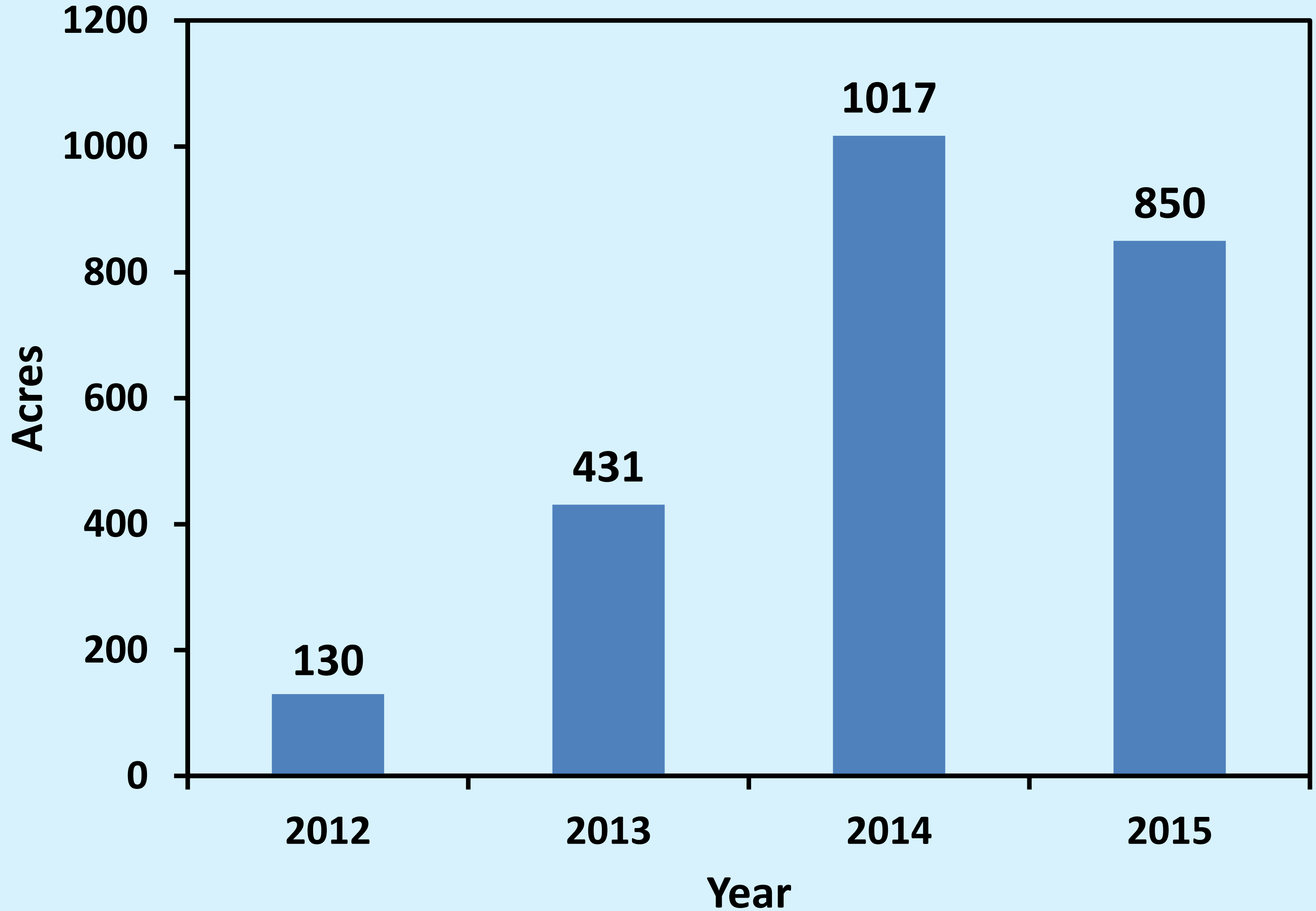
Momma et al., 2013

ASD: in California

Farm Fuel Inc. (FFI) personal communication www.farmfuelinc.com

ASD: in California

Cumulative ASD-treated acreages in California (all crops)



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ASD: in California

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ASD: in California

In 2013 on a total ASD-treated area of 431 acres (29 growers and 49 sites):

- **71%** were **organic** and **29% conventional**
- 59% were located in Northern California and 31% in Southern California
- Crop distribution was **71% strawberry**, **19% raspberry**, 10% other crops (vegetables, almond and walnut)

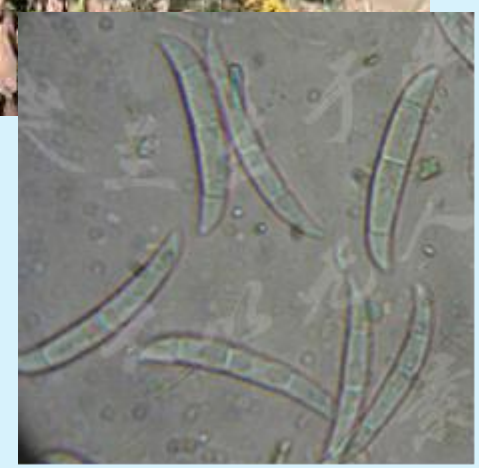
Farm Fuel Inc. (FFI) personal communication www.farmfuelinc.com

ASD: in China

Xinqi Huang, MBAO 2015

ASD: in China

Control of Banana Fusarium wilt (Xinqi Huang, MBAO 2015)



ASD: in China

Control of Banana Fusarium wilt

Control

RSD

Xinqi Huang, MBAO 2015

How to apply the anaerobic soil disinfestatio? in 3 steps

ASD: principle & application method

- Incorporate in the soil readily decomposable **organic material** (optimal **C:N = 30:1**)
  ✓ provide C source and activate soil microbes

- Cover with **oxygen impermeable tarp**
  ✓create/maintain anaerobic conditions and stimulate anaerobic decomposition of incorporated organic material

- **Irrigate the soil to saturation**
  ✓ saturate the soil, create anaerobic conditions and stimulate the anaerobic decomposition of incorporated organic material
  ✓ enhance diffusion of **by-products** in the soil

ASD: mechanisms

- Accumulation of **toxic/suppressive products** deriving from the anaerobic decomposition (e.g. **organic acids**, **volatile organic compounds**)
- **Biological control** by facultative anaerobic microorganisms
- Low pH
- Low oxygen
- Generation of **Fe^{2+}** and **Mn^{2+}** ions
- **Combination of all of these**

ASD: in Florida

Is ASD suitable for the Florida vegetable production system?

ASD: in Florida

- **Florida vegetable production system:**

✓Crops: tomato, pepper, eggplant, cucurbits
✓Raised-bed plasticulture
✓Sandy soils
✓Seepage and drip irrigation system
✓Good water availability
✓Summer fallow period (**good for cover crops**)
✓Solarization potential (Fall season)

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ASD: in Florida

- **ASD demonstrated to be effective against all the key soil-borne pathogens, nematodes and weed:**

✓ Phytophthora blight (*P. capsici*)

✓ Fusarium wilts (*F. oxysporum*)

✓ Southern blight (*Sclerotium rolfsii*)

✓ Charcoal Rot (*Macrophomina phaseolina*)

✓ Root-knot nematodes (*Meloidogyne* spp.)

✓ Yellow and purple **nutsedges** (*Cyperus* spp.)

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ASD: obstacles to adoption in Florida

- **Availability of low cost and consistent C sources**
  - ✓ locally-sourced waste products
  - ✓ cover crops
- **Organic amendment and Food Safety**
  - ✓ salmonella testing   Composting is the solution
- **Nitrogen management**
  - ✓ nitrate leaching and GHG emissions

ASD: Carbon sources and rates

- **Japan:** Rice bran, wheat bran, ethanol
- **The Netherlands:** Grass, potato haulms, crop residues
- **California:** Rice bran (4.5 to 9 t/acre; ~5.5 to 11 mg C g^{-1} soil)
  Mustard cake, mustard seed meal, almond hulls
- **Florida:** Liquid molasses (1,500 gal/acre 3.5 t DM/acre)
  Cover crop residue (variable)
- **Tennessee:** Dry molasses (~1.3 to 2.5 t/acre)
  Cover crop residue (variable, 1 to 4.2 mg C/g soil)
  wheat bran

ASD: potential C source in Florida

- **Warm-season cover crops fit well into existing Florida production systems**

- **Greenhouse study**

- 2 legumes: cowpea, sunn hemp

- 2 grasses: pearl millet, sorghum-sudangrass

- **Cowpea mixed with each grass**

All cover crops assured a level of anaerobiocity similar to that of molasses (Butler et al. 2012)

ASD: potential C source in Florida

- Yard waste compost

ASD: on tomato in Florida

- **2015 Spring experiment on fresh-market tomato**

  Treatments:

  PicClor 60 (200 lb/acre)

  ASD1 (9 t/acre CPL + 1,500 gal/acre of molasses)

  ASD2 (9 t/acre CPL + 3,000 gal/acre of molasses)

  Crop cycle: February 2015 – June 2015

  Irrigation: hybrid seepage - drip irrigation system

  Objective:

  evaluate the effect of ASD on weed and nematode control, fruit yield and quality

ASD: on tomato in Florida

Application of bottom mix

ASD: on tomato in Florida

Form false beds

ASD: on tomato in Florida

Composted poultry litter application

9 t/acre

ASD: on tomato in Florida

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Molasses application

Diluted 1:1 with water to facilitate application

ASD1 1,500 gal/acre **ASD2 3,000 gal/acre**

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ASD: on tomato in Florida

Organic material tilled into the top 8’’

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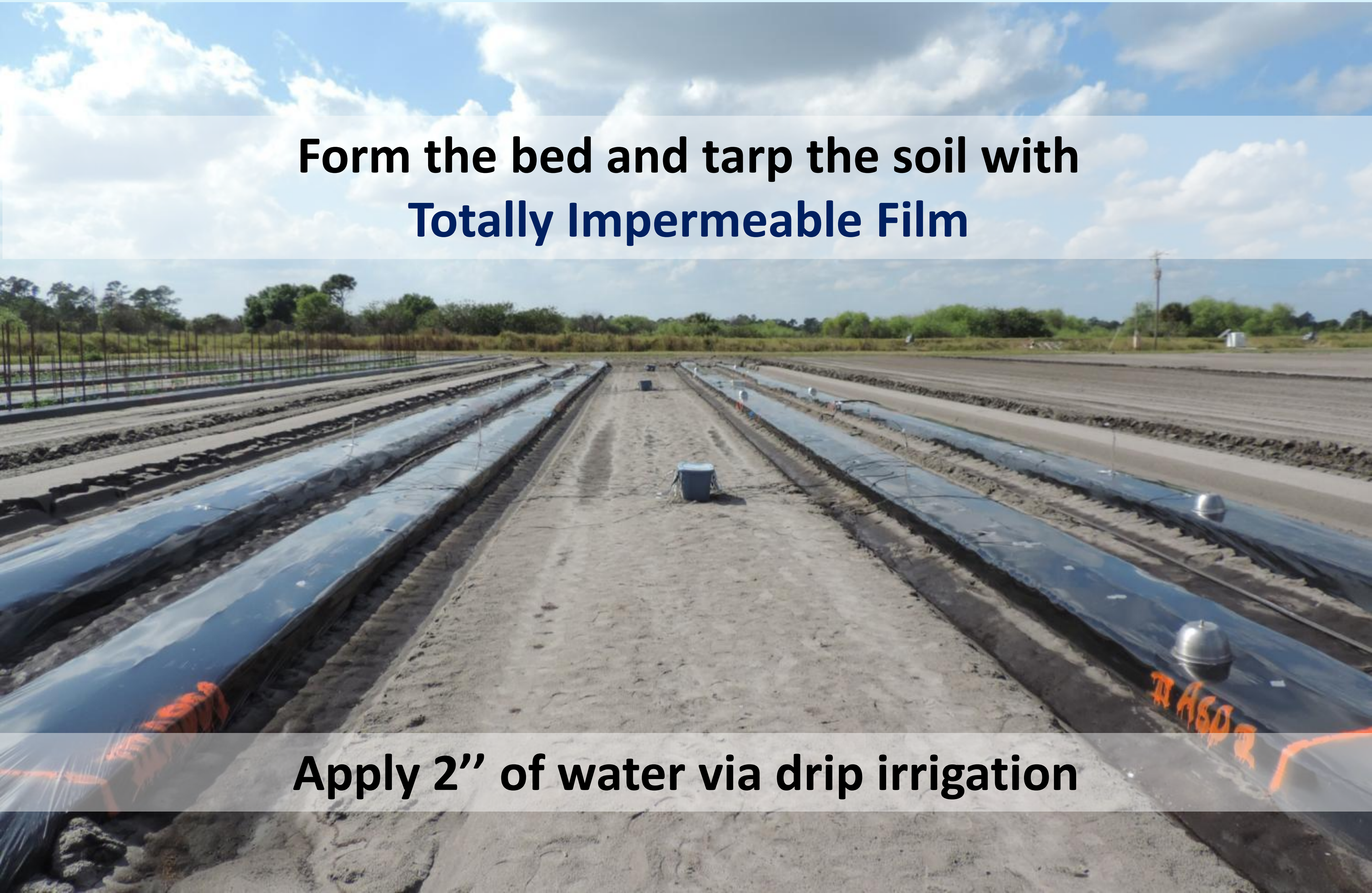
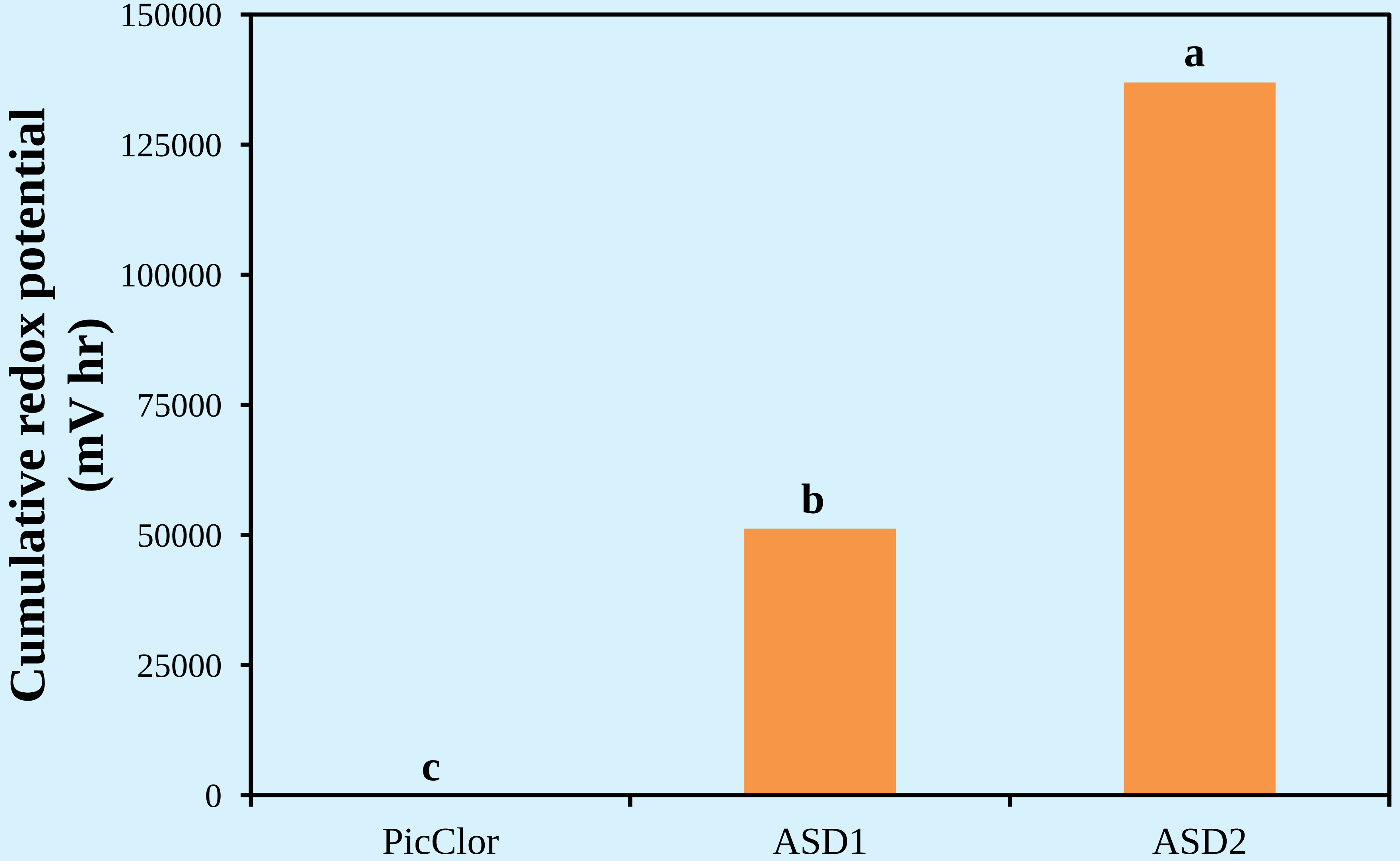
ASD: on tomato in Florida

Form the bed and tarp the soil with
Totally Impermeable Film



Apply 2'' of water via drip irrigation

ASD: cumulative anaerobicity



Means separation by Duncan's multiple range test at P = 0.05.

ASD: on tomato in Florida

3 weeks after ASD treatment it is possible to transplant

ASD: on tomato in Florida

ASD weed control in the alleys between beds

ASD: on tomato in Florida

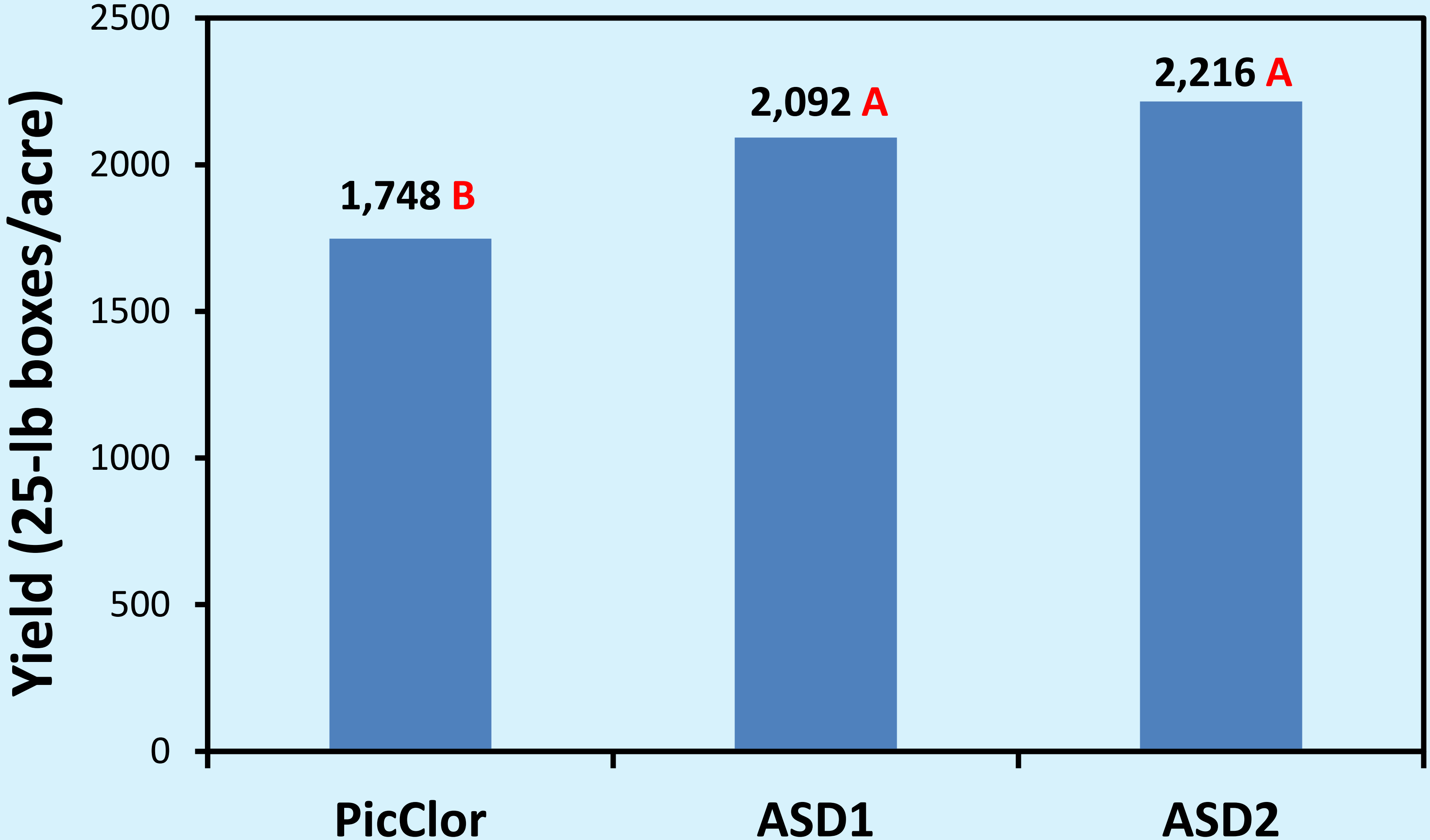
ASD parasitic and non-parasitic nematode control

Assessment timing	Treatments	Root-knot nematodes (J2 cm^{-3} soil)	Non pathogen (number cm^{-3} soil)
Pre-treatment		2.84	238.14
Post-treatment	PicClor	0.00	0.00 b
(21 DATA)	ASD1	0.00	2098.00 a
	ASD2	0.00	2840.80 a
	P-values	*na*	*0.004*
Harvest	PicClor	2.84	209.75
	ASD1	17.01	572.75
	ASD2	0.00	303.25
	P-values	*0.36*	*0.50*

NA by Nancy Burelle, Means separation by Duncan's multiple range test at P = 0.05.

ASD: on tomato in Florida

ASD effects on tomato marketable yield



Means separation by Duncan's multiple range test at P = 0.05.

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ASD: on tomato in Florida

ASD effects on tomato fruit quality

Treatments	Deformation (mm)	Color (1-6 scale)	Total soluble solids (Brix°)	pH (0-14)	Dry matter (g kg^{-1} FW)
PicClor	**2.42 a**	5.8	4.09	4.09	34.1
ASD1	**2.01 b**	5.6	4.08	4.12	32.7
ASD2	**1.91 b**	5.4	4.11	4.15	35.4
P values	**0.02**	0.17	0.93	0.42	0.4

Means separation by Duncan's multiple range test at P = 0.05.

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