Status of Race 4 *Fusarium oxysporum vas infectum* in California Cotton

Bob Hutmacher, Mauricio Ulloa, Mike Davis, Steve Wright, Mark Keeley, Gerardo Banuelos, Rebecca Bennett, Brian Marsh, Dan Munk, Raul Delgado, Pete Goodell

Thanks to:

- **Grower and PCA Cooperators**
- **Cotton Incorporated State Support Committee**
- **National Cotton Council**
- **CPCSD and CA Cotton Growers Alliance**
- **Supima Assoc., CA Department Food and Agriculture**
- **seed companies**

Fusarium wilt (FOV) Symptoms

Vascular staining *- easily seen in lower stem & upper tap root – how differ from verticillium vascular symptoms?*

1. *Seen more readily in root as well as lower stem*
2. *timing/growth stage when first seen much earlier*
3. *Staining tends to be more continuous rather than "flecking" or discontinuous discoloration*

Field Scale Symptoms:

- Typical field has affected areas about this size, with stunted “survivor” plants that produced harvestable bolls
- Other fields have had much larger affected areas

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Marsh,Keeley,Bennett

Large areas can be affected once the disease is established and inoculum levels increase

Early Observations – screening trials

- Planting date impacts were evident in multiple early field screenings, with reduced severity of impacts when plantings done under warmer, rapid germination conditions
- Screenings done under more challenging conditions (earlier, colder, wetter, range of seedling diseases) – typically result in higher mortality and more severe impacts (stunting, higher levels of plant damage)
- Early on identified Phy-800 Pima and several USDA-ARS experimental Pimas as consistently more resistant than other commercial Pimas & better than most Upland / Acalas)
- Gradually, with multiple years of plantings of at least moderately susceptible varieties, race 4 FOV disease symptoms and stand losses increased even in more resistant entries (such as Phy-800) and in Acala/Upland varieties (5-20% in general – generally <20% stand loss in worst areas) at first

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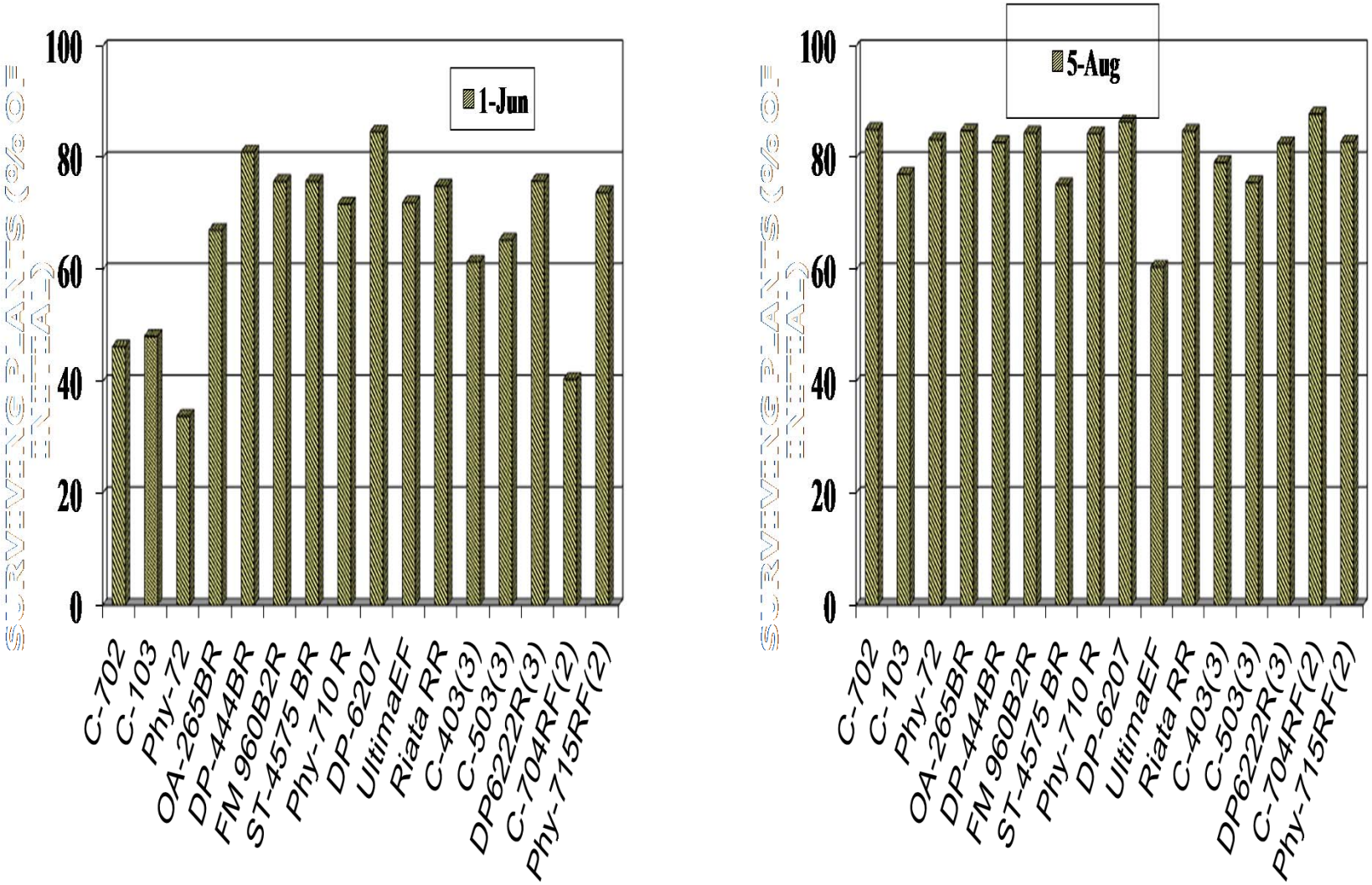
Stand Loss Evaluations (% OF INITIAL) – Kern Co. site-

Acala/Upland entries – 2 planting dates same site



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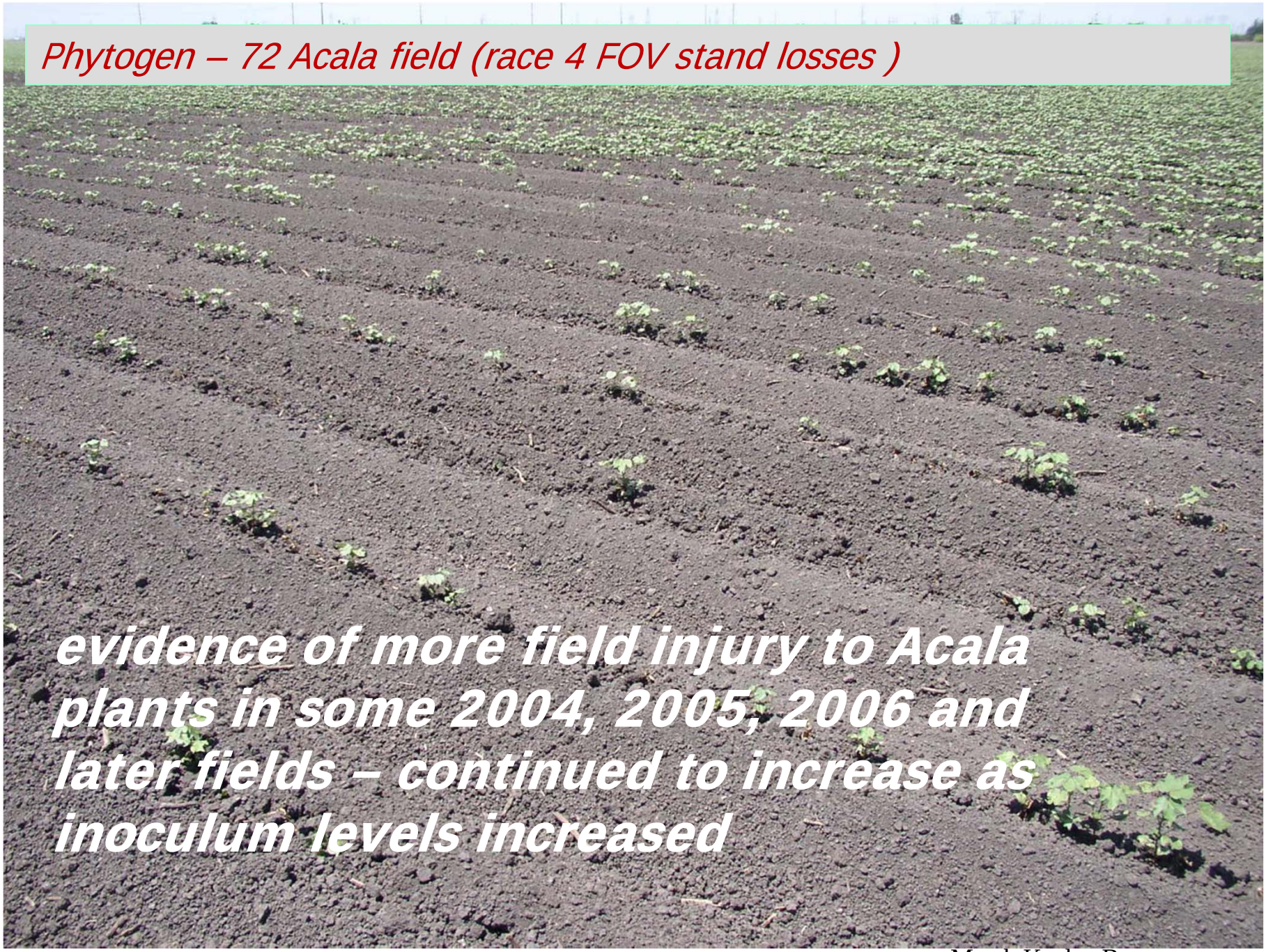
Phytogen – 72 Acala field (race 4 FOV stand losses)



evidence of more field injury to Acala plants in some 2004, 2005, 2006 and later fields – continued to increase as inoculum levels increased

Containment issues for growers as sites with FOV are identified ?

- *spores of this organism can be very long-lived - so limit practices that expand movement*
- *What rotation crops will reduce inoculum / pop'ns ? most non-cotton crops will reduce inoculum levels, but unlikely any crop will eradicate it*
- *Transmissable via infected seed? Yes – Rebecca Bennett, USDA-ARS confirmed possible (albeit at low frequency)*
- *Can this strain influence other crop spp? Highly unlikely, but can impact Acalas/Uplands and Pimas*
- *Can inoculum be spread in fields with soil transport or movement of plant parts (leaves, flowers,squares?) ...yes.. By irrigation? ...yes... cultivation ...yes*

Fields with FOV Race 4 confirmed by DNA-based plant sample pathology tests (*mid-2010 & part of 2011 in red)*

- **Fresno County**
  - Farm #1 (1 in 2001, 4 in 2003, 3 in 2006, 2 in 2010)
  - Farm #2 (3 in 2003)
  - Farm #3 (3 in 2004, 2 in 2009, 2 in 2010)
  - Farm #4 (2 in 2004, 3 in 2005, 1 in 2006; 3 in 2010)
  - 27 addt'l 2005-2010 **(+19)**
- **Kings County**
  - 17 fields 2004-2010 **(+ 13)**
- ***TOTAL confirmed fields over 200 since 2003***

- **Tulare County**
  - Farm #5 (1 in 2003, 1 in 2004, 2 in 2007; 2 in 2010)
  - Farm #6 (2 in 2005; 2 in 2010)
  - Farm #7 (1 in 2006; 2 in 2009)
  - 10 addt'l 2006-2010 **(+12)**
- **Kern County**
  - Farm #8 (1 in 2004)
  - Farm #9 (3 2005-6)
  - Farm #10 (2 in 2004, 1 in 2005, 2 in 2006-7
  - 13 addt'l fields 2006-2010) **(+8)**
- **Madera & Merced Co.** – sites identified in 2010 and 2011 **(+9)**

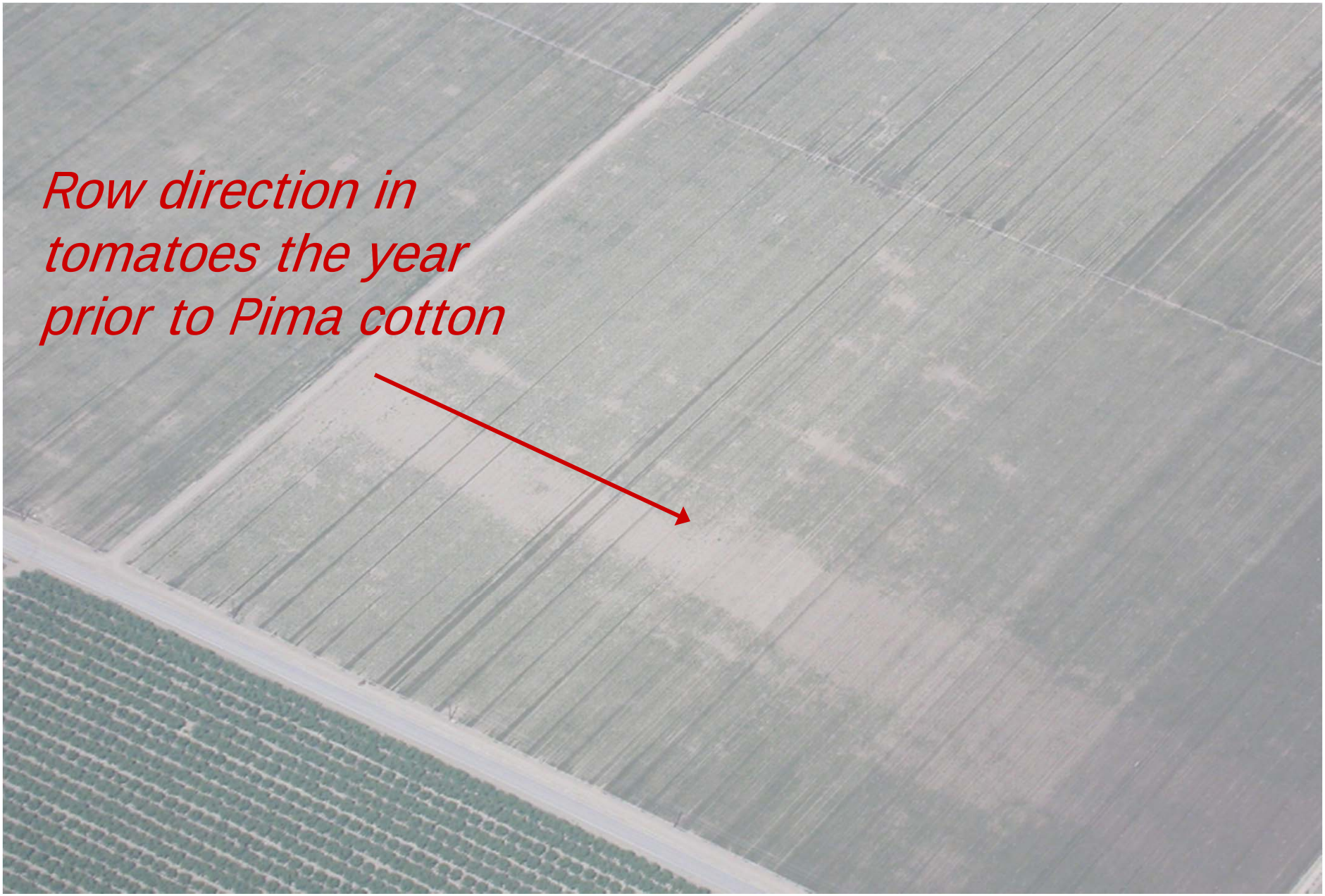
FOV Race 4 potential/likely – but not sampled pathologically – fields inspected / symptoms and vascular staining a match for FOV (most likely race 4 based on soil types (as of 6/15/08)

- **Fresno County**
  - Farm #1 (2 in 2003)
  - Farm #3 (2 in 2004)
  - Farm #4 (1 in 2006)
  - Farm #11 (1 in 2004, 1 in 2005
  - Farm #12 (1 in 2005)
  - Farm #13 (3 in 2006)
  - Farm #14 (2 in 2006)
  - Farm #15 (7 in 2006)
  - Farm #16 (2 in 2006)

11 addt'l fields in 2006 to 2008

- TOTAL of 71 separate fields in 7 of same farms as confirmed race 4 sites, plus 16 more farms
- Many more in 2009 through 2011

- **Tulare County**
  - Farm #17 (1 in 2005)
  - Farm #18 (1 in 2005)
  - Farm #19 (1 in 2006)
  - 9 addt'l fields in 2006-2008
- **Kern County**
  - Farm #8 (1 in 2004)
  - Farm #10 (1 in 2006)
  - Farm #20 (1 in 2006)
  - 7 addt'l fields in 2006-2008
- **Kings County**
  - 11 addt'l fields in 2005-2008



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Recommendations for Field Scouting for Fusarium – race 4 or others?

- Scouting needed EARLY in crop development….
- Differentiate between seedling disease losses and potential FOV by looking for dark, continuous vascular staining in tap roots, which is symptomatic of FOV (Fusarium)
- evaluations of fields best done from seedling stage if possible, but could start mid-squaring to no later than early bloom) to look for race 4 Fusarium symptoms (much easier to see than in late season or when Verticillium could be evident
- Make sure to scout seed production fields with extra efforts and care

Containment issues / rationale

- **WHAT CAN ANY OF THESE EFFORTS DO FOR YOU?**

1. Containment efforts buy some time while more resistant / tolerant varieties are found, developed and field tested for yield and quality as well as resistance
2. Better containment or slowing of disease spread allows you more years of broader choices in types of cotton to grow
3. Improves chances that you can identify areas for seed production fields


KEEP THIS FARM
FUSARIUM
WILT FREE


WARNING
COME CLEAN GO CLEAN
AUTHORISED ACCESS ONLY
RESTRICTED AREA
for
DISEASE CONTROL
FOR ACCESS AUTHORISATION PLEASE CONTACT
ANTHONY McALARY on 68 47 9197
or REPORT TO THE OFFICE UHF 4
AFTER HOURS CONTACT NUMBER
FARM MANAGER 0408 410 228
AGRONOMIST 0407 479 197

Containment / research issues

- *Evaluations of metam sodium applications and injections for upper soil treatment*
- *in-furrow and seed applied materials field evaluations and greenhouse evaluations*
- *flooding and solarization potential*
- *do evaluations on both more susceptible entries as well as moderately resistant varieties as space allows*
- *idea is that materials ineffective on highly susceptible varieties might be able to reduce infection rates or impact survival in more tolerant varieties*

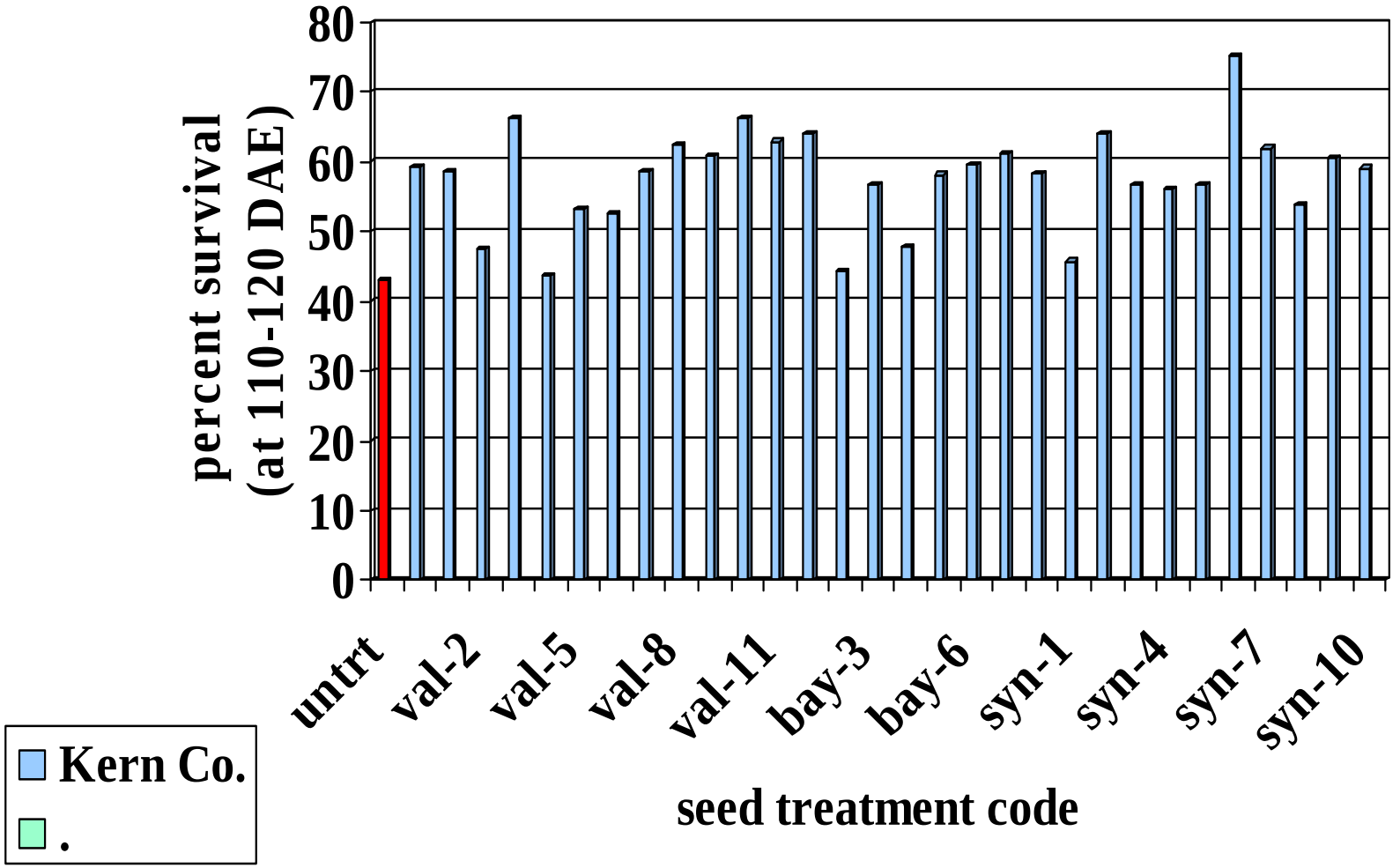
Seed Treatments

A range of seed-applied chemical treatments were field tested in known infested fields on cotton varieties known to vary in resistance to FOV race-4.

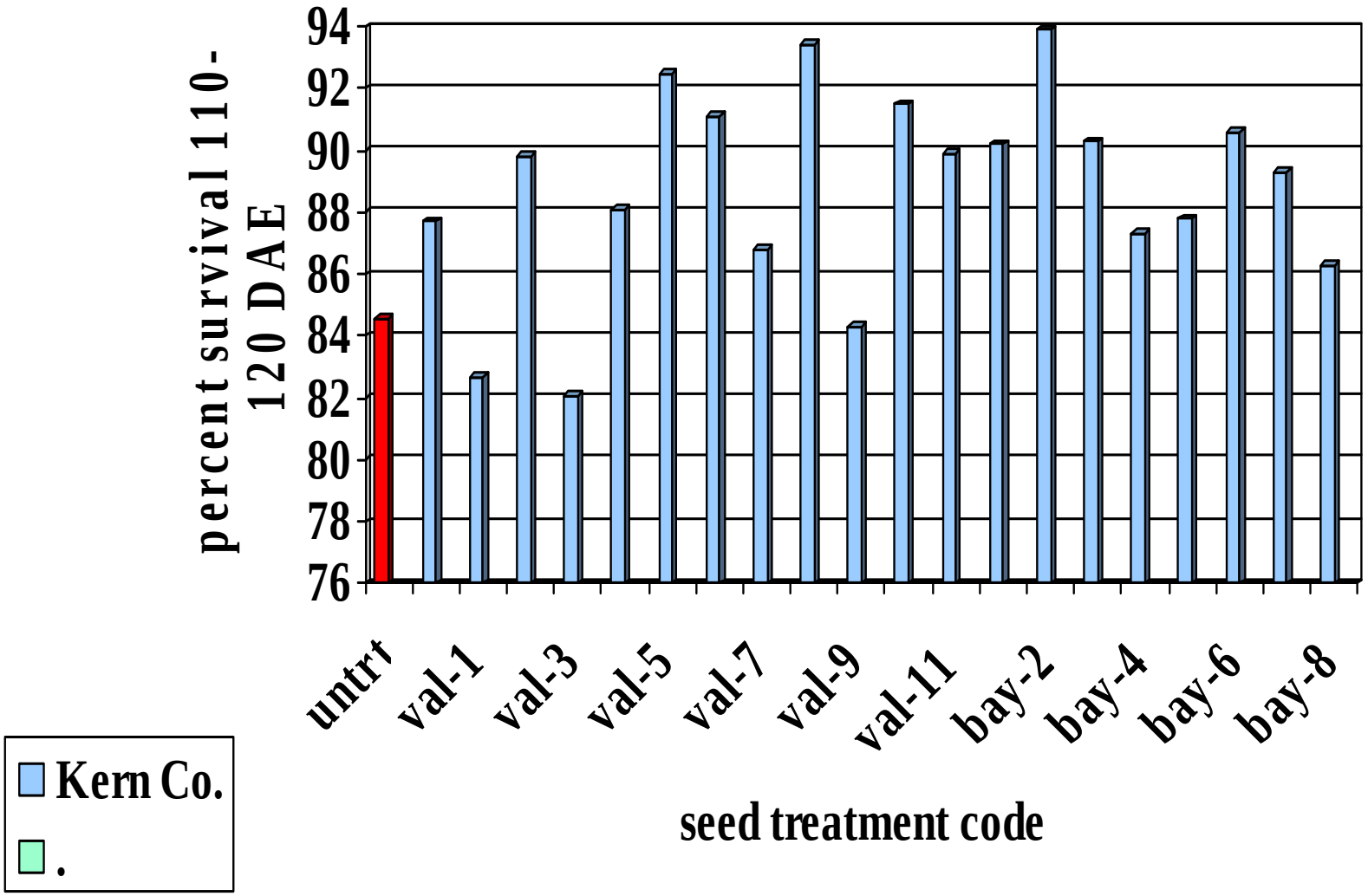
The mix of chemicals evaluated included many commercially-available and currently-utilized seed treatments for cotton in the U.S. production areas, plus some experimentals not fully described to the investigators at this time.

The figures shown indicate average responses from a site with what plant bioassays would suggest high race 4 inoculum levels.

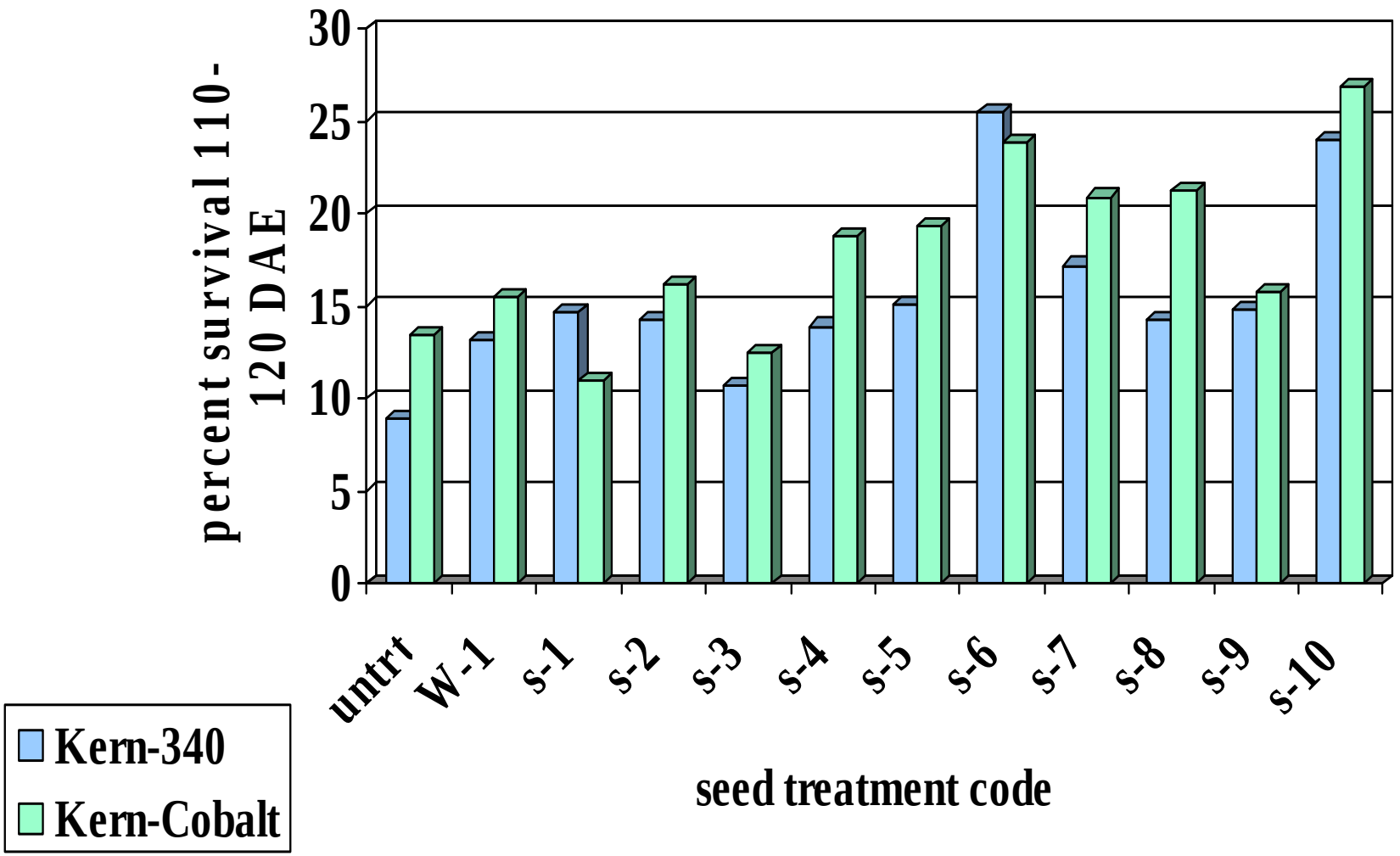
Percent plant survival at 110-120 DAE across seed-applied treatments from range of companies for widely-grown Acala varieties (Phy-72 and Summit, two-year and two site averages).



Percent plant survival at 110-120 DAE across seed-applied treatments from range of companies for widely-grown Pima variety (Phy-800) generally identified as more resistant to FOV race 4 losses.



Percent plant survival at 110-120 DAE across seed-applied treatments from range of companies for widely-grown Pima variety (DP-340 or CPCSD-Cobalt) generally identified in earlier screenings as less resistant to FOV race 4 losses.



Soil treatments, in-furrow and seed treatments

- Soil treatments (Bennett et al, Hutmacher et al):

MeBr:Chloropicrin significant control, but too expensive for broad application since spores more widespread over time. Metam sodium, telone-II some efficacy, perhaps more useful for spot treatments to reduce inoculum survival and impacts on plants (some growers this year trying drip-injected Metam sodium, alternatives such as steam treatments in “hot spots”).

- In-furrow treatments:

No materials tested to date had major impact when tested on susceptible or moderately susceptible varieties. Some data shows more efficacy if used on more resistant varieties.

- Seed treatments:

Chemical seed treatments tested to date not effective with susceptible or moderately susceptible varieties.

Roadblocks or at least limits in sanitation to limit soil movement

- **crop rotation (careful attention to avoiding wet soil operations and movement – must carry on through rotatiolettuce, tn crops to work) ie. Harvest operations in omatoes, etc.**

- **dust control measures / road watering**

- **efficient water use efforts – tailwater reuse and recovery methods**

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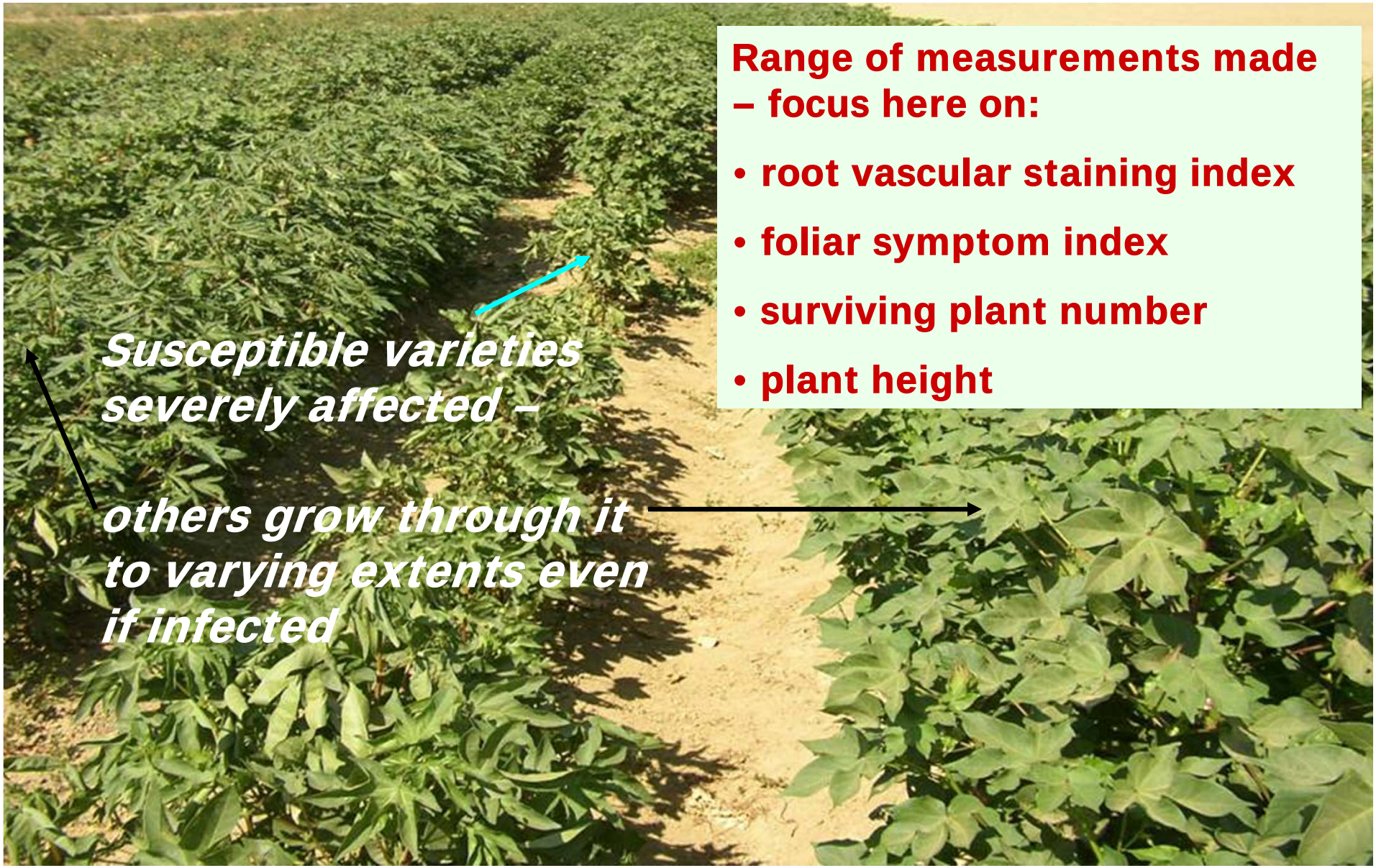
Varietal Resistance Evaluations of Race 4 *Fusarium oxysporum vas infectum* in California Cotton – 2003-2011

Bob Hutmacher, Michael Davis, Mauricio Ulloa, Steve Wright, Brian Marsh , Dan Munk, Mark Keeley, Gerardo Banuelos, Rebecca Bennett, Richard Percy, Monica Biggs, Sarah & Kelly Hutmacher, Anna Brown, Raul Delgado, Univ. CA Shafter and Kearney Res. Ext. Center staff

Thanks to:

- **Grower and PCA Cooperators**
- **National Cotton Council, Cotton Inc. State Support, CPCSD Grower Board, CCGGA, Supima Association**
- **seed companies**

Field Variety Screens – FOV race 4 sites



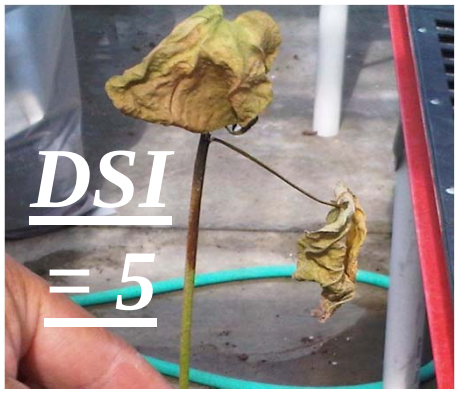
Range of measurements made – focus here on:

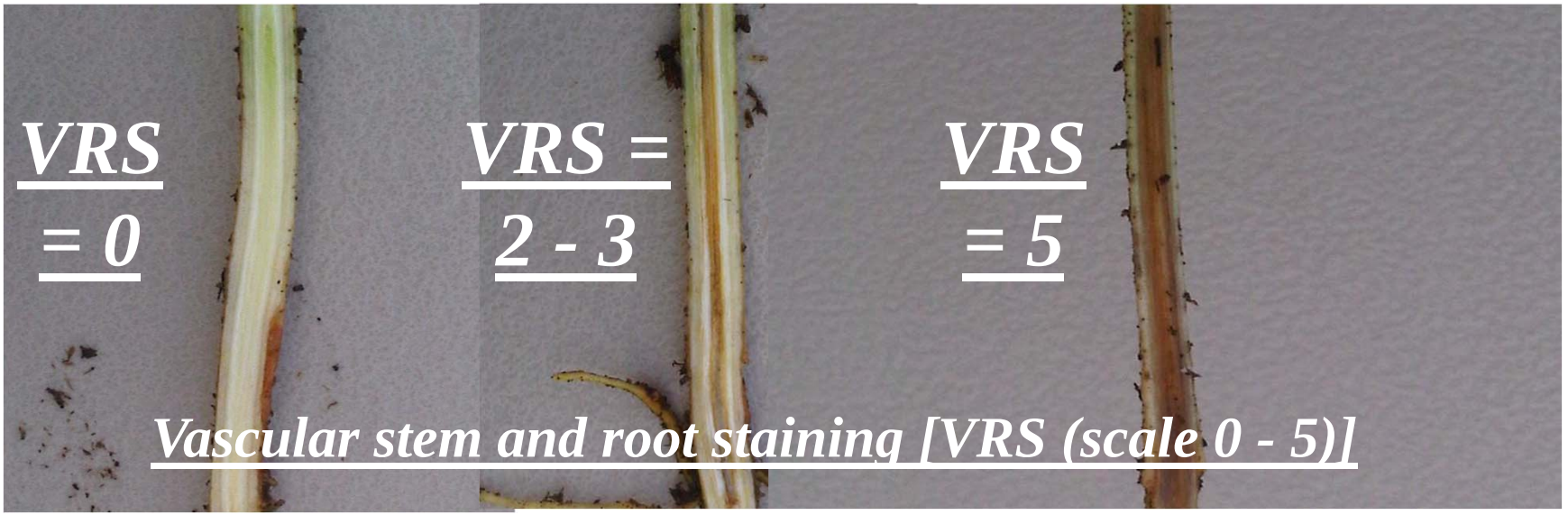
- **root vascular staining index**
- **foliar symptom index**
- **surviving plant number**
- **plant height**

Plant Infection

Resistant < 2.0 & Susceptible > 2.0

Disease severity index (DSI) of leaves, (scale 0 – 5)



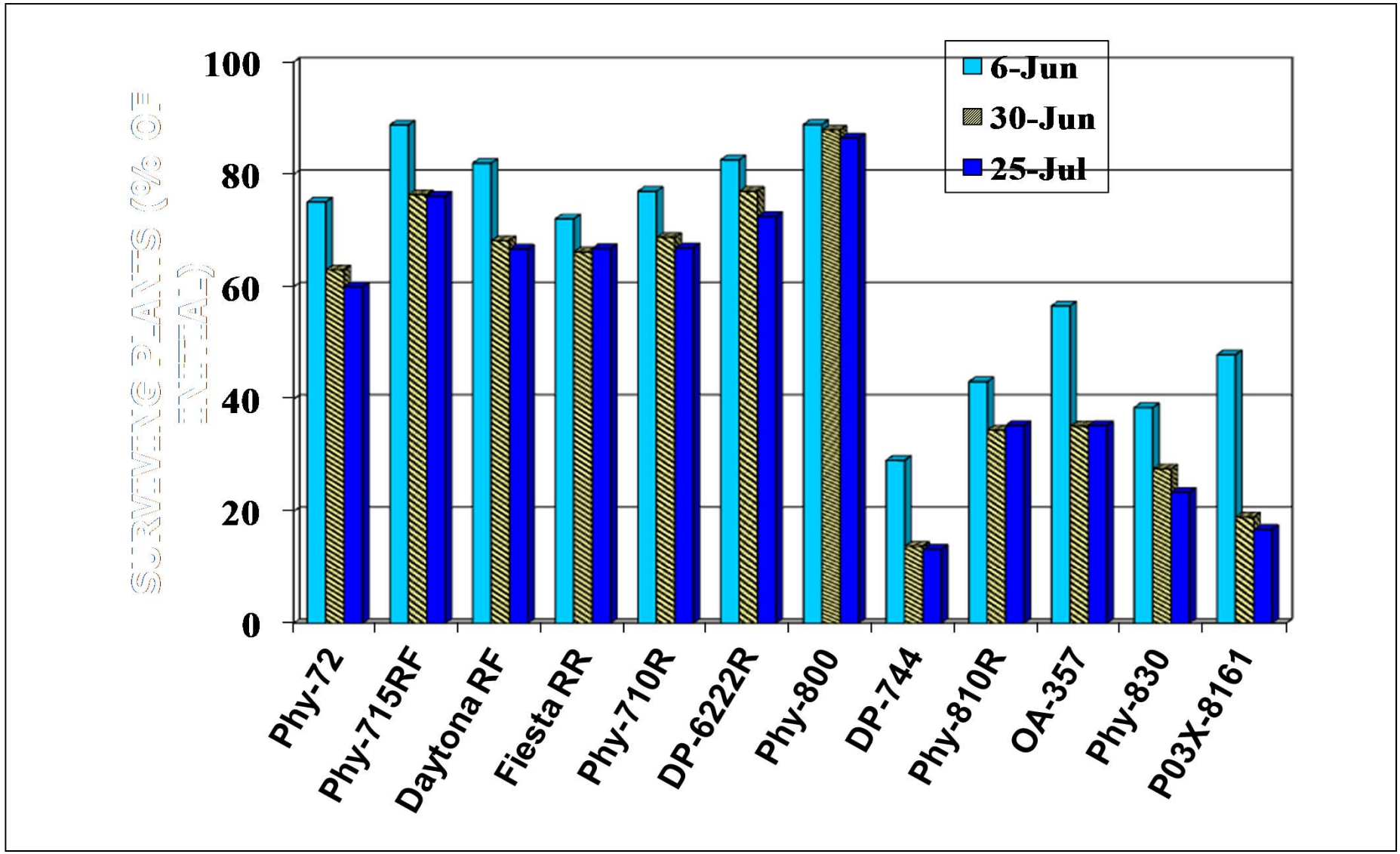


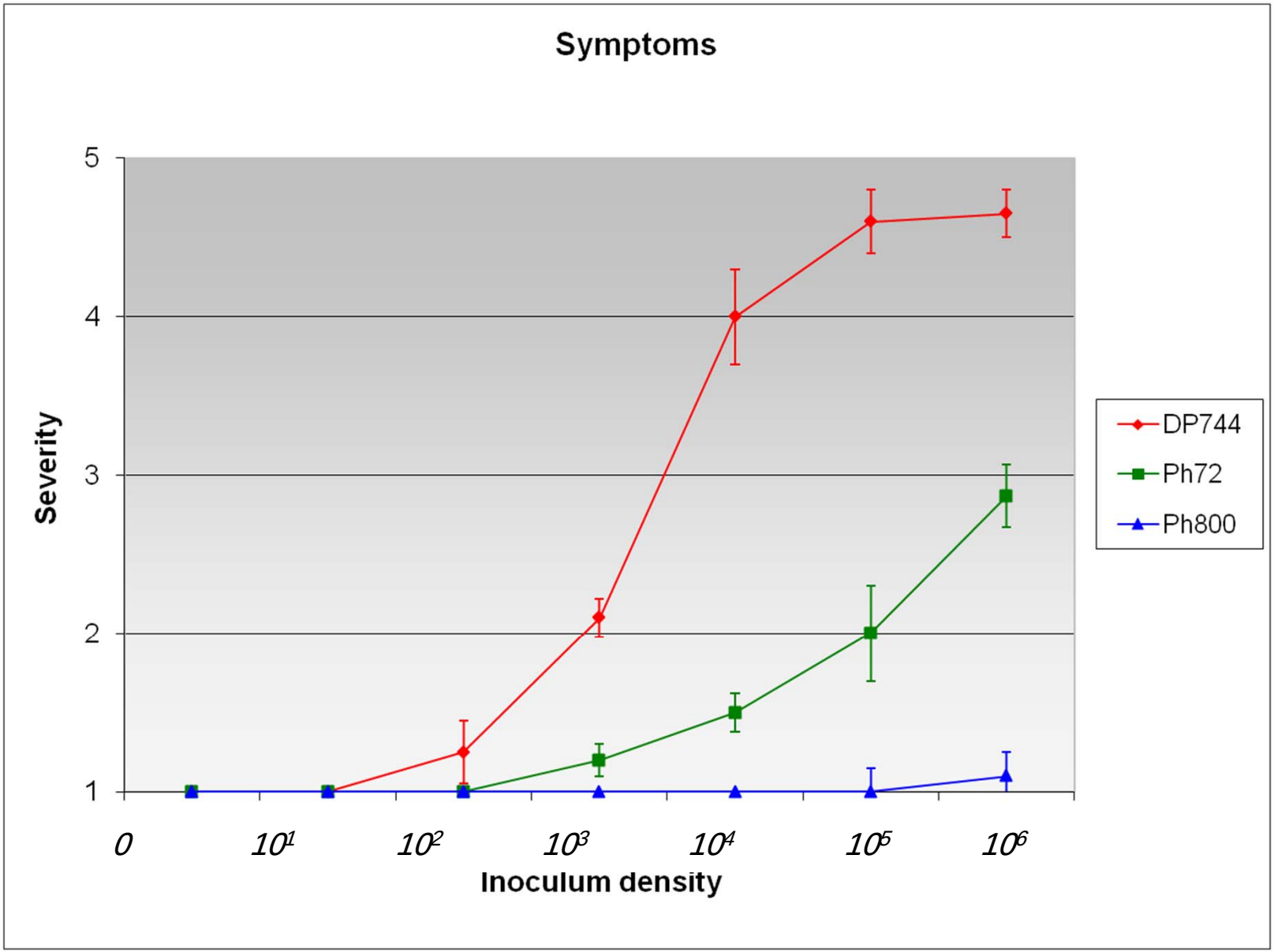

Phy-800
race 4 FOV
tolerant”
DP-744 Race 4
FOV
susceptible
V
5311
05
R
V
5311
05
S

Evaluation Date Effects

Stand Loss Evaluations (% OF INITIAL) –

Kern Co. site- Acala / Pima entries in May 17 planting




Symptoms
Severity
5
4
3
2
1
0
10¹
10²
10³
10⁴
10⁵
10⁶
Inoculum density
DP744
Ph72
Ph800

Impacts of different years & conditions on stand survival % of select varieties – FOV race 4 sites (Upland in black, Pima in red

VARIETY	Year 1 Fresno	Year 2 Kern	Year 3 Kern	Year 4 Fresno	Year 4 Kern	Year 5 Fresno	Year 5 Kern	Year 6 Fresno	Year 6 Kern
Phy-72	80	77	33	72	60	61	22	41	38
Ultima RF	91	83	71	76	70	88	39	43	48
Phy-725RF			52	79	68	78	34	36	53
Phy-800	93	95	90	88	87	96	78	85	84
Phy-830			27	43	21	22	6	20	14
DP-744	27	8	5	17	12	16	4	4	10

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Impacts of different years & conditions on root vascular stain index of select varieties – FOV race 4 sites

VARIETY	Year 1 Fresno	Year 2 Kern	Year 3 Kern	Year 4 Fresno	Year 4 Kern	Year 5 Fresno	Year 5 Kern	Year 6 Fresno	Year 6 Kern
Phy-72	2.0	1.8	2.6	1.7	2.1	2.2	2.7	1.9	2.5
Ultima RF	1.3	1.65	2.4	1.5	1.45	1.7	2.6	2.1	2.3
Phy-725RF			2.3	1.6	1.6	1.8	2.4	2.4	2.1
Phy-800	0.2	0.6	0.8	0.65	0.8	0.4	0.95	0.4	0.7
Phy-830			3.3	1.75	2.3	2.85	3.0	2.7	3.4
DP-744	3.5	3.7	4.5	2.75	3.1	2.85	3.3	4.1	3.7

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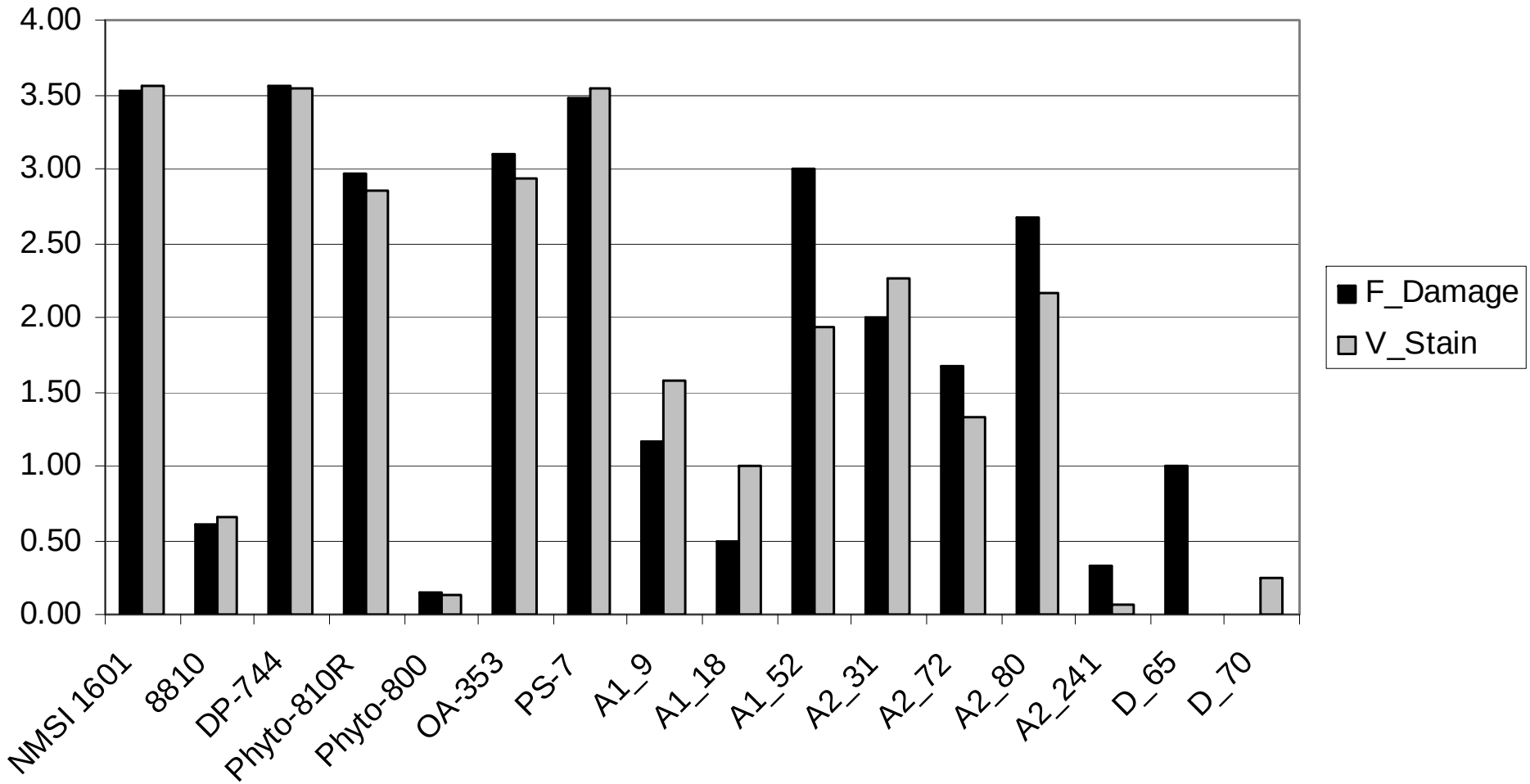
Evaluations for Resistance to FOV 2003 - 2011

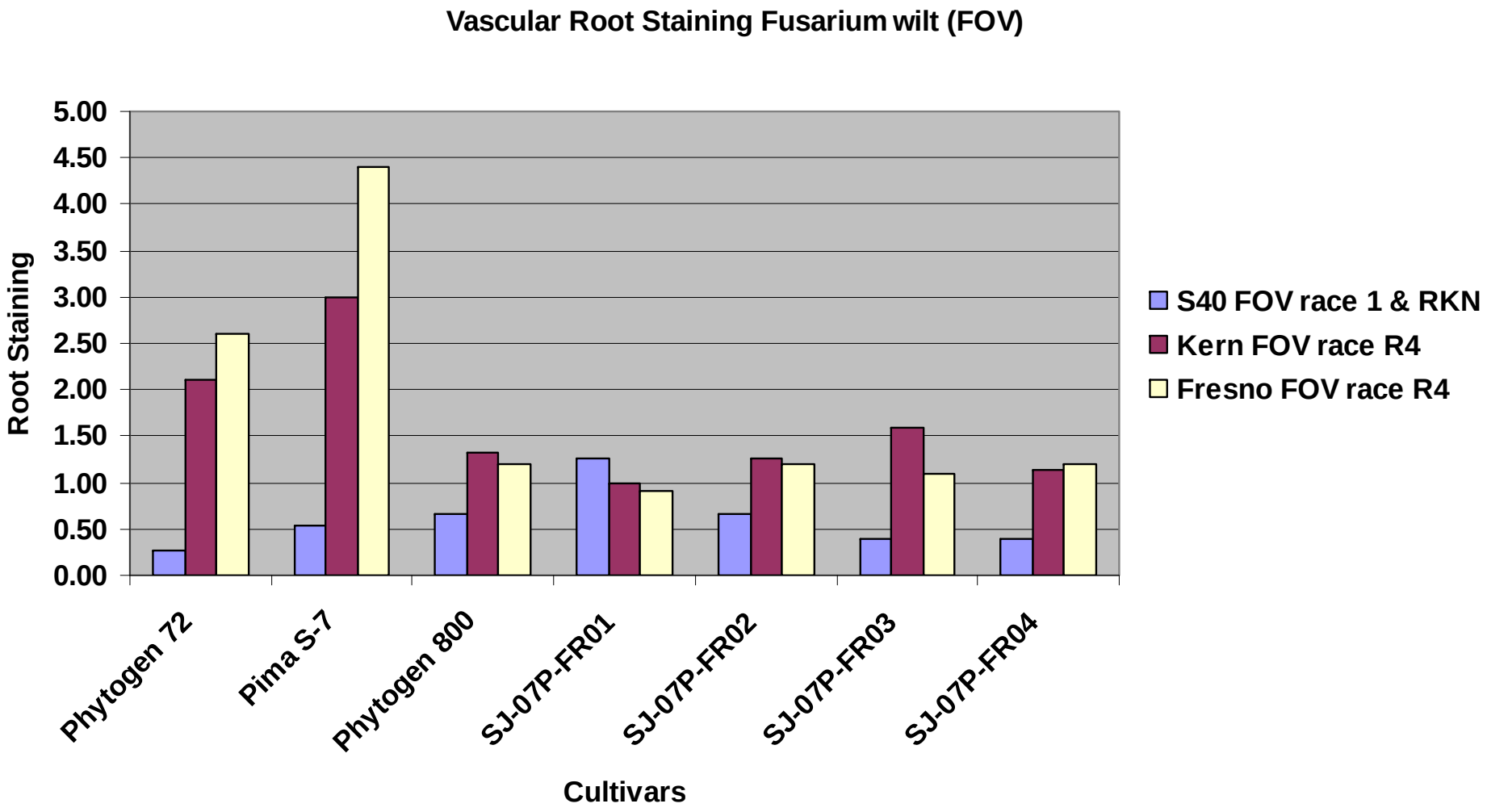
- Field and Greenhouse Evaluations
  - FOV race 4

More than 15,000 plants have been assayed in multiple greenhouse and field evaluations representing more than 1000 progeny of selected crosses, germplasm breeding lines, and commercial cultivars.

Identification of Resistant Sources from Early Evaluations Pima Cottons and Accessions



Root Vascular Stain Evaluation



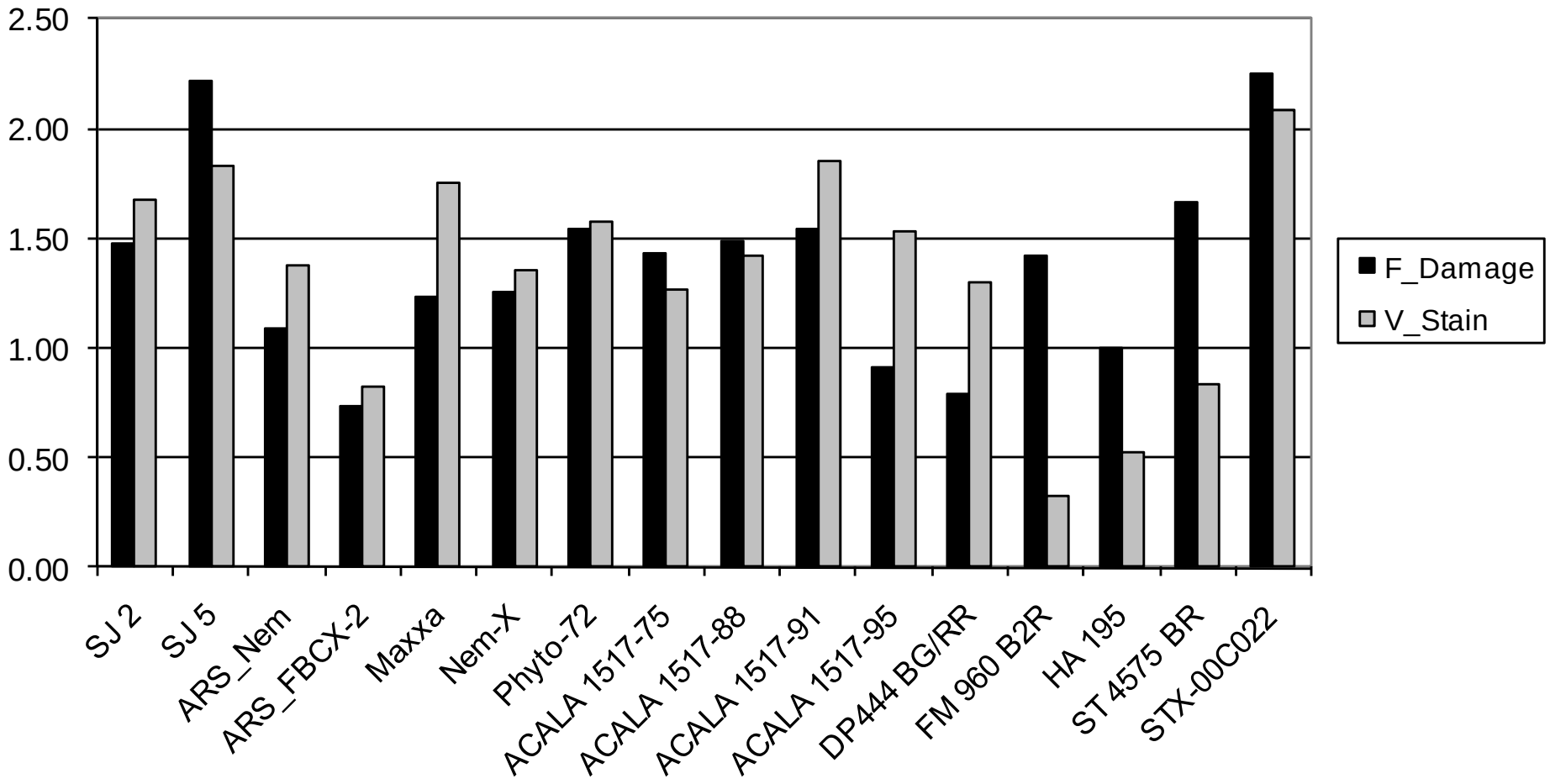
FOV race 1 = R1, FOV race 4 = R4, & Root-Knot Nematode = RKN

Four Pima Germplasm Lines Jointly Released by USDA-ARS, Univ. of California, & NMSU

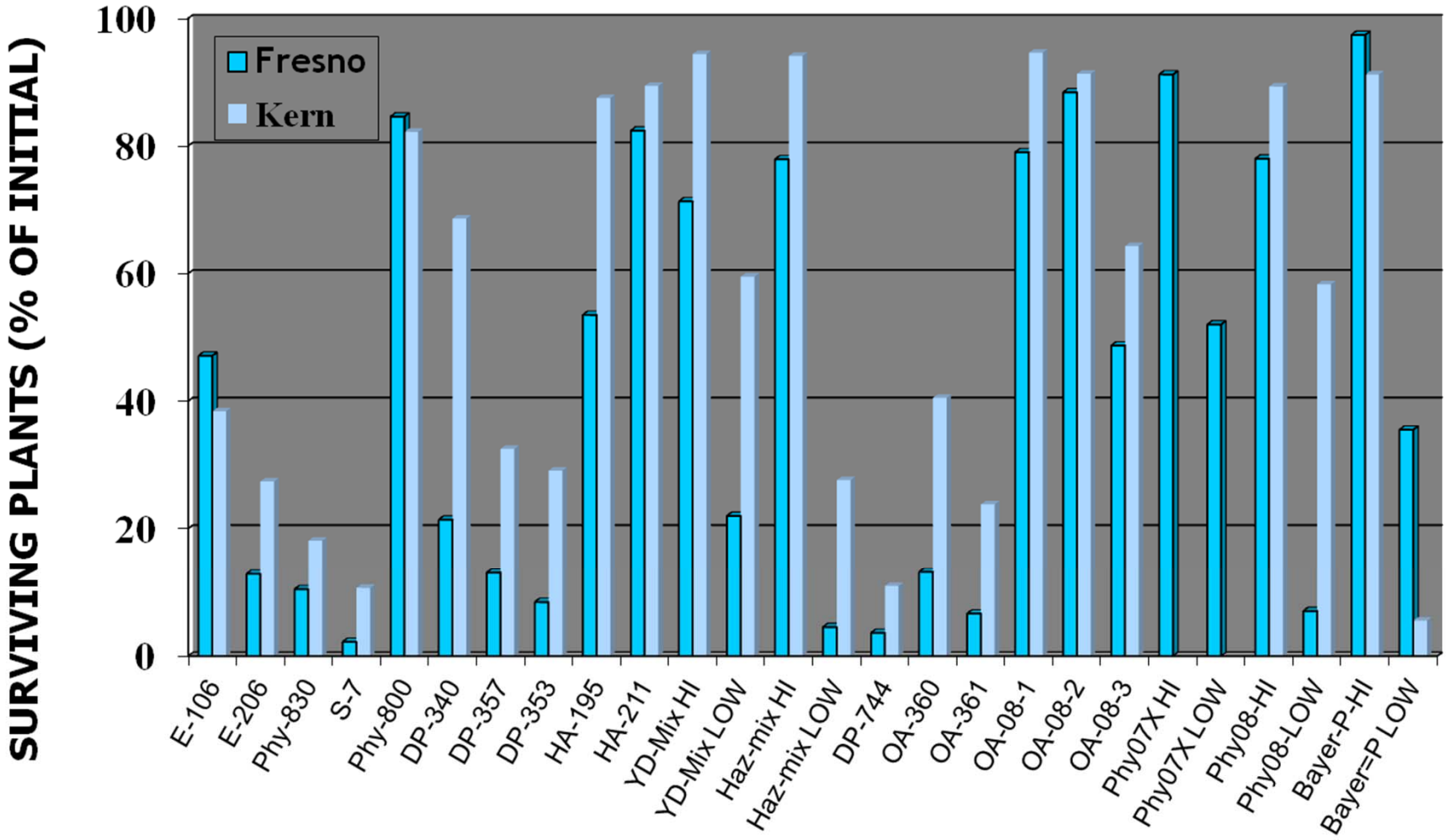
- ***SJ-07P-FR01***
- ***SJ-07P-FR02***
- ***SJ-07P-FR03***
- ***SJ-07P-FR04***

- *Continuing efforts for releasing additional germplasm with improved Yield, Fiber, and Pest Resistance*

Identification of Resistant Sources from Early Evaluations Acala and Upland Cottons



Stand Loss Evaluations (% OF INITIAL) – Fresno Co. 2008 Pima entries



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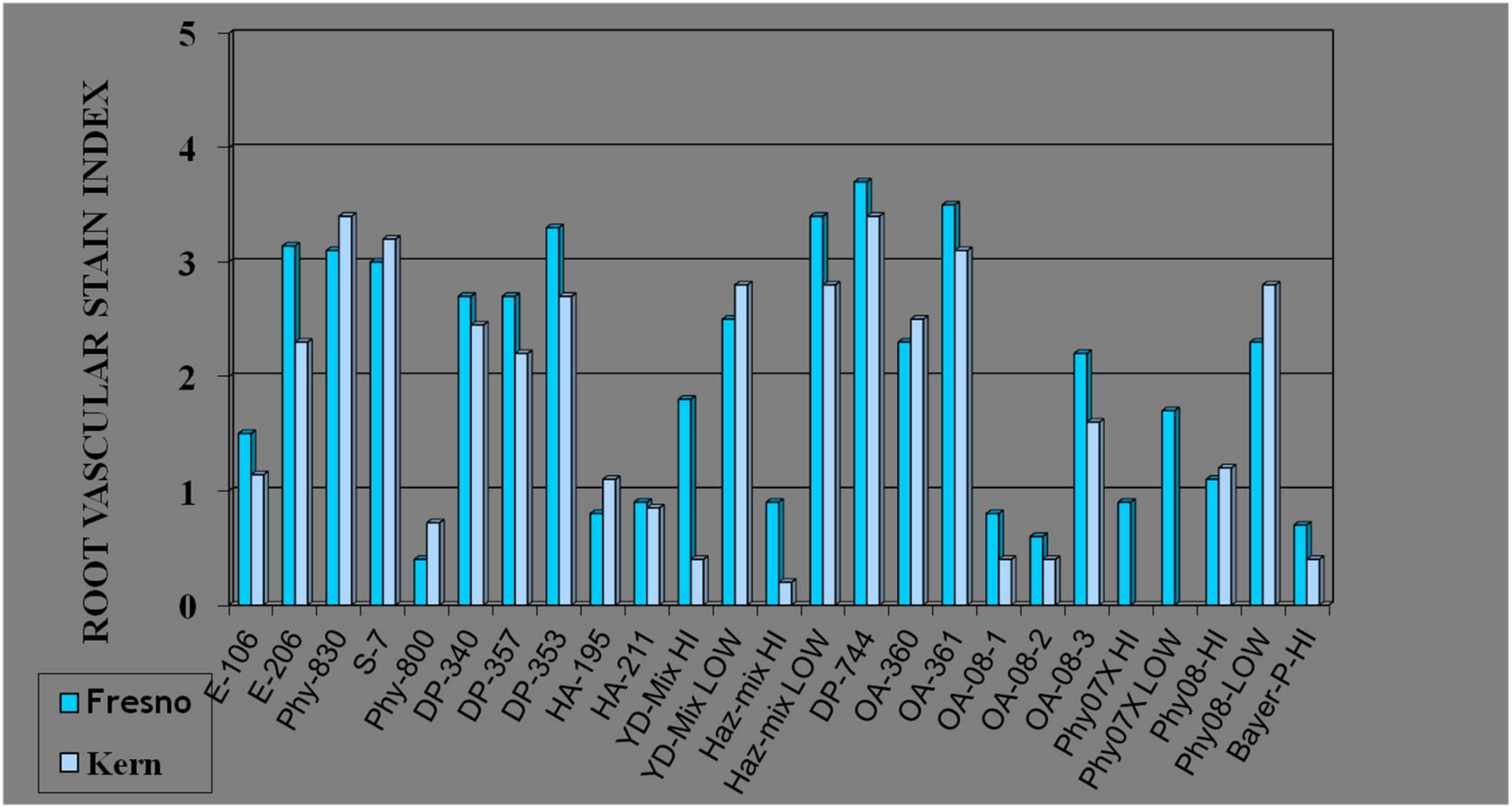
(12/08)

Root Vascular Stain Index – Fresno & Kern Co. 2008

Pima entries – Commercials & Expt's



Hutmacher, Ulloa, Wright, Davis,
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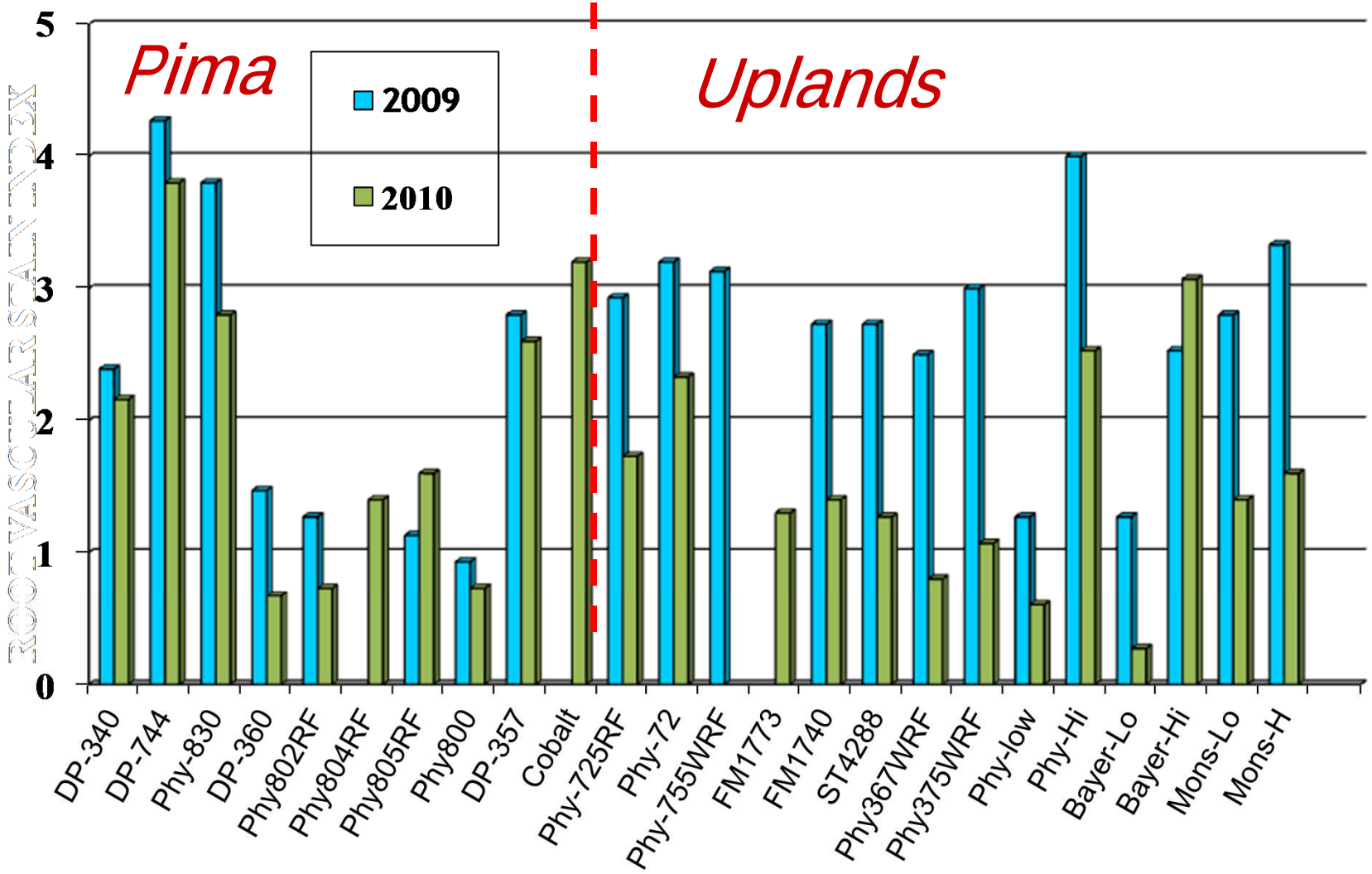
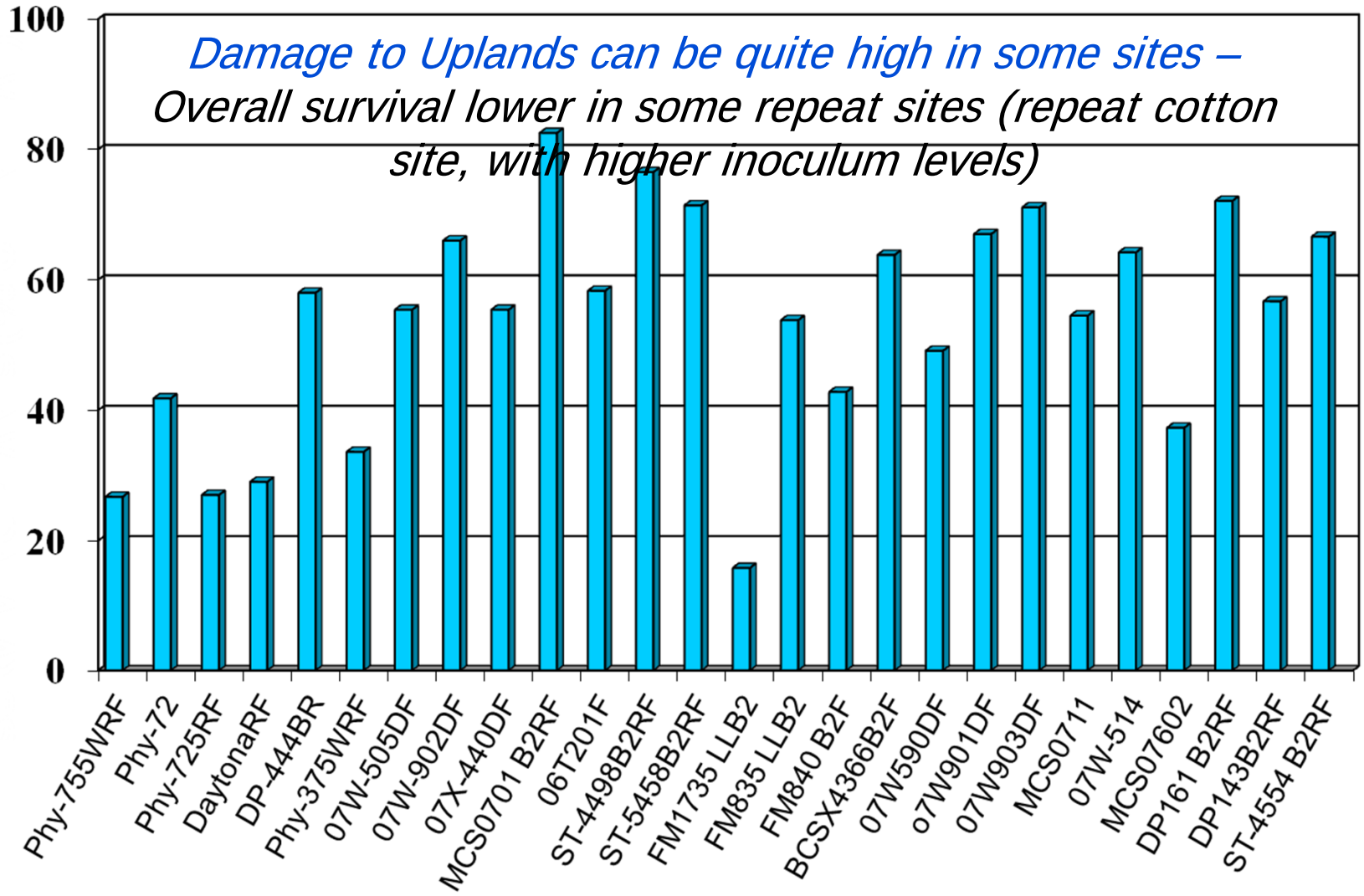
(12/08)

Vascular Stain Index – Kern Co. 2009 & 2010
Commercial & Experimental PIMA and ACALA/UPLANDS

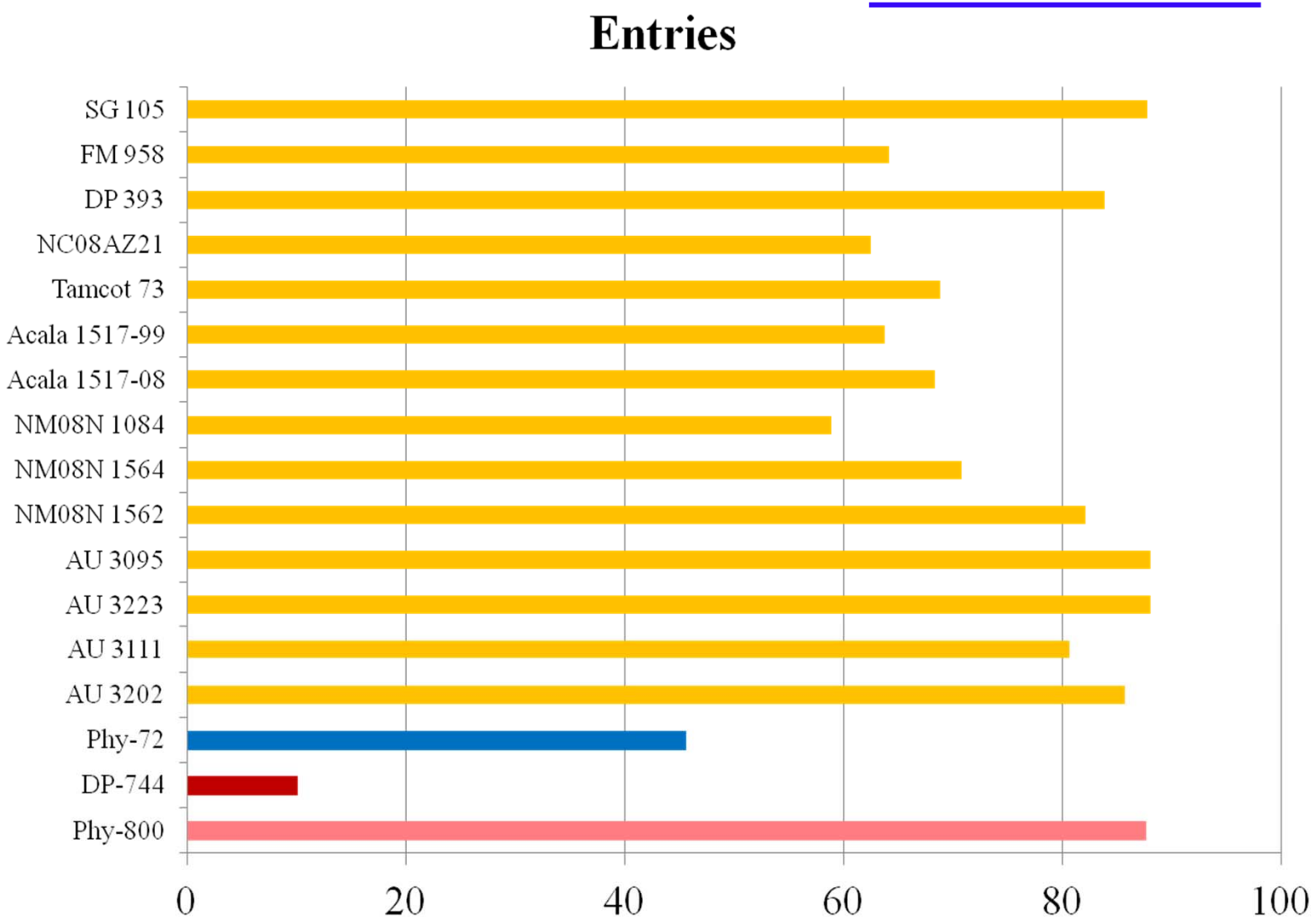


Stand Loss Evaluations (% OF INITIAL) – Kern Co. 2009 Upland / Acala entries - Commercials



Plant Survival Percentage – West Kern site – 2011-

RBTN second set



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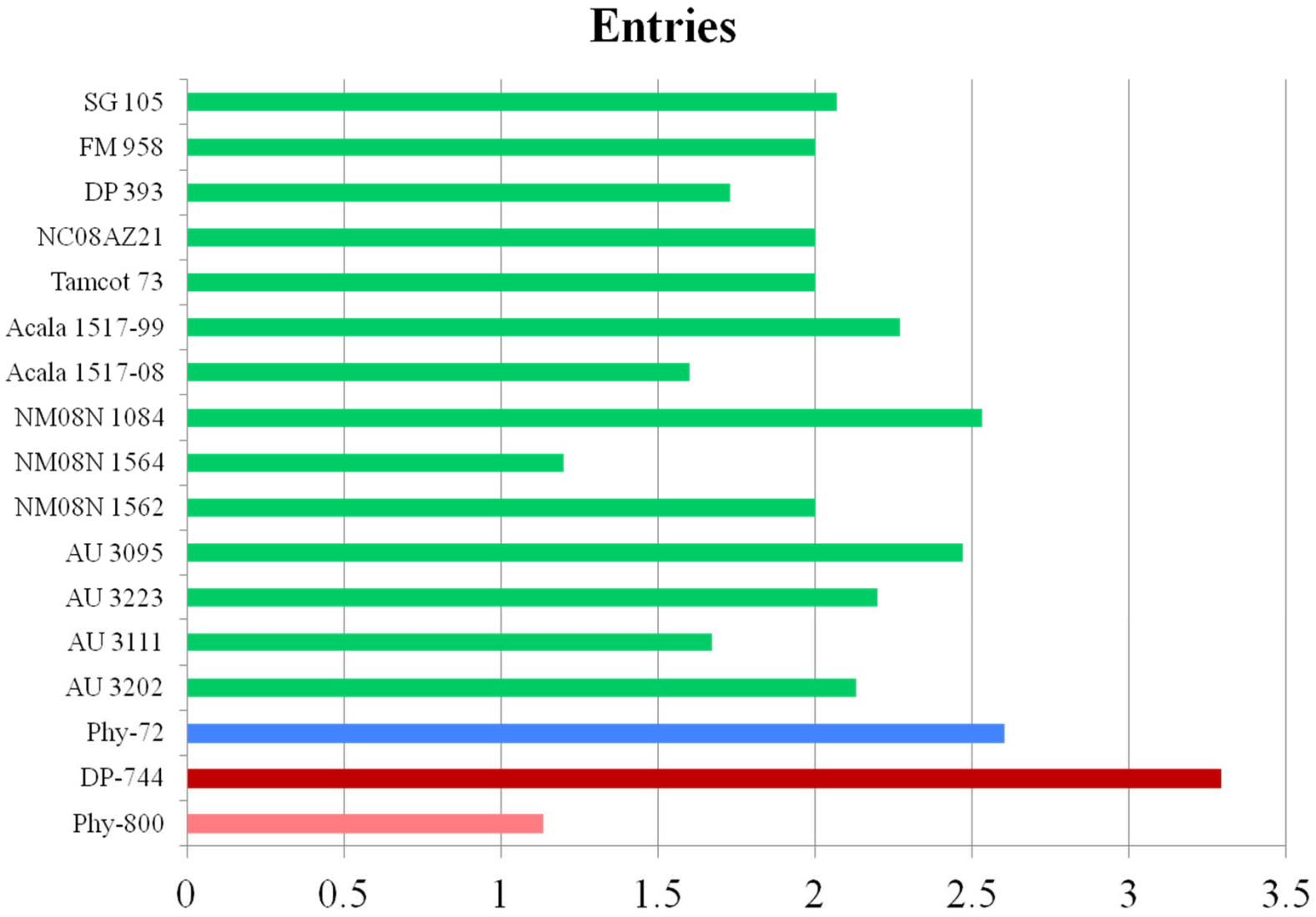
Vascular staining index rating – West Kern site – 2011-

RBTN second set



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SUMMARY

- **FOV race 4 recognized within past 9-10 years in California**
- **Many evaluated Pima varieties observed to be more susceptible to & damaged by FOV race 4 (stand loss, stunting, etc) than most evaluated *G. hirsutums,* but Uplands tested to date clearly have been broadly susceptible to race 4 FOV**
- **Some continuing results show some Pima germplasm with more complete resistance to race 4.**
- **The impact for Acala and Upland cottons (stand loss, stunting generally milder than on susceptible Pimas, but still a problem, since Acala/ Upland cottons were infected by FOV race 4 up to levels that could cause damage at higher soil inoculum levels**
- **Continuing screening and efforts needed both in commercial and public breeding programs**

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Munk, Keeley, Marsh, Banuelos

Further information (symptoms, containment recommendations) available on UC cotton web site:

http://cottoninfo.ucdavis.edu

Thank you

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Marsh,Keeley,Bennett