Choosing the Right Rootstock for Your Almond Orchard

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Half of the tree is underground!

- **Roots have a large impact on performance of the above ground portion of a tree**
- **Almond trees are “tailor made” at the nursery allowing a grower to choose a variety and rootstock independently**
- **Growers often agonize over which varieties to plant but ignore rootstock**

According to Southwick et al., 1999….

….. a desirable rootstock is

- **easy to propagate**
- **has good anchorage**
- **has resistance to all major pests and diseases**
- **is free from suckering**
- **controls tree size to a degree (high yield efficiency)**
- **produces large crops**
- ****is tolerant to all chemical soil problems****

Such a rootstock does not currently exist !

Although a rootstock that's desirable in all respects may not currently exist…

…..rootstock characteristics *can* make a difference in an orchard's economic viability under certain limiting conditions.

Functions of Root Systems ---

- Anchorage
- Absorption of water & nutrients.
- Synthesis of plant hormones
- Storage

Functions of Root Systems ---

- **If water supply is limited, soil conditions marginal, or nematodes or diseases are present then the rootstock choice becomes especially important.**

- **Some rootstocks perform certain functions better than others.**

Rootstocks Commonly Used for Almond in California

- **Nemaguard (seedling)**
- **Lovell (seedling)**
- **Marianna 2624 plum (cutting)**
- **Peach / Almond Hybrids (clonal or seedling)**
  - Hansen, Nickels, Brights, Titan, Cornerstone, etc.
- **Complex hybrids (peach, almond, plum, apricot) - cutting**
  - Viking, Atlas

Nemaguard & Nemared (peach)

- **Advantages**
  - “Immune” to rootknot nematode
  - Vigorous rootstock
  - Compatible with all almond varieties
  - Performs well in sandy loam & loam soils
  - “Decent” anchorage
  - Industry standard in San Joaquin Valley

Nemaguard & Nemared (peach seedling)

- **Disadvantages**
  - *Susceptible to:*
    - ring & root lesion nematodes
    - bacterial canker
    - Phytophthora
    - Oak root fungus
    - Crown gall
    - High soil pH / high lime
    - High salt in soil & water (sodium, chloride, boron)

Lovell (peach seedling)

- **Advantages**
  - Better anchorage than Nemaguard
  - Slightly more tolerant of wet soil than Nemaguard
  - More tolerant to ring nematode and bacterial canker than Nemaguard

Lovell (peach seedling)

- **Disadvantages**
  - *Less vigorous than Nemaguard (lower yields?)*
  - *Susceptible to:*
    - all nematodes
    - bacterial canker (less than Nemaguard)
    - Phytophthora & Oak root fungus
    - Crown gall
    - High lime soils
    - High salt in soil & water (sodium, chloride, boron)

Nemaguard →

← Lovell

Peach/Almond Hybrids

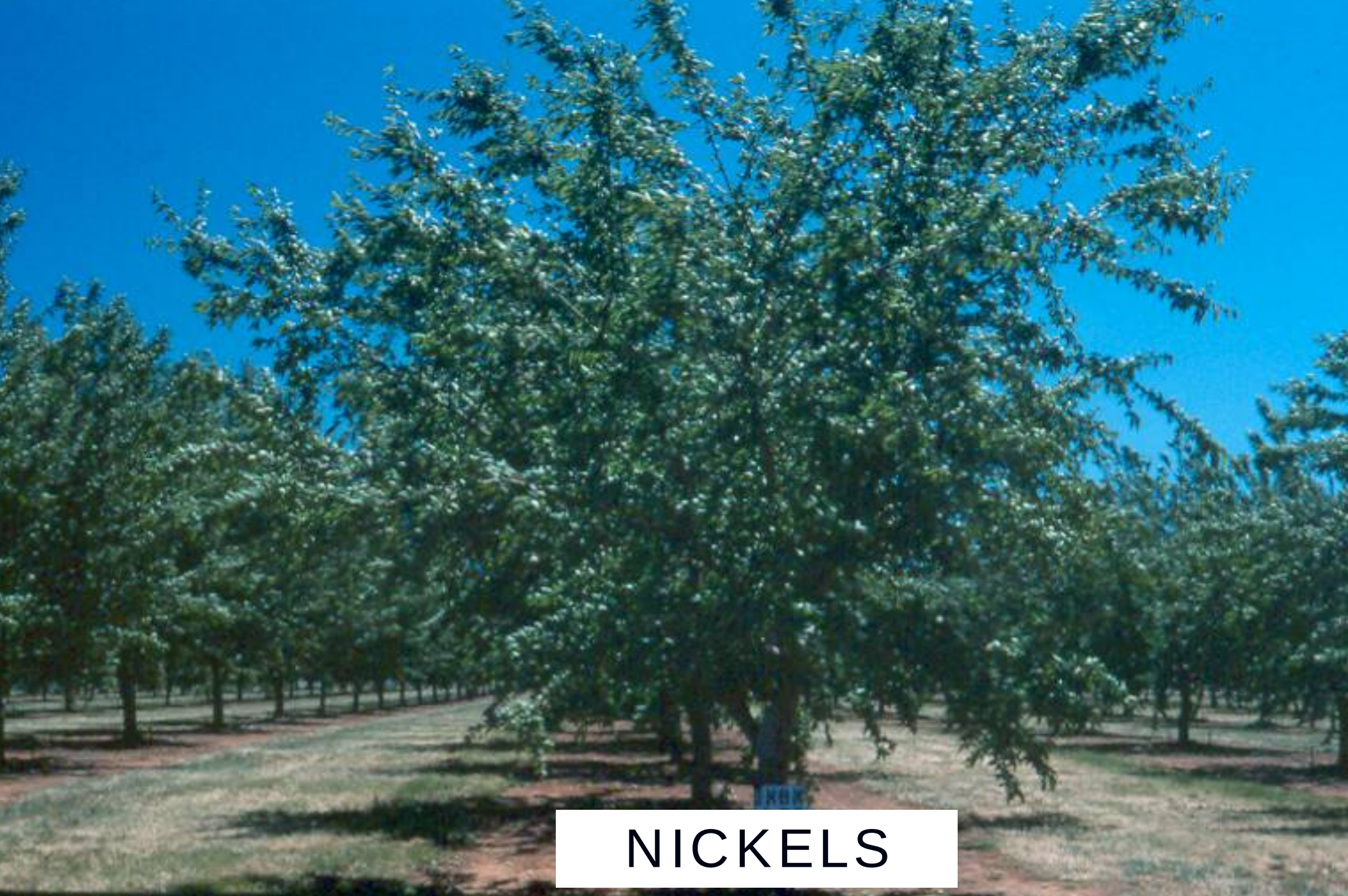
- **Almond x Nemaguard peach**
- **Clonal or seedling propagated**
  - Hansen 536
  - Nickels
  - Bright's Hybrid
  - Titan
  - Cornerstone

Peach / Almond Hybrids

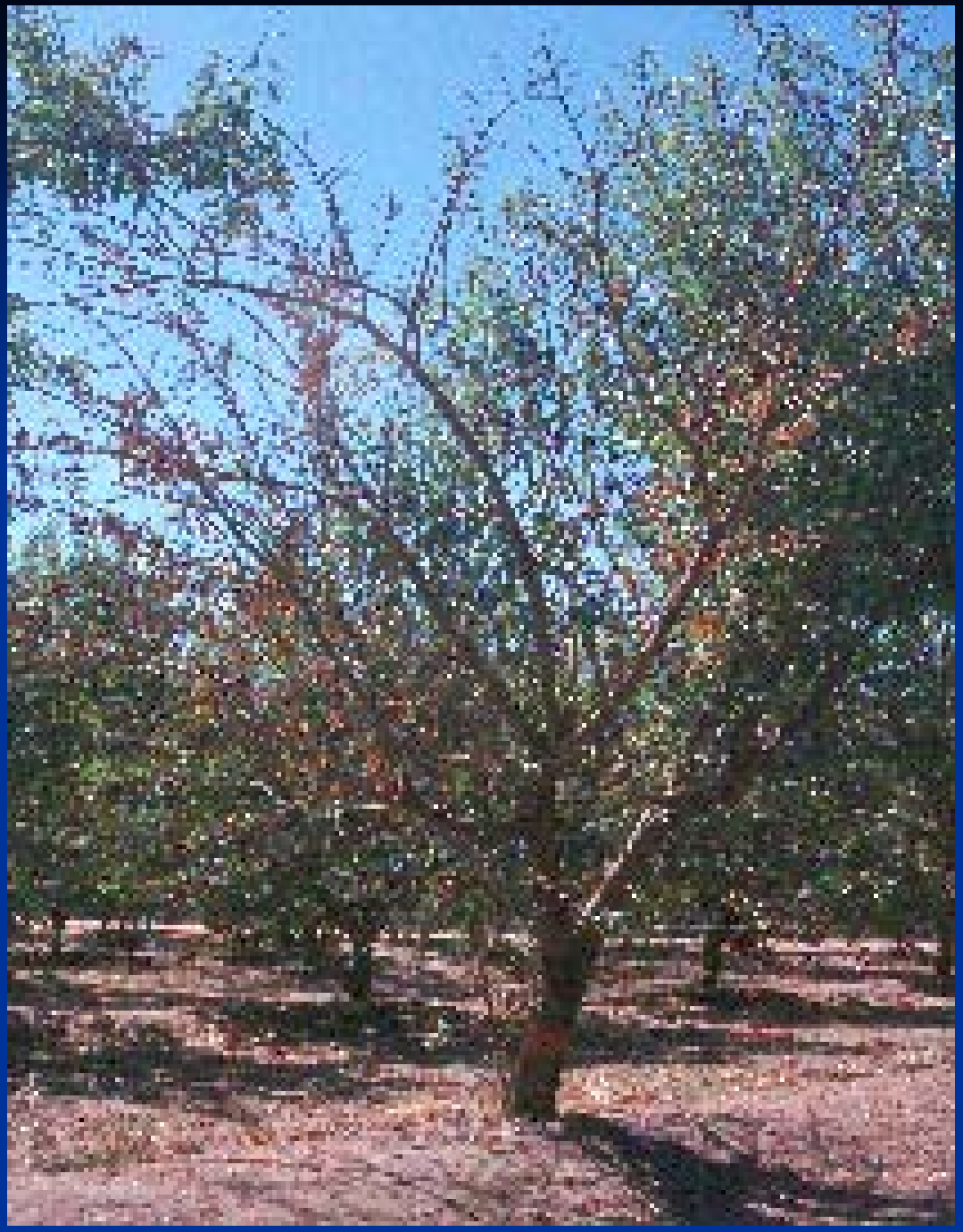
- **Advantages**
  - Very vigorous - can fill space more quickly
  - Excellent anchorage
  - Highly tolerant to rootknot nematode
  - Tolerant to high lime / high pH soils
  - More tolerant to high chloride than peach
  - More drought tolerant than peach

Peach / Almond Hybrids

- **Disadvantages**
  - Very vigorous
    - Trees get too big on deep, fertile soil
    - may delay fruit maturity (flowering??)
  - Very susceptible to ring nematode and bacterial canker
  - Very susceptible to root diseases
    - Phytophthora, Oak root fungus, Crown gall


NICKELS

Crown Gall on Hansen Rootstock



Bacterial canker of almond on Hansen 536 rootstock

(San Joaquin County rootstock trial, 2002)

Marianna 2624 (plum cutting)

- **Advantages**
  - Resistant to rootknot nematode
  - Tolerant to “wet feet”
  - Tolerant to Phytophthora
  - Tolerant to crown gall
  - Resistant to “heart rots”
  - *Resistant to Oak Root Fungus

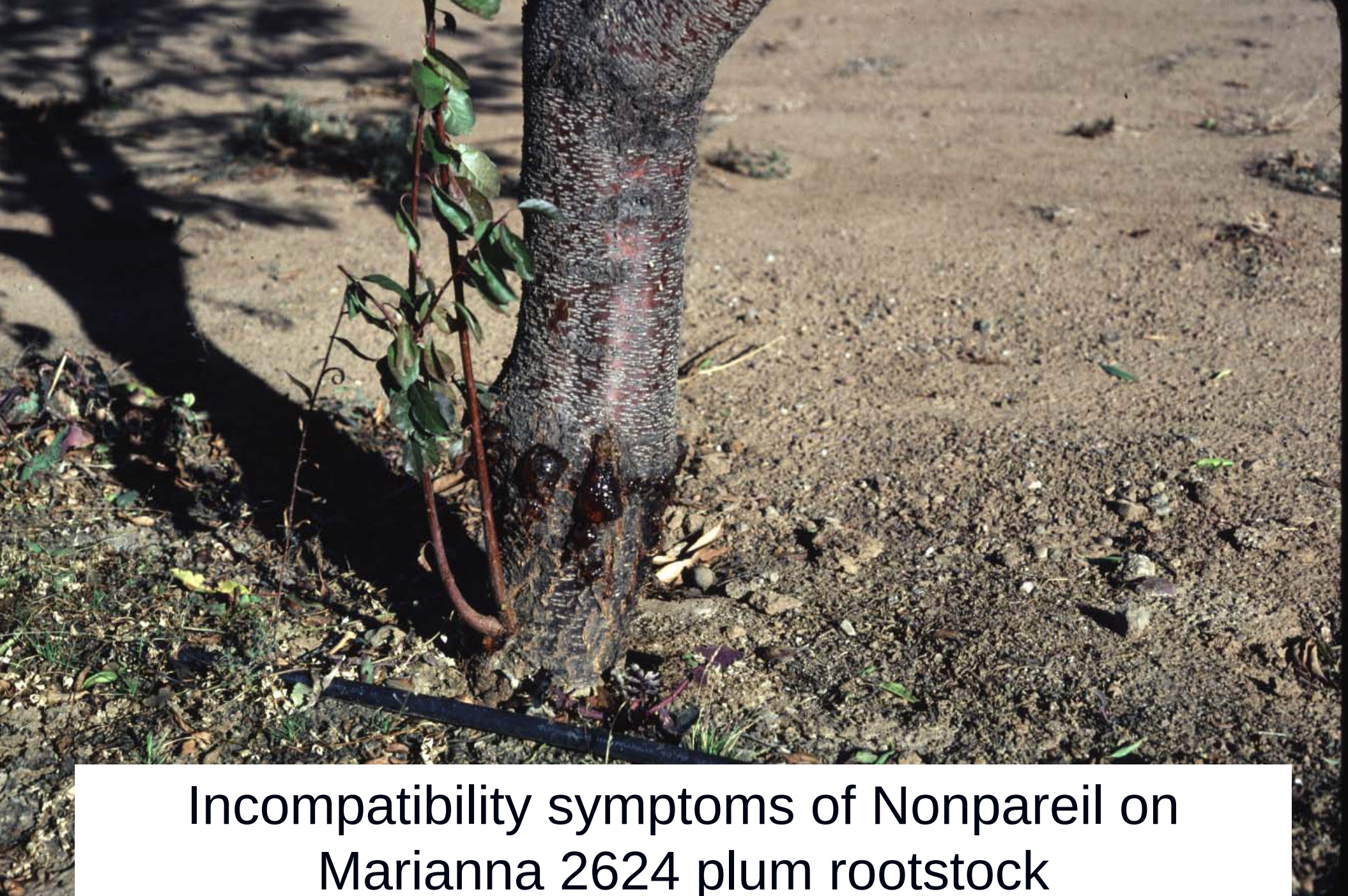
Marianna 2624 (plum cutting)

- **Disadvantages**
  - Highly dwarfing rootstock
  - Suckers profusely
  - Incompatible with Nonpareil and Livingston
  - Marginal compatibility with Butte & Monterey
  - Susceptible to brown line & union mild etch
  - Susceptible to ring and root lesion nematodes
  - Very susceptible to bacterial canker


Padre/M2624 at 14 years
Butte/M2624 at 14 years

Overgrowth at union on Marianna 2624 rootstock

Root suckering of Marianna 2624 plum rootstock



Incompatibility symptoms of Nonpareil on Marianna 2624 plum rootstock

Marianna 2624 is very shallow-rooted

Viking

- **Interspecific hybrid of peach, almond, apricot & plum (Zaiger)**
  - Less is known about Viking than others
  - Vigor is similar to Nemaguard (less?)
  - May have better anchorage than Nemaguard
  - Resistant to rootknot nematode (?)
  - Somewhat tolerant to ring nematode
  - *May be more tolerant to bacterial canker than other commonly used rootstocks

Viking, cont.

- Appears to be more tolerant of high lime soils than Nemaguard or Lovell
- Less susceptible to chloride than Nemaguard (less tolerant than P/A hybrids?)
- Susceptible to dehydration during cold storage or transplanting

Atlas

- Interspecific hybrid of peach, almond, apricot & plum
- Don’t have enough experience with it to speak very intelligently about it in front of 200 people
- Less susceptible to chloride than Nemaguard & Lovell (similar to P/A hybrids)
- Appears to be more susceptible to ring nematode than Viking
- May be more precocious than Nemaguard

Planted Four Regional Rootstock Trials ---

- **Butte - planted 1998**
  J. Connell, R. Buchner & Almont Orchards
- **Colusa - planted 1997**
  J. Edstrom & Nickels Estate
- **Kern - planted 1996 & 1997**
  M. Viveros, Tejon Ranch & Dosanjh Bros. Farm
- **San Joaquin - planted 1998**
  R. Duncan, P Verdegaal, Darpinian & Sons

- B. Lampinen, S. Metcalf, W. Micke & J. Yeager
  UC Davis

9 Rootstocks ---

- Bright's
- Hansen 536
- Hansen 2168
- Nickels (1-82)
- Viking
- Atlas
- Guardian
- Nemaguard
- Lovell

Rootstocks challenged - - -

- **Butte**
  - ✓ **high rainfall environ., deep loam soil**
- **Colusa**
  - ✓ **shallow gravelly loam soil**
- **Kern**
  - ✓ **“Santa Ana” winds, deep sandy loam**
- **San Joaquin**
  - ✓ **bacterial canker site, sandy soil**

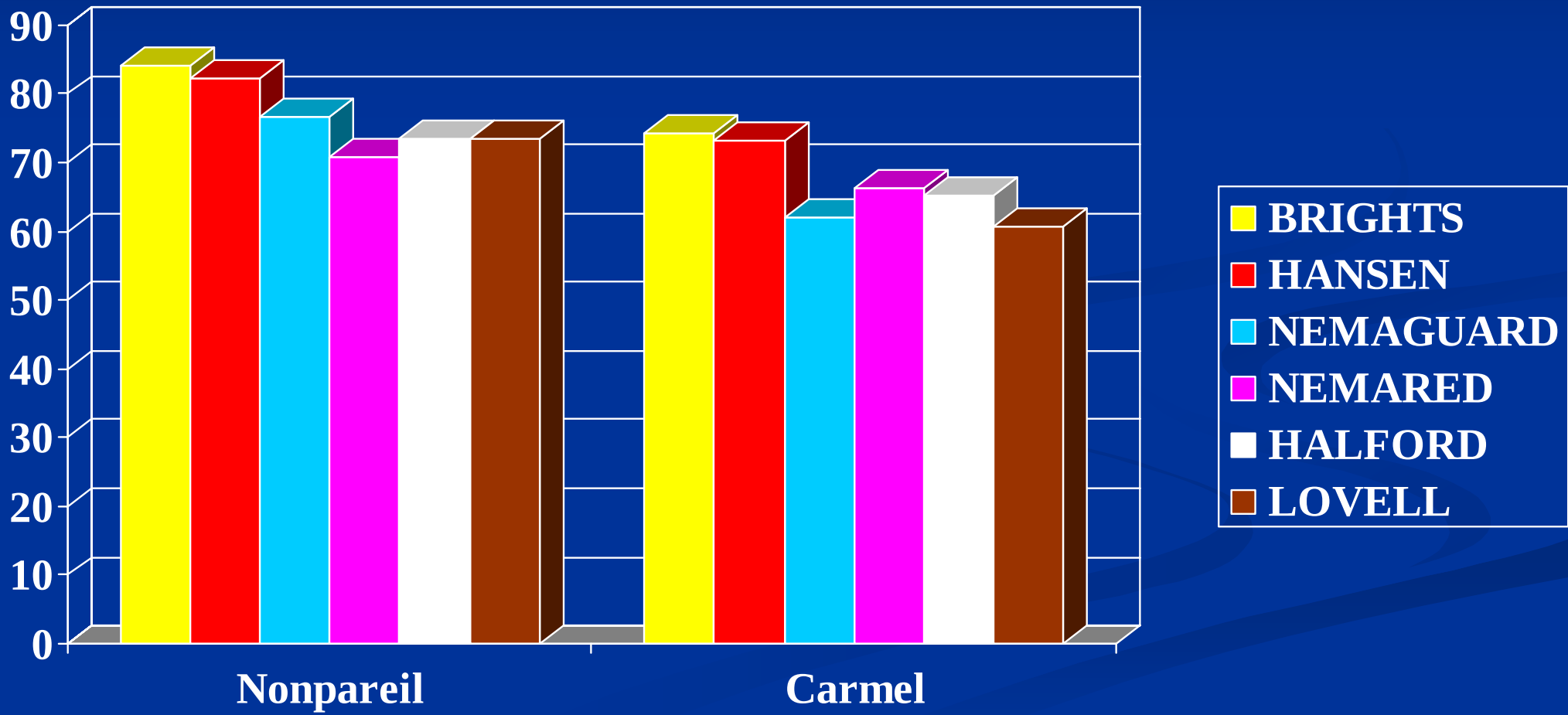
Other local trials

- **Merced County Almond Rootstock Trial**
  - Planted 1989
  - Sandy soil but not bacterial canker prone
  - Fairly weak ground
  - Wide spacing
- **Peach rootstock trial in Ceres**
  - History of severe bacterial canker

Trunk Circumference (cm) after 5th season ---

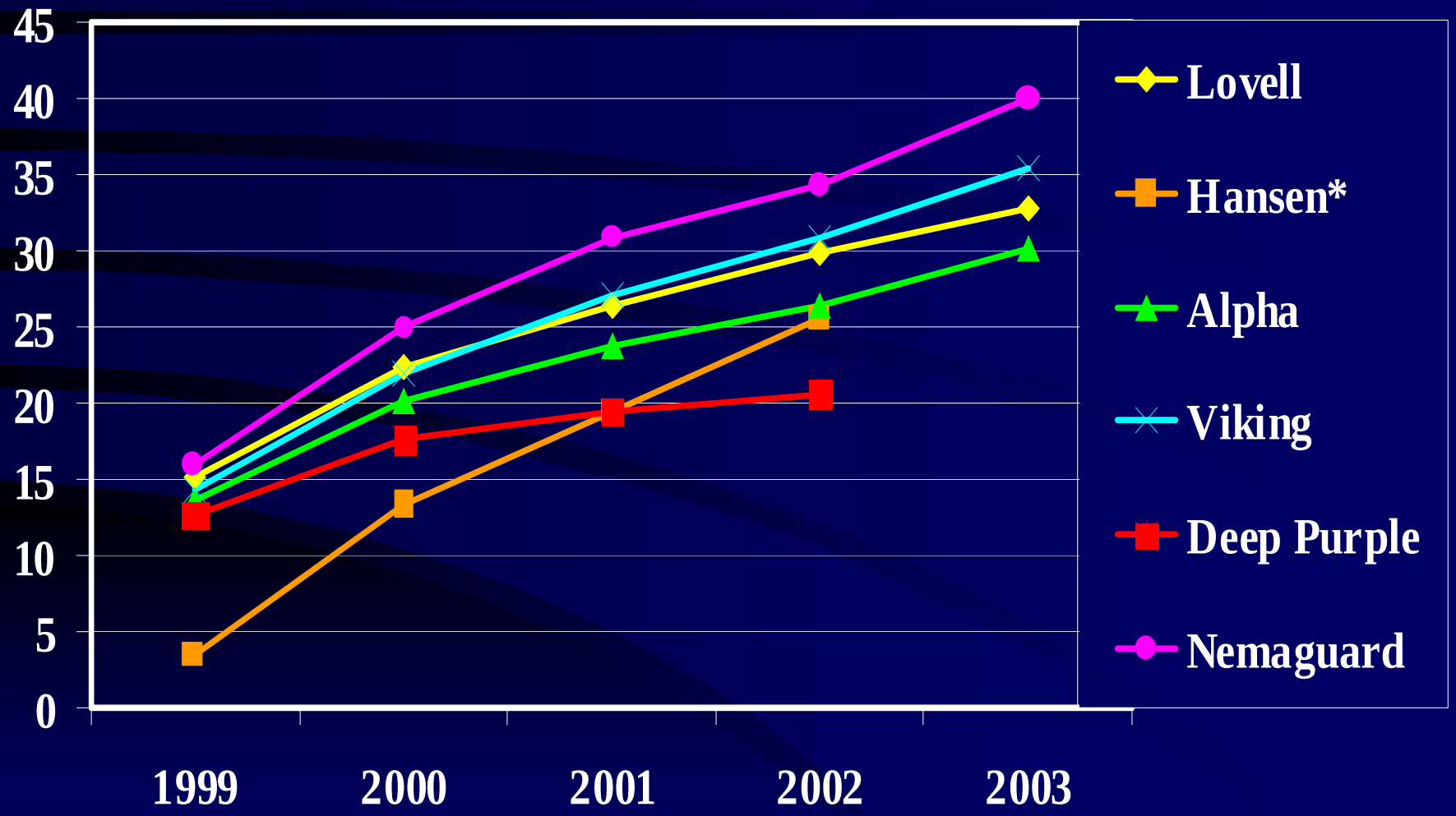
Rootstock	San Joaquin	Colusa
Bright's Hybrid	51.9 b	53.6 b
Hansen 536	52.3 b	56.2 a
Nickels (1-82)	55.2 a	52.6 bcd
Viking	50.9 b	51.7 bcd
Atlas	50.6 b	50.5 d
Guardian	50.8 b	------
Nemaguard	51.2 b	52.0 bcd
Lovell	50.6 b	51.1 cd

1989 Merced Co. Rootstock Trial: Trunk Circumference (cm) 1997



Trunk Circumference (cm)

Superior Fruit Ranch Rootstock Trial



*Hansen planted July, 1999. Others planted Feb. 1999

Anchorage Challenge ---

‘Santa Ana’ wind, Kern County

March 4, 2001 winds gusting at 75 to 84 mph for 5 hours with 1.75” rain.

Tree loss at 6th leaf during "Santa Ana" winds & effect on average yield per TREE SITE (Kern, 2001)

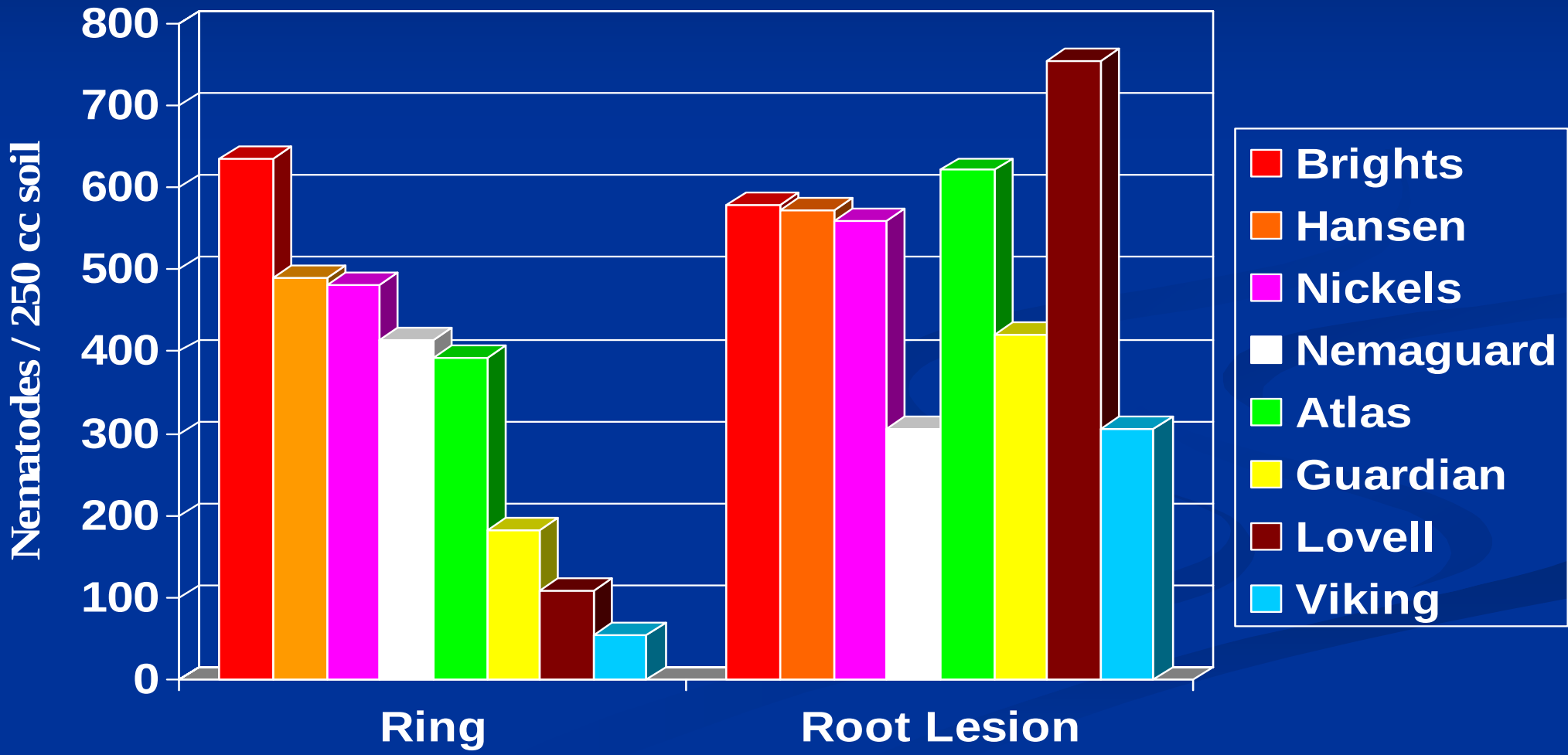
Rootstock	% Blown over	Lbs. kernel per *Tree Site*	Lbs. kernel per tree
Bright's Hybrid	13.0 a	14.4	16.0
Hansen 536	9.3 a	14.4	16.0
Hansen 2168	4.2 a	11.8	12.3
Viking	4.2 a	13.5	14.0
Atlas	30.0 b	9.2	13.7
Nemaguard	58.0 c	6.8	18.9

*** March 4, 2001 winds gusting at 75 to 84 mph for 5 hours with 1.75" rain.**

Rootstock Susceptibility to Nematodes and Bacterial Canker

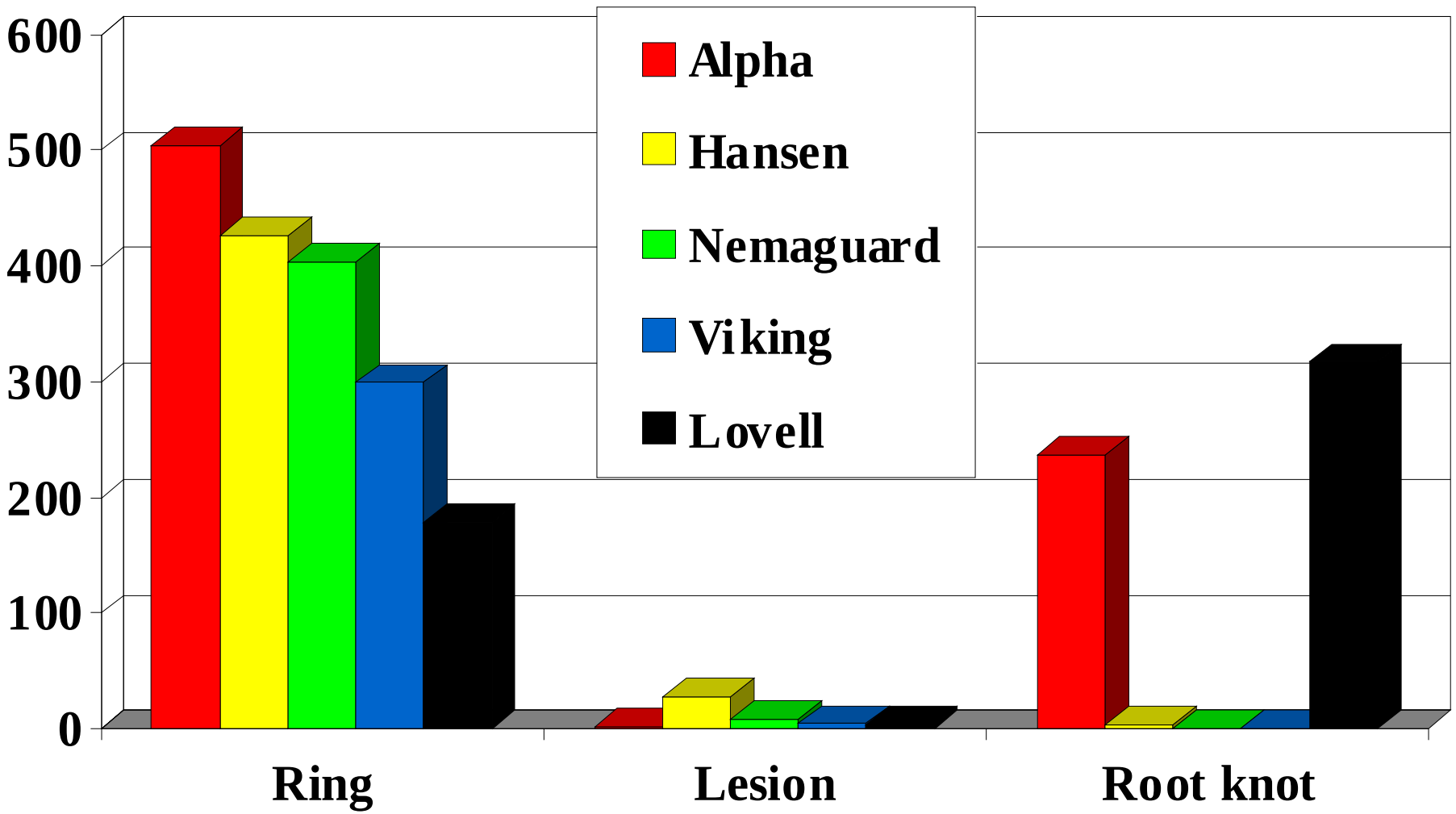
Soil Numbers of Pathogenic Nematodes as Influenced by Almond Rootstock

Escalon, CA. January, 2005

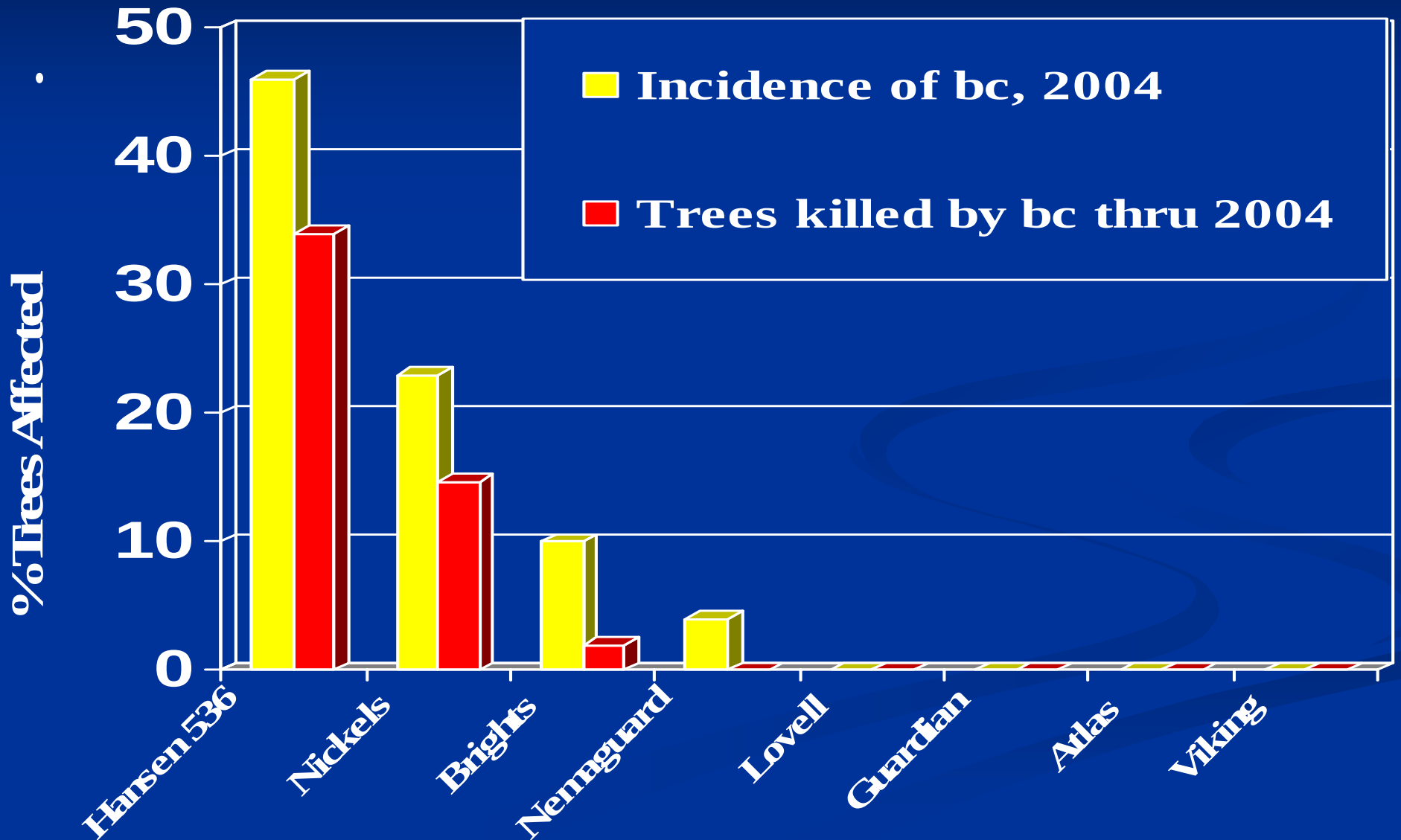


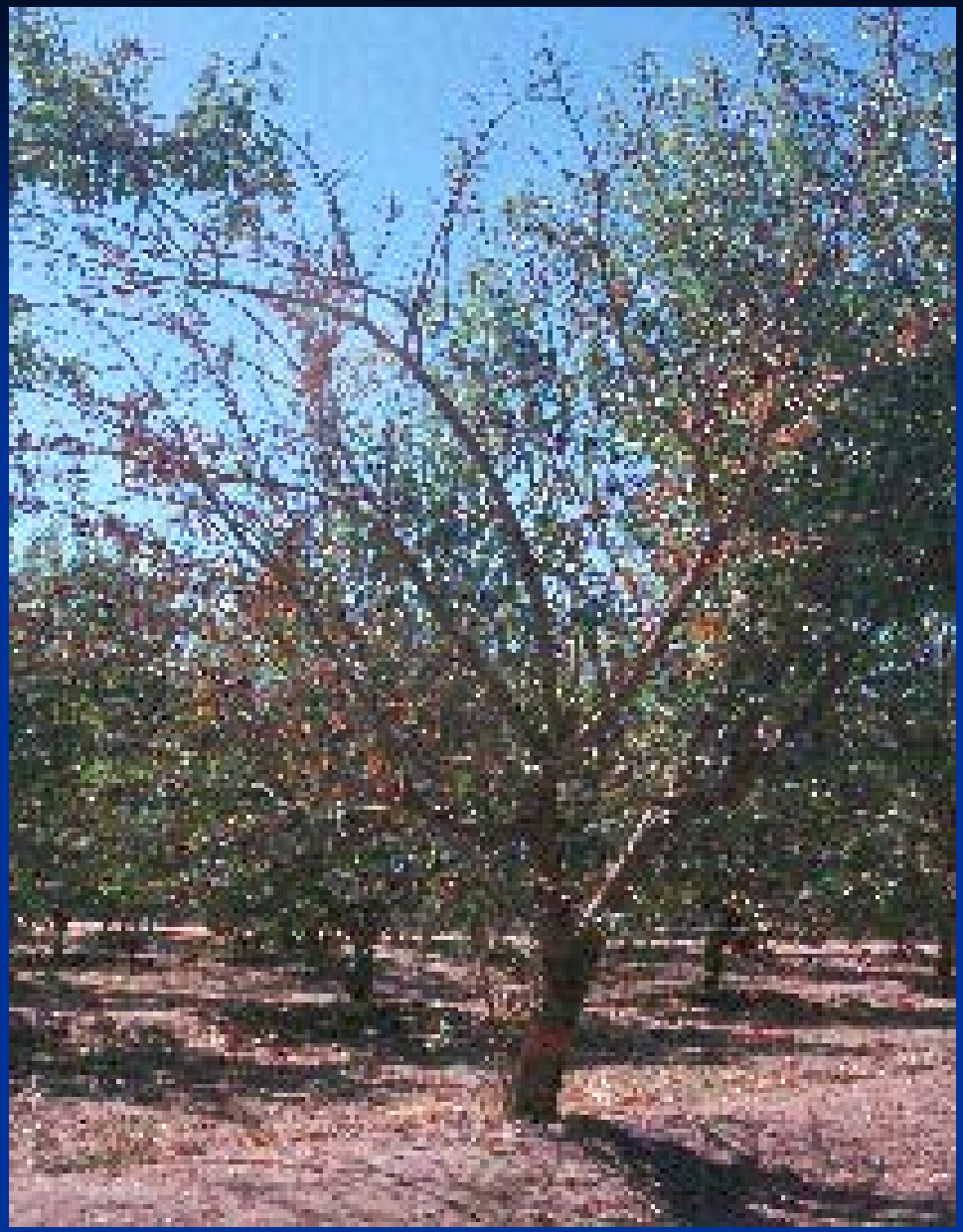
Nematode numbers per 250 cc of Soil for Rootstocks of Peach

Reigel Rootstock Trial, April 2003



Rootstock Susceptibility to Bacterial Canker
Almond Rootstock Trial. Escalon, CA



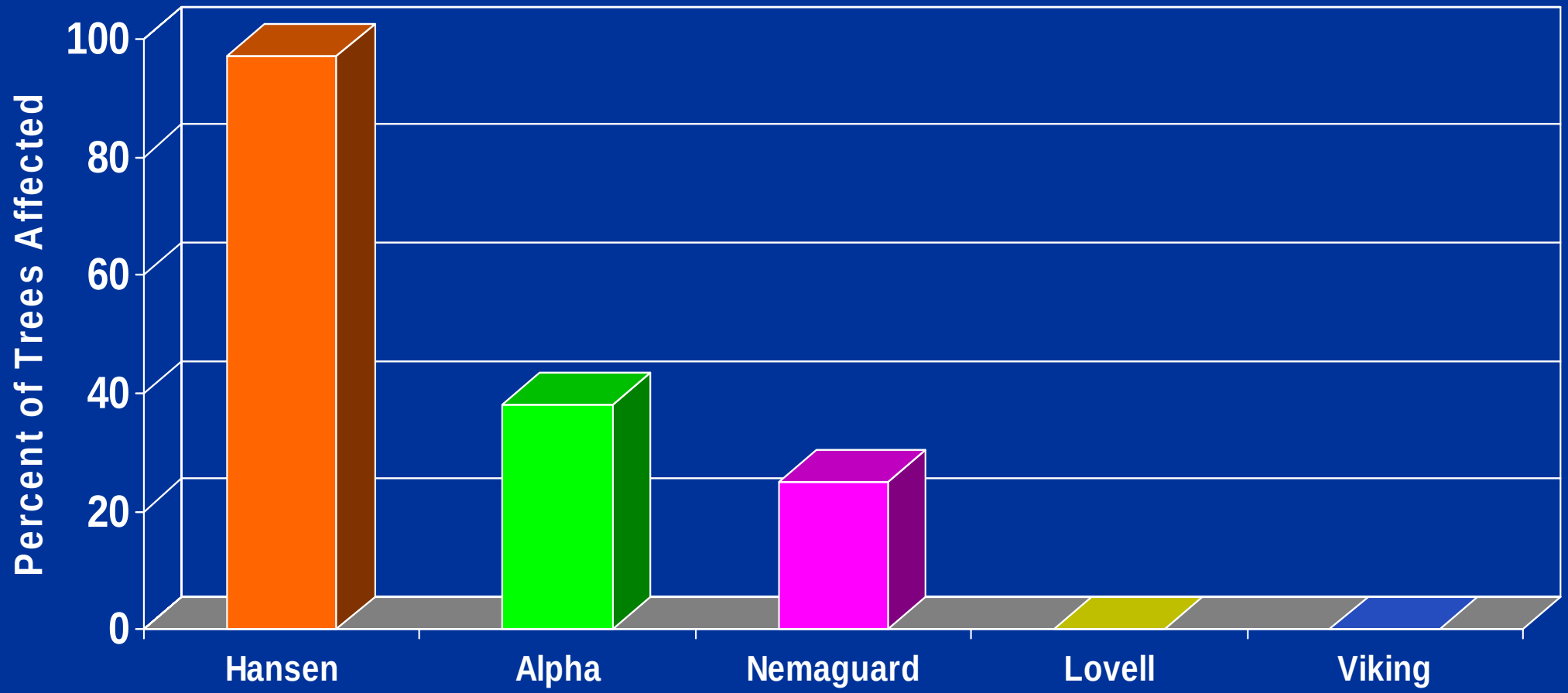


Hansen 536 showing a severe bacterial canker attack in the 5th leaf.

(San Joaquin County rootstock trial, 2002)

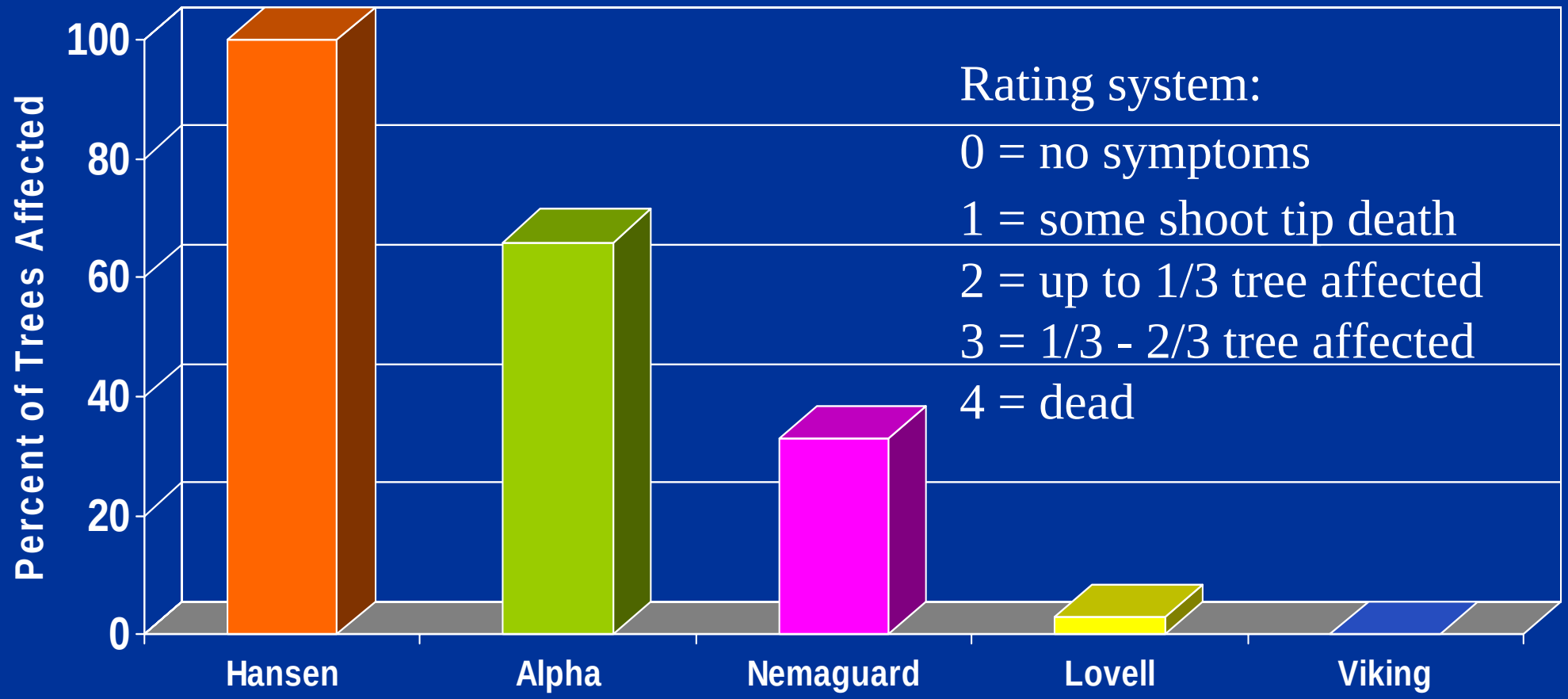
A Comparison of Peach Rootstocks Killed by Bacterial Canker

Ceres, CA 2004 (6th leaf)



A Comparison of Peach Rootstocks with Bacterial Canker Rating Severity > 1

Ceres, CA 2004 (6th leaf)



Rootstock Influence on Tree Nutrition

Rootstock Influences on Tree Nutrition

Escalon Rootstock Trial Leaf Analyses, July 2004

	Nitrogen (%)	
Nemaguard	2.30	a
Lovell	2.28	a
Guardian	2.32	a
Atlas	2.27	a
Viking	2.26	a
Nickels	2.13	b
Brights	2.09	b
Hansen	2.08	b

Rootstock Influences on Tree Nutrition

Escalon Rootstock Trial Leaf Analyses, July 2004

Potassium (%)

Nemaguard	2.76	abc
Lovell	2.92	ab
Guardian	2.57	cd
Atlas	2.70	bc
Viking	2.99	a
Nickels	2.27	e
Brights	2.40	de
Hansen	2.00	f

Rootstock Influences on Tree Nutrition

Escalon Rootstock Trial Leaf Analyses, July 2004

Chloride (%)

Nemaguard	0.09	a
Lovell	0.08	a
Guardian	0.08	a
Atlas	0.04	b
Viking	0.04	b
Nickels	0.03	b
Brights	0.03	b
Hansen	0.03	b

Rootstock Influences on Tree Nutrition

Escalon Rootstock Trial Leaf Analyses, July 2004

Boron (ppm)		
Nemaguard	47	a
Lovell	47	a
Guardian	47	a
Atlas	49	a
Viking	45	ab
Nickels	42	bc
Brights	42	bc
Hansen	40	c

Rootstock Influences on Tree Nutrition

Escalon Rootstock Trial Leaf Analyses, July 2004

Calcium (%)		
Nemaguard	3.54	de
Lovell	3.56	e
Guardian	3.73	e
Atlas	4.23	bc
Viking	4.11	cd
Nickels	4.78	a
Brights	4.44	b
Hansen	5.03	a

Peach / Almond Hybrids

- **Have lower leaf levels (than peach) of:**
  - nitrogen
  - potassium
  - boron
  - chlorides

- **Have higher:**
  - Calcium
  - Zinc
  - Manganese

Viking & Atlas

- **Are similar to peach:**
  - nitrogen
  - potassium
  - boron
  - zinc
- **Intermediate between Peach & PA Hybrids**
  - Calcium
  - Chloride

Rootstock Influence on Almond Yield

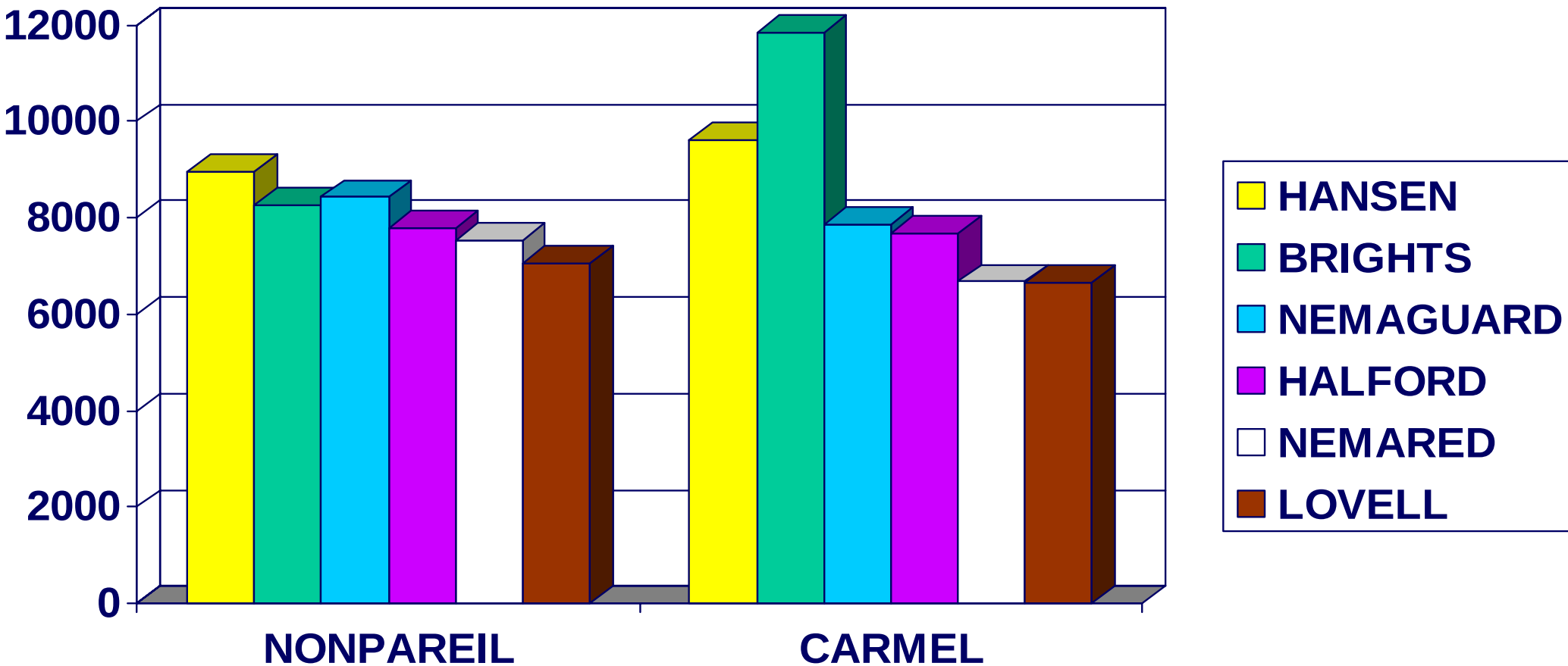
- Highly dependent on circumstances

Yield and quality of sixth-leaf Nonpareil almonds on various rootstocks. Escalon, CA.

Rootstock	2004 Yield (meat lb. / tree)	Kernel Weight (g)	Shriveled Kernels (%)	Cumulative Yield / Tree (4^{th} - 7^{th} leaf)	Cumulative Yield / Acre (4^{th} - 7^{th} leaf)[3]
Atlas	18.3 a[1]	1.08 bcd	7.4 ab	60.4	8335
Guardian	17.3 a	1.14 ab	4.4 cd	59.2	8170
Nickels	17.1 a	1.12 abcd	3.0 d	37.8	5216
Viking[2]	17.0 a	1.07 d	4.8 bcd	50.4	6955
Bright's	17.0 a	1.16 a	3.4 d	53.9	7438
Nemaguard	15.9 a	1.14 abc	6.6 abc	57.3	7907
Lovell	14.8 a	1.08 cd	9.2 a	52.3	7217
Hansen 536	8.5 b	1.09 bcd	3.8 cd	42.9	5920

1989 Merced Co. Rootstock Trial: Accumulated Yield 1992-98*

* 4th through 10th leaf.



1989 Merced Co. Rootstock Trial 2002 yield (14th leaf)

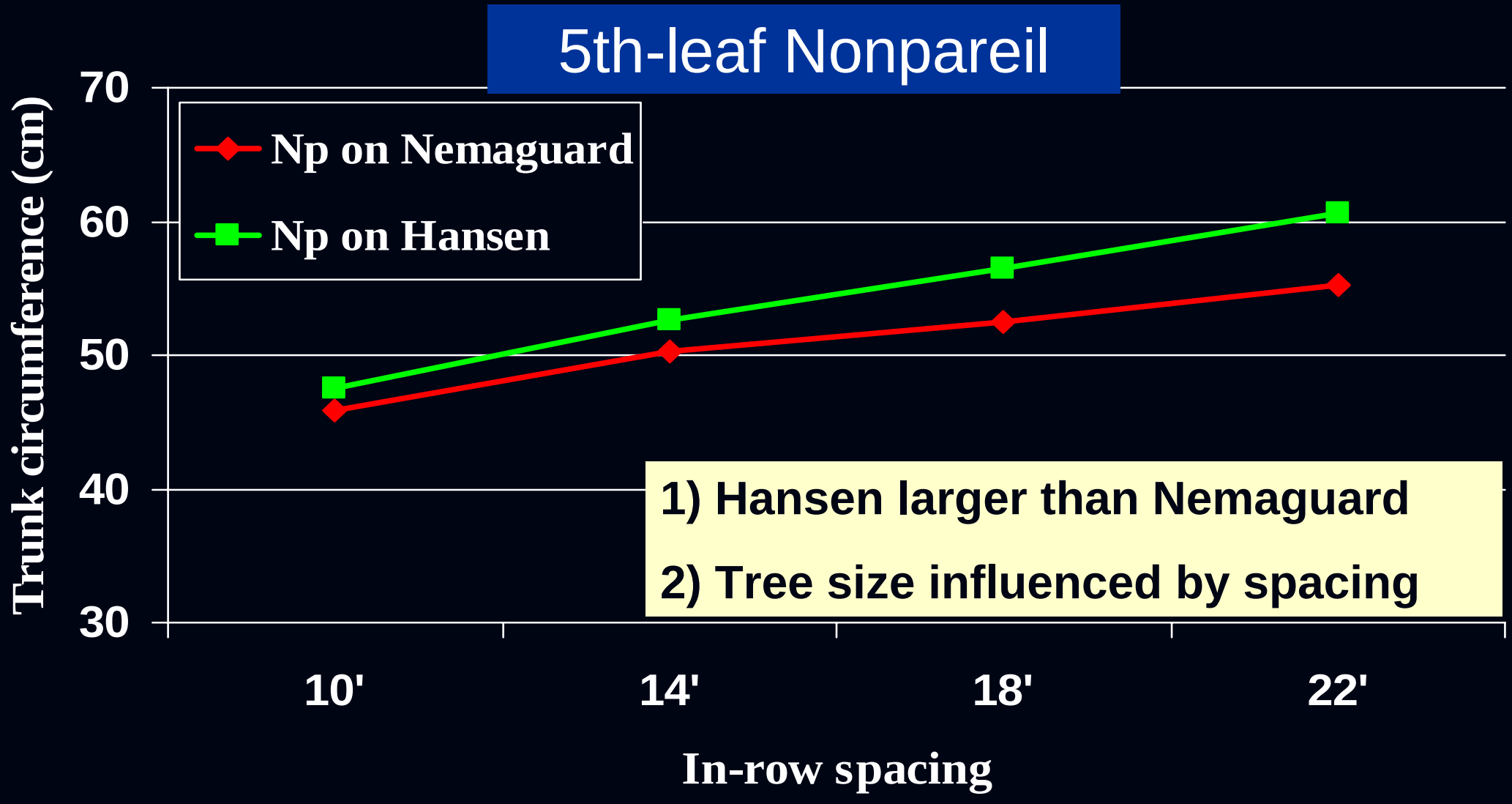
Rootstock	Nonpareil Kernel lb/ac		Carmel Kernel lb/ac	
Bright's Hybrid	3256	a	3701	a
Hansen 536	3044	a	3098	ab
Nemaguard	2466	b	2203	bc
Lovell	1944	bc	1458	c
Red-leaf Nema	1350	c	1350	c
Halford	1216	c	1216	c

1989 Merced Co. Rootstock Trial

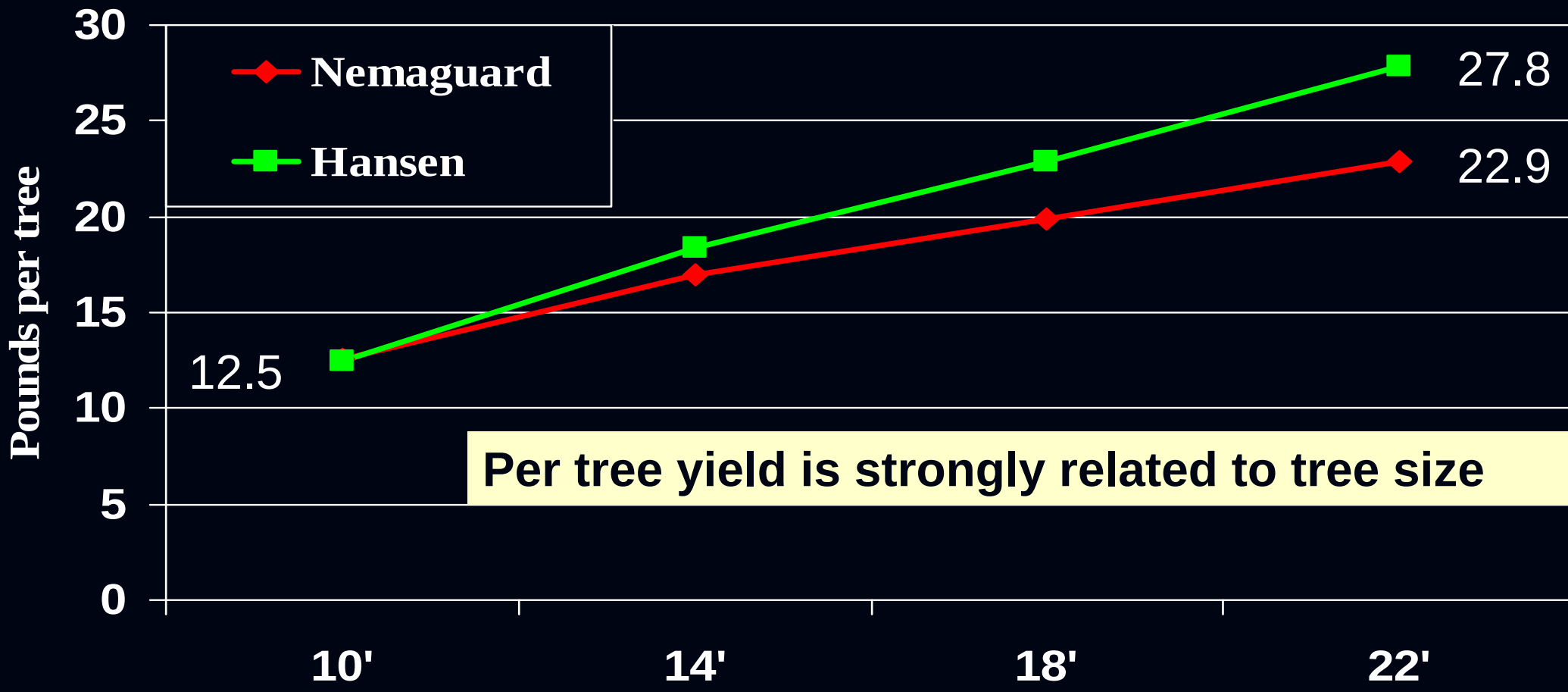
- **Yield performance depends on tree size & the ability to fill the orchard space.**
- **Trial was planted on a sandy loam soil with ring & lesion nematodes present.**
- **Planting density = 76 trees/ac (24' square)**

☺ **Each rootstock has an optimum planting density based on vigor, variety growth habit, soil type & irrigation practice.**

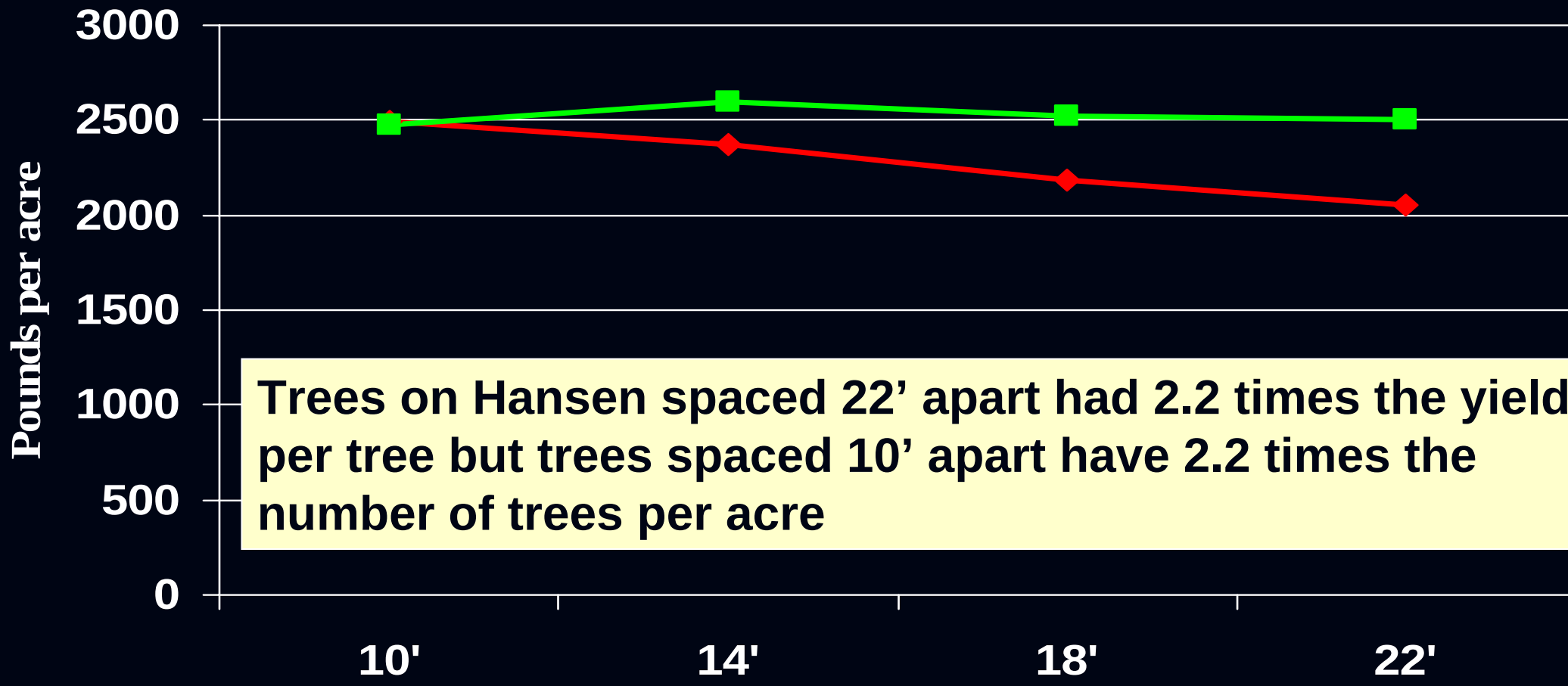
Effect of Tree Spacing & Rootstock on Trunk Circumference. May 2004



Effect of Tree Spacing & Rootstock on per Tree Yield of Fifth-leaf Nonpareil 2004



Effect of Tree Spacing & Rootstock on per Acre Yield of Fifth-leaf Nonpareil 2004



Trees on Hansen spaced 22’ apart had 2.2 times the yield per tree but trees spaced 10’ apart have 2.2 times the number of trees per acre

Conclusions from Claribel Road Trial

- There is no early yield advantage to a vigorous rootstock in a close planted orchard

OR

- There is no early yield advantage to a high density planting if trees are on a vigorous rootstock

Other Rootstocks on the Horizon

- Marianna M-40: May be as tolerant to oak root fungus as Marianna 2624 with less suckering

- Ishtara: May be as tolerant to oak root fungus as Marianna 2624 but less dwarfing and no suckers

- Guardian: Widely planted in southeast US for tolerance to peach tree shortlife

Other Rootstocks Being Tested in Stanislaus County for Almond

Cadaman (France and Hungary)

- Reported to:
  - Perform well in replant situations in sandy soils where high numbers of nematodes are present
  - Highly resistant to rootknot nematode
  - Be resistant to bacterial canker
  - Moderately tolerant to chlorosis (high lime soils)

Other Rootstocks Being Tested in Stanislaus County for Almond

Adesoto 101 (Spain)

- Reported to be:
  - Tolerant of drought & wet feet
  - Highly resistant to chlorosis (high lime soils)
  - Immune to rootknot nematode
  - Probably resistant to oak root fungus

Other Rootstocks Being Tested in Stanislaus County for Almond

- Barrier 1 Primo (Italy)
  - Good performance in replant sites
- Julior (France)
  - Immune to rootknot, tolerant to wet feet
- Kuban 86
  - Resistant to rootknot nematodes, root rot.
  - May be productive and increase fruit size

Other Rootstocks Being Tested in Stanislaus County for Almond

- Paramount (France)
  - Most widely planted peach rootstock in Europe
  - Probably resistant to bacterial canker
- Penta (Italy)
  - high yield efficiency
  - resistant to rootknot and lesion nematodes
  - Tolerant to oak root fungus

So …. Which Rootstock ??

- Select a new orchard's rootstock for a particular reason. It should not be simply because of habit.

So …. Which Rootstock ??

- Considerations:

✓ Potential for diseases.
- Oak root fungus - Marianna 2624
- Bacterial canker - Viking or Lovell, NOT PA hybrid

✓ Soil chemical imbalances
- high pH / lime, high salts - PA hybrid, Viking or Atlas
- NOT nemaguard or lovell

✓ Heavy ground, potential for wet feet
- Lovell, NOT a PA hybrid

So …. Which Rootstock ??

- Other considerations:

  - ✓ High wind area
    - PA hybrid or Viking
  - ✓ Variety size
    - Consider planting small varieties like Carmel or Wood Colony on a P/A hybrid
    - Vigorous varieties like Nonpareil, Aldrich, Butte, Padre, etc. may get too big on P/A hybrid

So …. Which Rootstock ??

- In many (most?) situations in the San Joaquin Valley, nemaguard will probably be the rootstock of choice unless a new rootstock is developed that has the same positive attributes but a higher yield efficiency