Field Evaluation of Alternative Rootstocks for Almonds and Peaches

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The Replant Problem

- Trees are less vigorous
  - Significant loss in production that can never be recovered.
  - Nonuniform orchard
  - Susceptible to weak secondary pathogens.

The Replant Problem

- Not just a nematode issue
- Ring (*Mesocriconema xenoplax*) is the most devastating nematode for almonds and stone fruit in the San Joaquin Valley
- Bacterial canker is the ultimate replant problem

Bacterial canker

- Extensive dieback of limbs
- Tree death

"Gummosis" or bleeding through the bark

Necrotic islands of bacterial colonization

Fermented or “syrup” smell

Necrotic spots coalesce into larger canker

Cankers extend across bud union

Do not extend below ground

- Different than Phytophthora

Because roots remain alive, suckers develop at base of tree

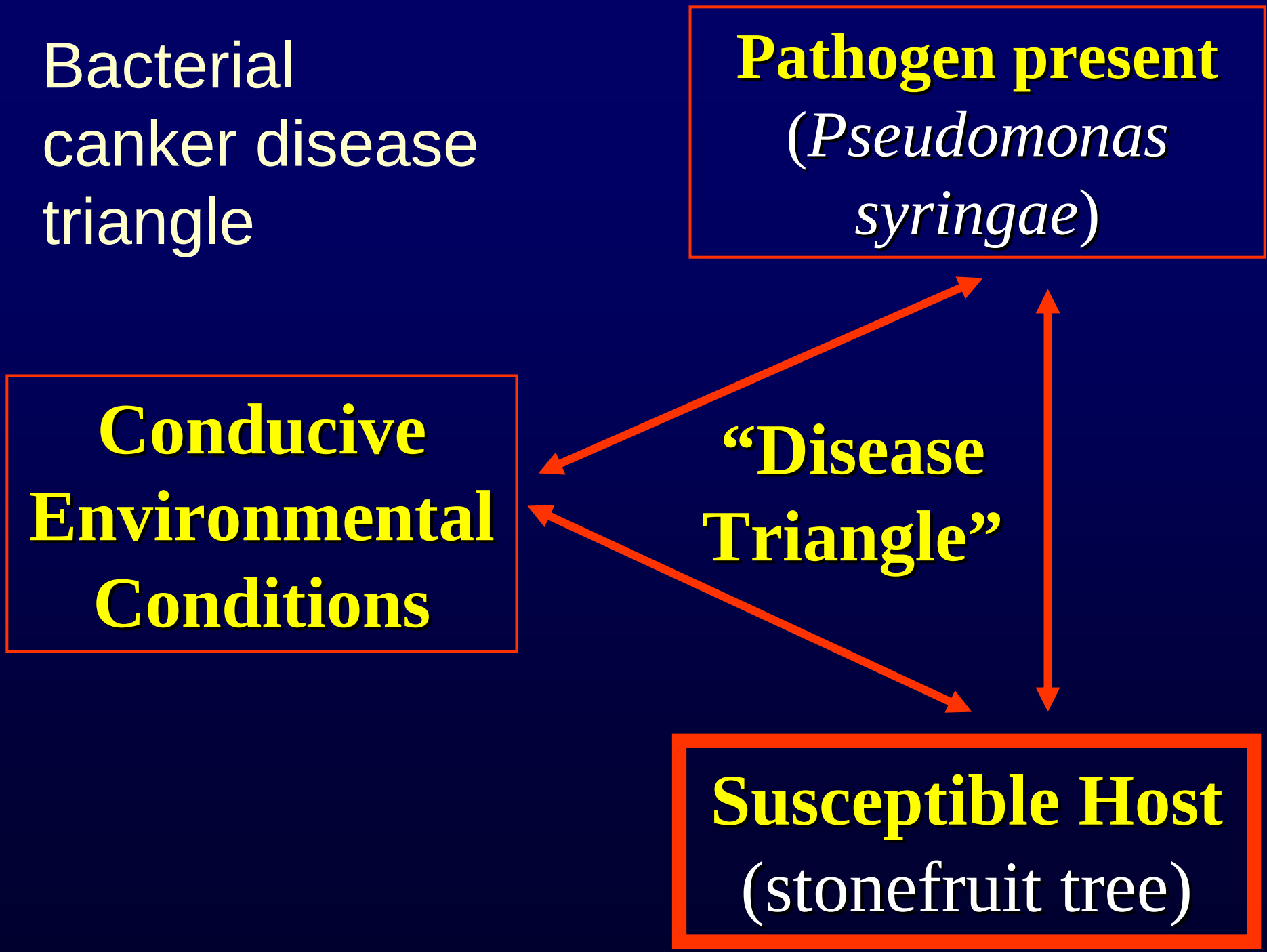
Bacterial Canker: a devastating disease of *Prunus spp.*

- *Pseudomonas syringae* pv. *syringae* (Pss)
- *P.s*. is “always” present on plant surfaces
- May enter through lenticels?
- Bacteria is stimulated to produce syringomycin which is toxic to tree tissue

Conditions Associated with Bacterial Canker

- Replanted almond and stonefruit orchards
- Sandy soil
- Young trees
- Ring nematode (*Mesocriconema xenoplax*)
- Plant nutrition (N, Ca, micronutrients?)
- Temperature (freezing/thawing)
- Soil conditions (texture, moisture, and pH)

Bacterial canker disease triangle



Strategies for Reducing Bacterial Canker

- Begin with good field preparation
  - Use Virgin Soil!
  - Fix Physical Soil Problems
    - Deep ripping, backhoe, etc.
  - Fix Chemical Soil Problems
    - Increase organic matter
      - Cover crop, etc.
    - Correct soil pH (sulfur or lime)

Strategies for Reducing Bacterial Canker

Field Preparation Continued…

- Fix Biological Soil Problems (nematodes and pathogenic organisms)
  - Fumigation is a must in many areas!
  - Annual nematode maintenance with nematicides?

Strategies for Reducing Bacterial Canker

Cultural Operations

- Rootstock
  - Very important management tool
  - No rootstock known resistant to ring nematode
  - A few “common” rootstocks support significantly fewer ring than nemaguard (standard)
  - Many “new” rootstocks being tested

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 !

Riegel Peach Rootstock Trial

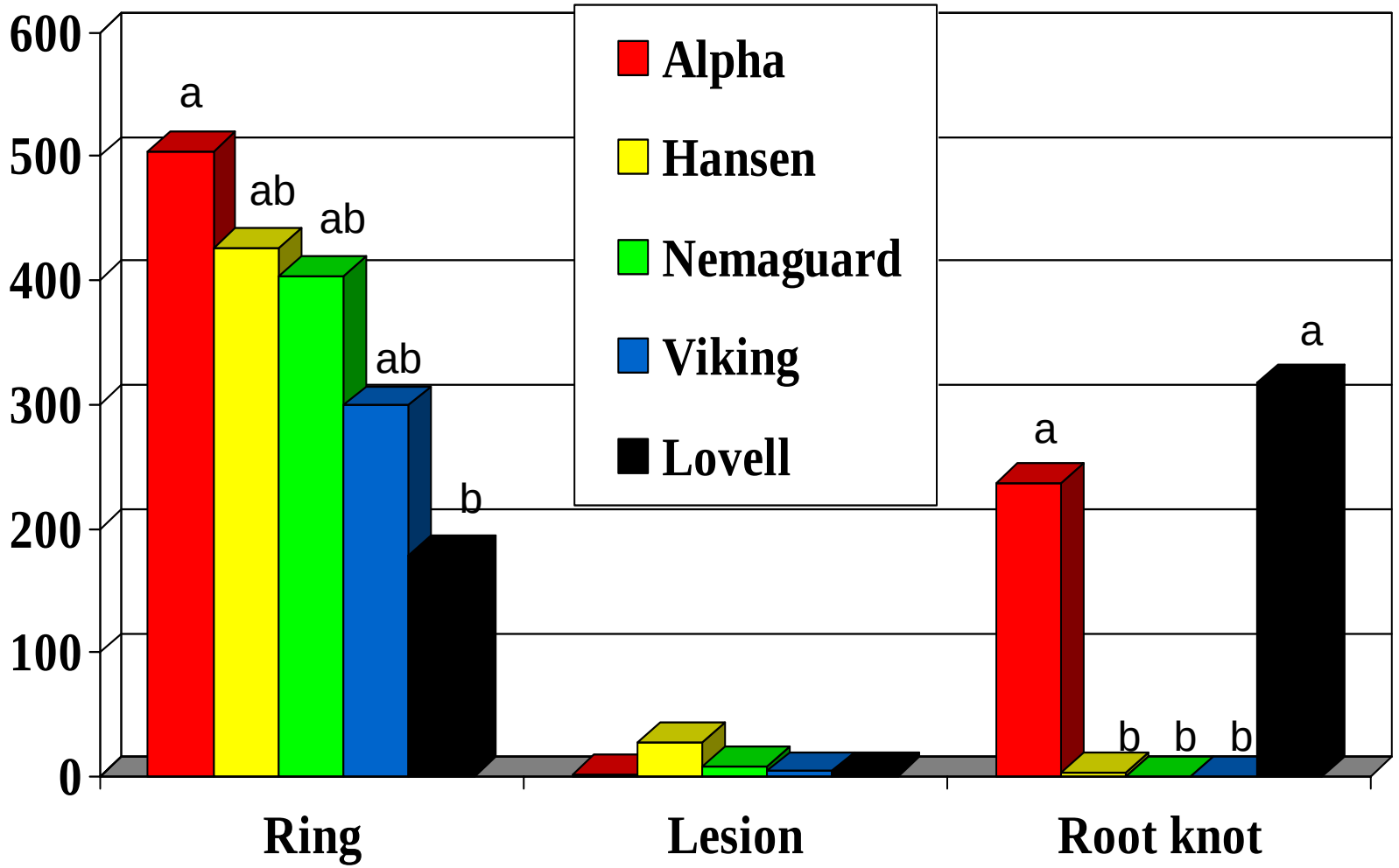
Superior Fruit Ranch. Planted 1999

Rootstocks include:

- **Lovell (peach)**
- **Nemaguard (peach)**
- **Deep Purple (plum)**
- **Hansen 536 (peach / almond hybrid)**
- **Alpha (peach / almond hybrid)**
- **Viking (peach / almond / plum / apricot hybrid)**

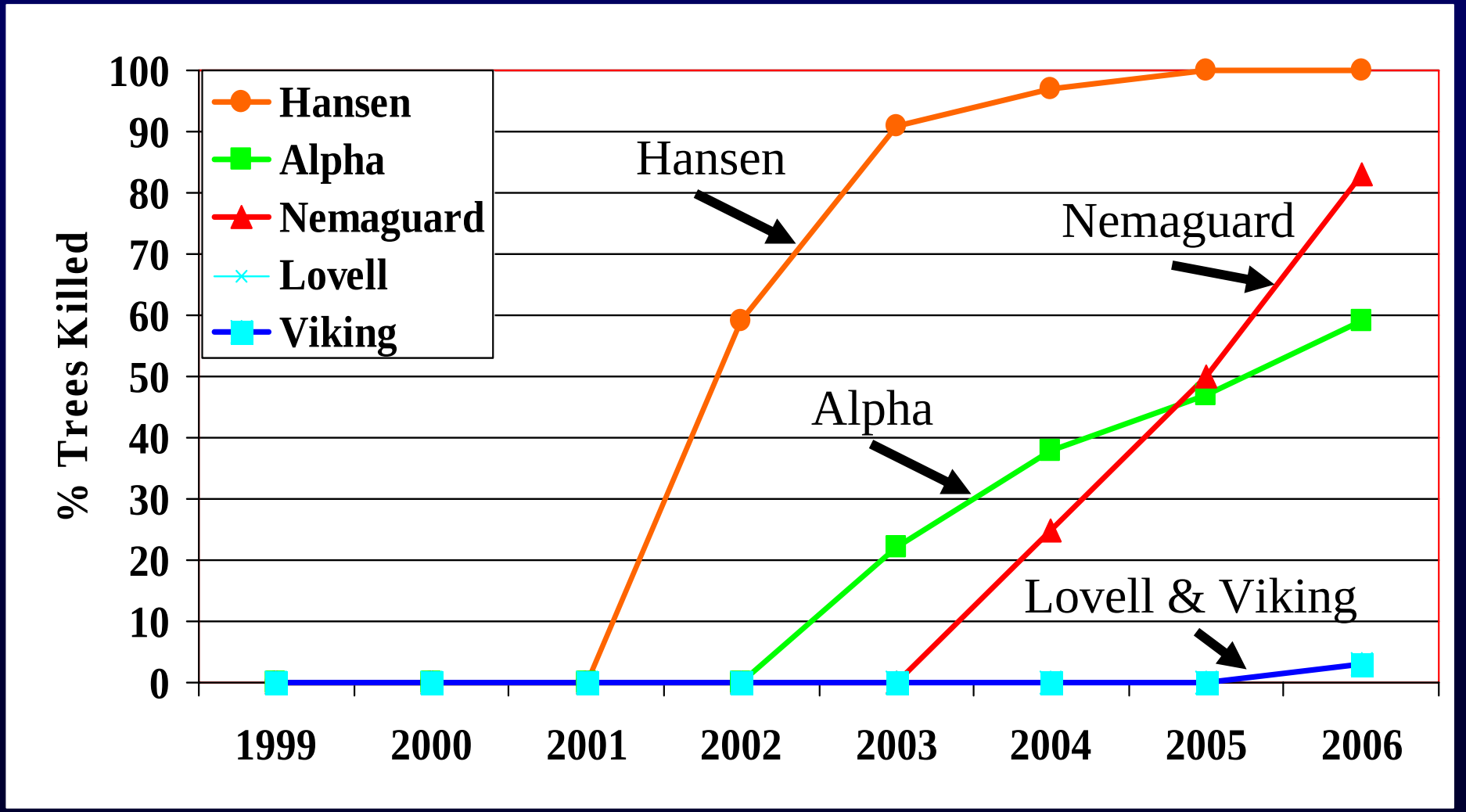
Nematode numbers per 250 cc of Soil for Rootstocks of Peach

Reigel Peach Rootstock Trial, April 2003

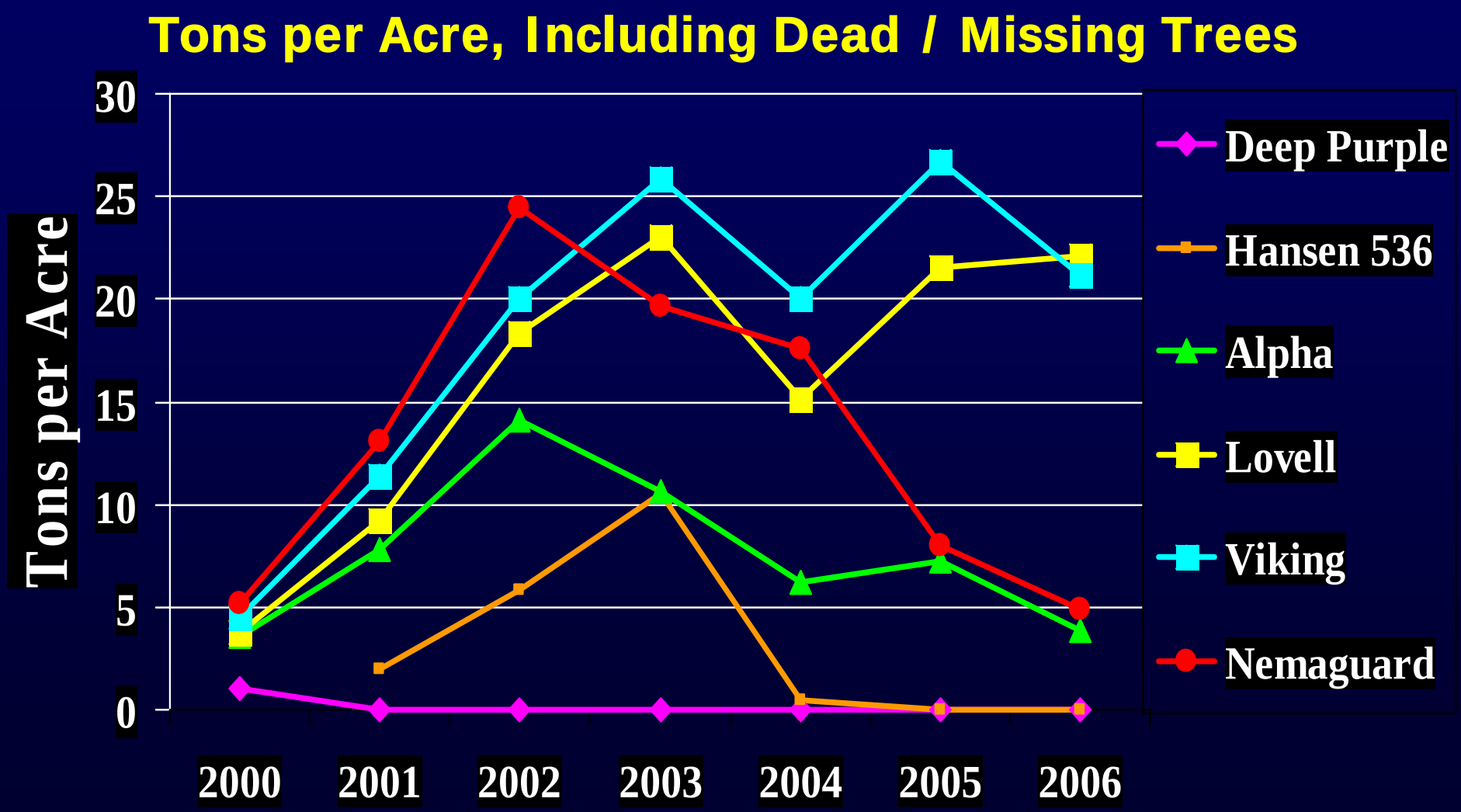


Rootstocks for Peach (cv. Reigel) Killed by Bacterial Canker

Ceres. Planted 1999



Yield Dynamics of Riegel Cling Peach on Various Rootstocks



Riegel Rootstock Trial Conclusions

- Nemaguard had the highest early yields until affected by bacterial canker
- One tree each on Lovell and Viking died from bacterial canker in 2006 (first time).
- Viking looked a little more “cankery” than Lovell early in the year but looked better by year’s end.
- Viking out-yielded Lovell until 2006.

Almond Rootstock Trial

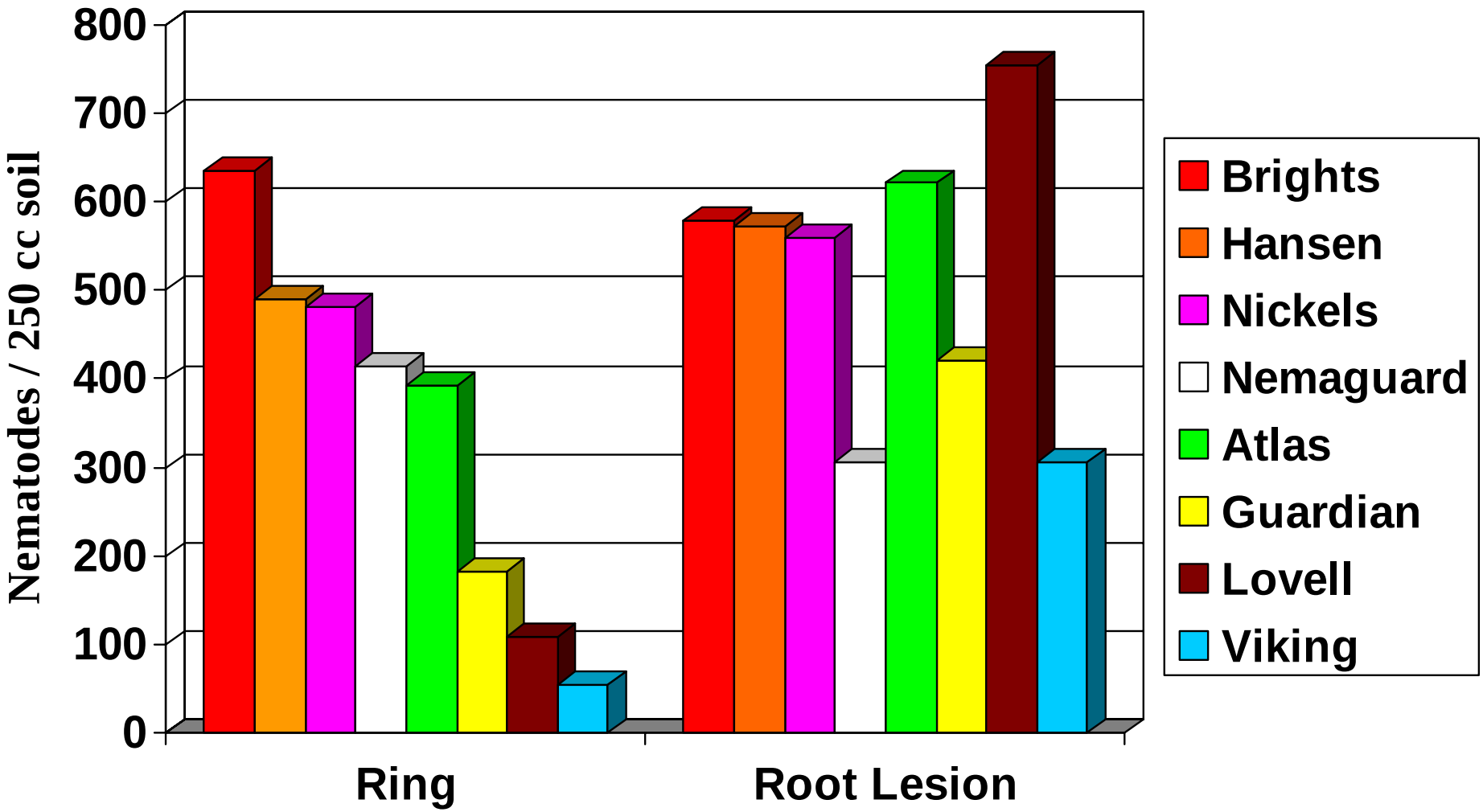
Escalon, CA. Est. 1998

cv. 'Nonpareil'

- Nemaguard – peach seedling
- Lovell – peach seedling
- Guardian – peach seedling
- Atlas – peach x almond x plum x apricot
- Viking – peach x almond x plum x apricot
- Hansen 536 - peach x almond
- Nickels – peach x almond
- Bright's Hybrid – peach x almond

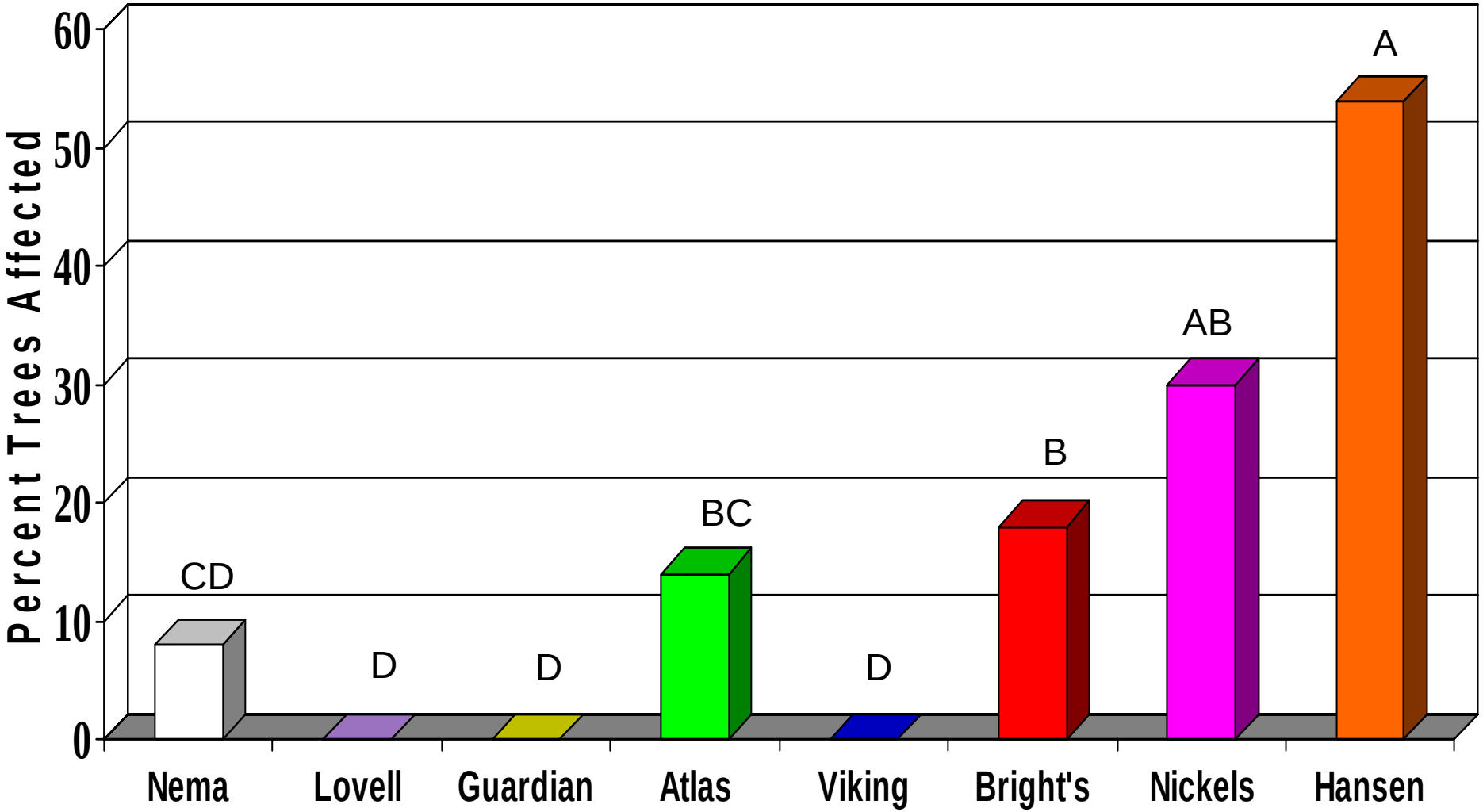
Soil Numbers of Pathogenic Nematodes as Influenced by Almond Rootstock

Escalon, CA. January, 2005



A Comparison of Almond Rootstocks for Incidence of Bacterial Canker

Escalon, CA 2005 (8th leaf)



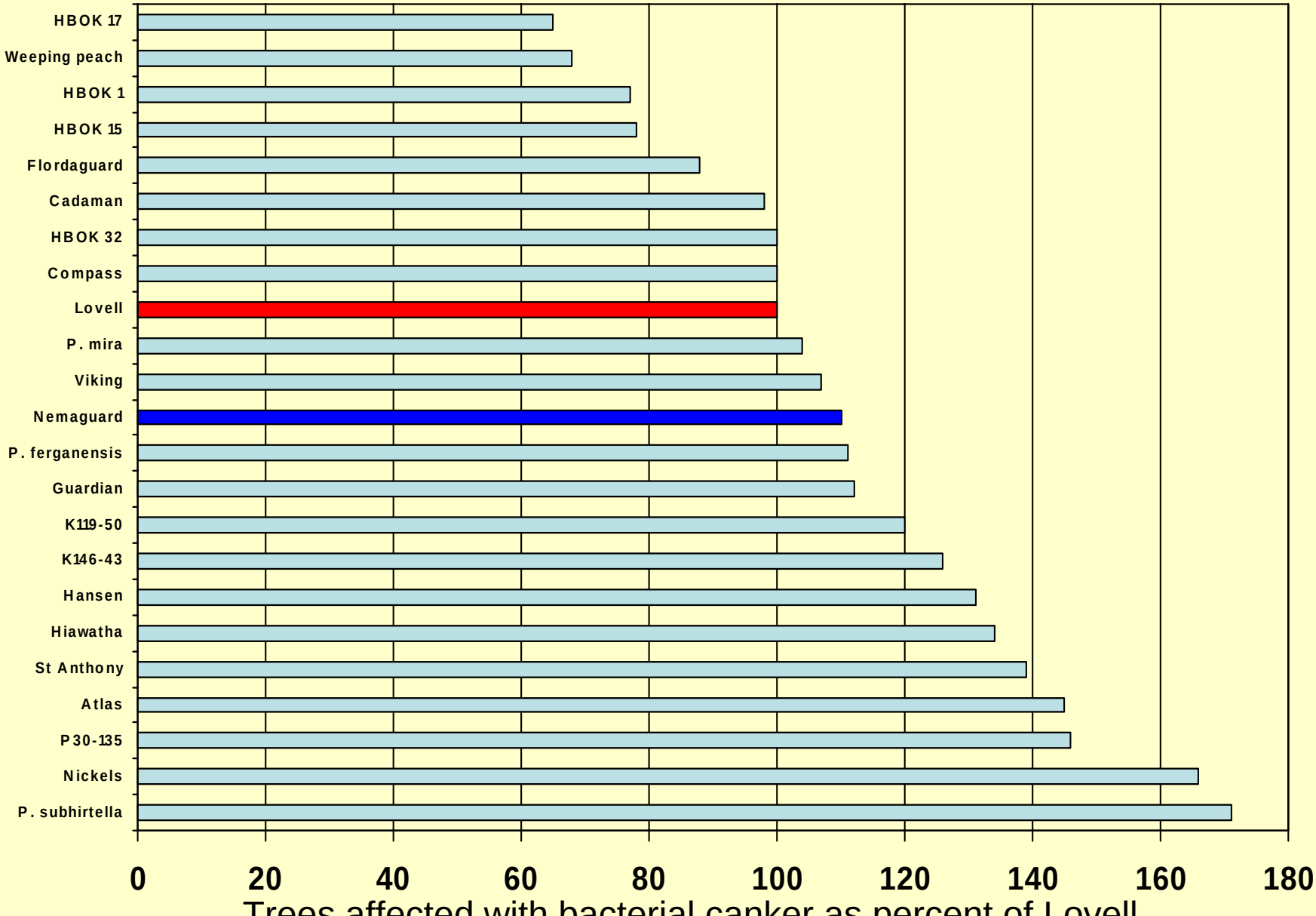
Susceptibility of Peach Rootstocks to Nematodes and Bacterial Canker

	Ring *M. xenoplax*	Root knot *Meloidogyne spp.*	Root Lesion *P. vulnus*	% Killed from canker
P. ferganensis	66	153	4	7
Viking	163	1	14	0
OKHB 1	163	0	61	0
OKHB 15	171	0	434	0
Lovell	215	12	101	0
Compass	249	5	172	0
P. mira	272	0	5	0
Guardian	275	67	3	0
Atlas	281	18	106	12
OKHB 32	413	5	108	9
St. Anthony	463	50	27	15

Susceptibility of Peach Rootstocks to Nematodes and Bacterial Canker

	Ring *M. xenoplax*	Root knot *Meloidogyne spp.*	Root Lesion *P. vulnus*	% Killed from canker
Cadaman	521	0	4	3
Flordaguard	587	0.1	107	0
K146-43	656	161	82	34
Nemaguard	676	0.8	218	0
P30-135	860	125	38	41
P. subhirtella	895	426	12	17
Hiawatha	937	4	35	33
Hansen 536	1239	0.3	148	16
K119-50	1347	165	6	18
Nickels	1704	11	24	25

Peach Rootstock Susceptibility to Bacterial Canker Expressed as Percent of Lovell
Darpinian Peach Rootstock Trial, Escalon. April, 2006



Rootstock Influence on Tree Nutrition

Rootstock Influences on Tree Nutrition

Escalon Almond 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

Cumulative Yield of Escalon Almond Rootstock Trial

Rootstock	Cumulative Yield / Tree (4^{th} - 7^{th} leaf)	Cumulative Yield / Acre (4^{th} - 7^{th} leaf)
Atlas	60.4	8335
Guardian	59.2	8170
Nickels	37.8	5216
Viking[2]	50.4	6955
Bright's	53.9	7438
Nemaguard	57.3	7907
Lovell	52.3	7217
Hansen 536	42.9	5920

Colusa County Rootstock Yield Efficiency

Yield (lb per tree) / trunk circumference (cm)

	2000	2001	2002	2003	2004
Brights	0.10	0.16	0.50	0.38	--
Hansen 536	0.12	0.17	0.50	0.42	--
Hansen 2168	--	--	--	--	--
Nickels	0.13	0.17	0.48	0.39	--
Viking	0.15	0.19	0.47	0.34	--
Atlas	0.16	0.20	0.53	0.42	--
Guardian	--	--	--	--	--
Nemaguard	0.11	0.16	0.50	0.38	--
Lovell	0.15	0.20	0.48	0.36	--

Kern County Rootstock Yield Efficiency

24’ x 24’ (75.6 trees / acre)

	1999	2000	2002	2003	2004
Brights	0.09	0.16	0.47	0.44	0.53
Hansen 536	0.14	0.23	0.46	0.44	0.48
Hansen 2168	0.15	0.24	0.40	0.29	0.35
Nickels	*	*	*	0.46	0.50
Viking	0.09	0.18	0.38	0.39	0.47
Atlas	0.18	0.28	0.50	0.52	0.48
Guardian	--	--	--	--	--
Nemaguard	0.13	0.21	0.44	0.42	0.48
Lovell	--	--	--	--	--

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

Almond Rootstock Trial #2

Ceres, CA. Est.
Cvs. ‘Nonpareil’ and ‘Carmel’

- Second generation orchard
- Sandy soil
- One year fallow
- Not fumigated prior to planting
- Started with very low numbers of parasitic nematodes

List of Rootstocks Planted in Almond Replant Trial. Ceres, CA

Rootstock	Parentage	Origin
Nemaguard	Peach	USA
Lovell	Peach	USA
Guardian SC-17	Peach	Clemson University
Empyrean #1 (a.k.a. Barrier 1)	Peach x Chinese wild peach	Venice, Italy
Hansen 536	Peach x almond	UC Davis
Nickels	Peach x almond	UC Davis
Cornerstone	Peach x almond	Burchell Nursery
Paramount (a.k.a. GF 677)	Peach x almond (OP)	France
Avimag (a.k.a. Cadaman)	*(Peach x almond) x wild peach*	France & Hungary
Empyrean #2 (a.k.a. Penta)	*P. domestica*	Rome, Italy
Empyrean #101 (Adesoto)	*P. insititia*	Zaragoza, Spain
Julior	*P. insititia* x *P. domestica*	France
Krymsk 86 (a.k.a. Kuban 86)	*P. persica* x *P. cerasifera*	Russia
P30-135 (a.k.a. Controller 9)	*P. persica* x *P. salicina*	USDA
Atlas	Peach x almond x plum x apricot	Zaiger Genetics
Viking	Peach x almond x plum x apricot	Zaiger Genetics

Alternative Rootstocks Being Tested in Stanislaus County for Almond

Avimag (Cadaman)

- 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)

Alternative Rootstocks Being Tested in Stanislaus County for Almond

Empyrean 101 (Adesoto 101)

- 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

Alternative 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

Alternative 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


Nemaguard
Nickels


Lovell
Hansen

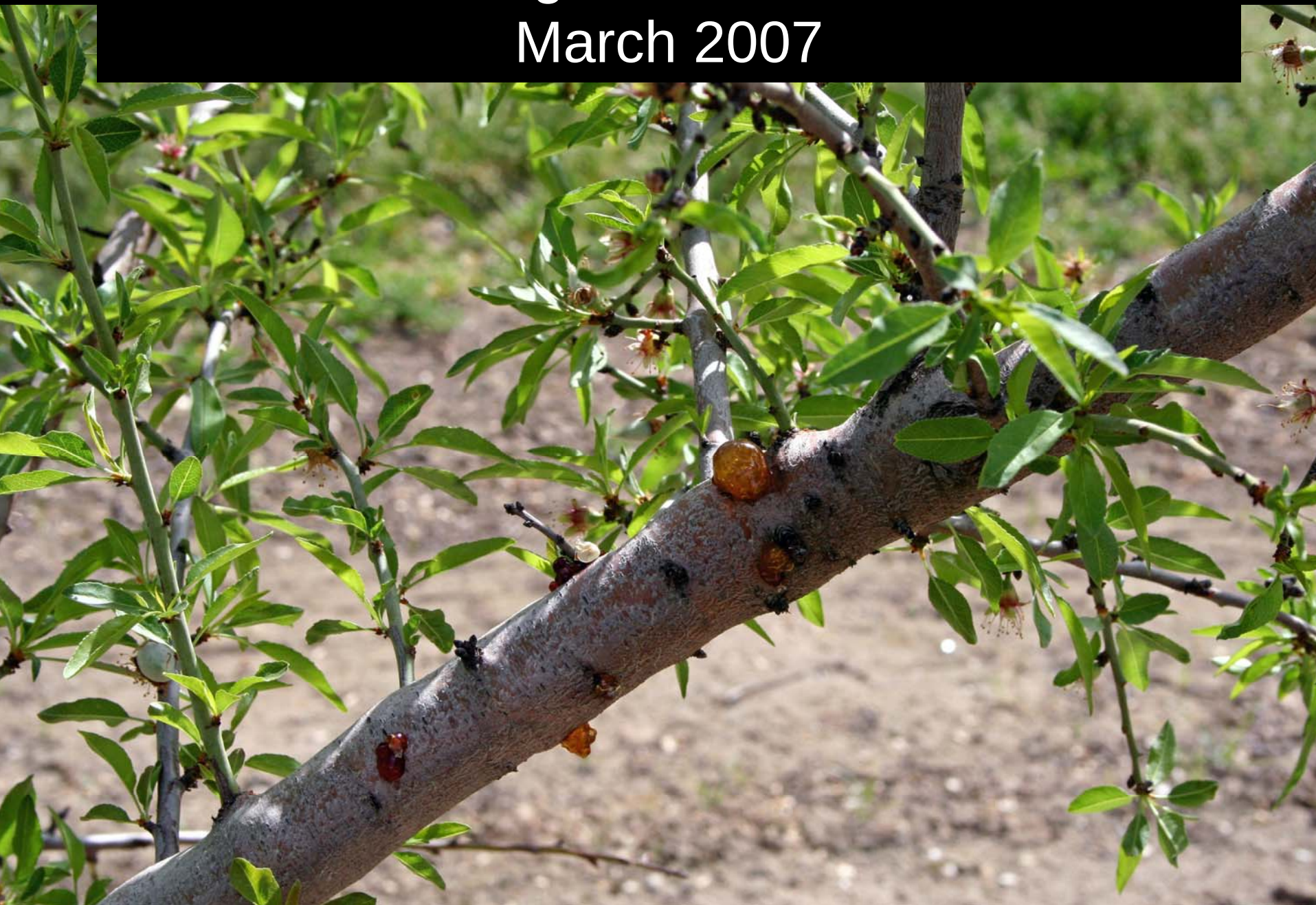
Nickels dead from Phytophthora – spring 2007

Crown Gall on Hansen Rootstock


Cornerstone
Adesoto

Third-Leaf Nonpareil Almond on Penta (a.k.a. Empyrean #2) with Signs of Incompatibility

Penta with signs of bacterial canker. March 2007



Ring Nematode Numbers on 3rd-Leaf Trees. February, 2006

P/A hybrids & Julior beginning to build high levels of ring nematodes after three years

Viking
Atlas
Paramount
Kuban 86
Lovell
Guardian
Barrier 1
Adesoto
Penta
Cadaman
Nemaguard
Julior
Nickels
Cornerstone
Hansen 536

0 50 100 150 200 250 300

ring nematodes / 250 cc soil

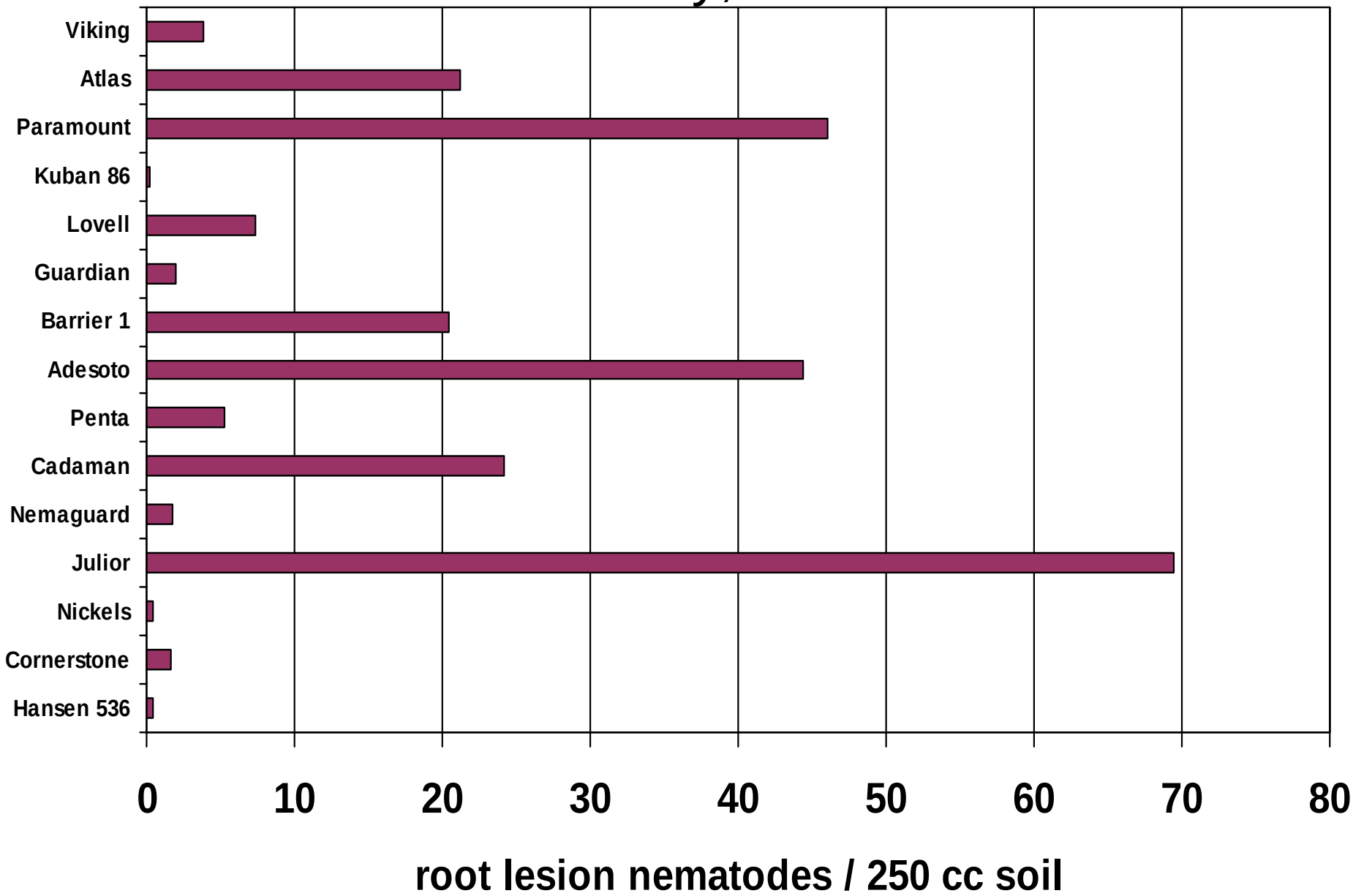
Ring Nematode Numbers on 4th -Leaf Trees. February, 2007

Viking
Atlas
Paramount
Kuban 86
Lovell
Guardian
Barrier 1
Adesoto
Penta
Cadaman
Nemaguard
Julior
Nickels
Cornerstone
Hansen 536

0 100 200 300 400 500

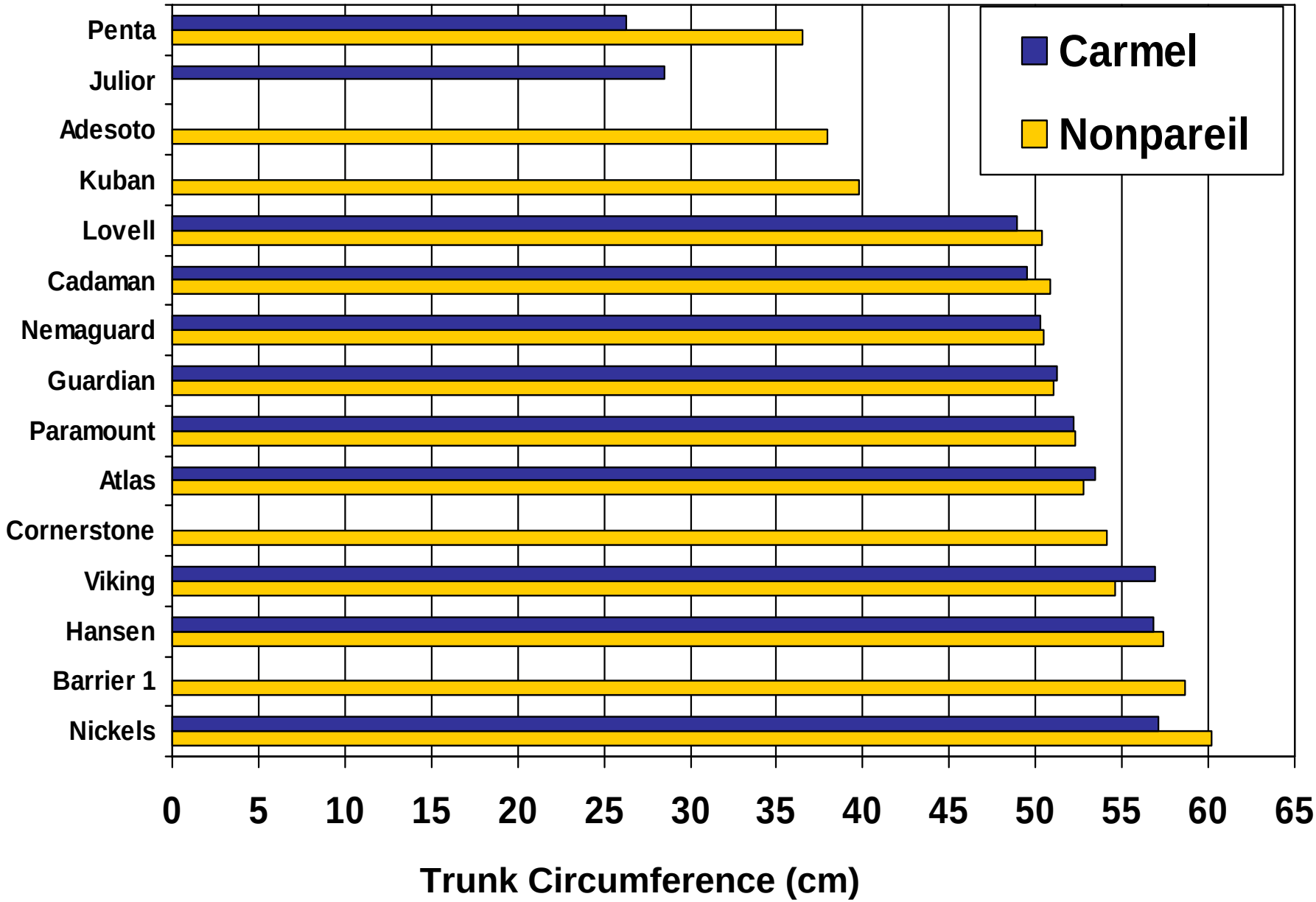
ring nemas / 250 cc soil

Root Lesion Nematode Numbers on 3rd-Leaf Trees. February, 2006



Rootstock Influence on Size of 4th-Leaf Trees

Gemperle-Bacon Almond Rootstock Trial. October 2006.



Bloom of Carmel Almond as Influenced by Rootstock. February 24, 2006.

Barrier 1 & P/A hybrid rootstocks bloomed earlier, had better bloom overlap with Nonpareil

Barrier 1
Nickels
Hansen
Cadaman
Atlas
Paramount
Viking
Lovell
Guardian
Nemaguard
Julior
Nonpareil / nemaguard

0 10 20 30 40 50 60 70 80 90

Percent Bloom

4th Leaf Yield (lb / acre) of the Various Rootstocks

2006

Rootstock	Nonpareil	Carmel
Nickels	684 a	1584 a
Barrier 1 (Empyrean 1)	669 a	--
Hansen	642 a	1354 ab
Cadaman (Avimag)	617 a	1094 bc
Paramount (GF 677)	--	1090 bc
Atlas	599 ab	1103 bc
Lovell	569 ab	992 bc
Viking	555 ab	1127 bc
Cornerstone	553 ab	--
Guardian	511 ab	1130 bc
Nemaguard	469 ab	857 c
Adesoto (Empyrean 101)	369 b	--

Early Conclusions

- Rootstock significantly affects tree size
  - Nickels, Hansen and Empyrean #1 (Barrier 1) are the most vigorous
  - Rootstocks with plum parentage are the least vigorous
- Early yields are largely influenced by tree size; the most vigorous rootstocks have the highest early yields. Atlas appears to have a relatively high yield efficiency

Early Conclusions cont…

- Peach / almond hybrid rootstocks (Hansen, Cornerstone and Nickels) and Julior are hosting dangerous levels of ring nematodes

- Many rootstocks advanced Carmel bloom substantially compared to nemaguard, resulting in better bloom overlap with Nonpareil

Early Conclusions cont…

- Controller 9 (P30-135) is incompatible with almond (also Empyrean #2, a.k.a. Penta?)

Conclusions of Previous Regional Rootstock Trials

- Viking very susceptible to dehydration during cold storage & planting
- Peach / almond hybrids most vigorous
  - Had highest yields only until orchard filled out
  - Atlas usually had highest mature yield efficiency
- P/A hybrids and Viking have very good anchorage

Conclusions of Previous Regional Rootstock Trials cont…

- Rootstock has a significant effect on nutrient uptake. In general:
  - P/A hybrid leaf tissue has less N, K, B, Cl and Na*
    - *Bright's accumulates more sodium
  - P/A hybrids pick up more Ca, Mg, Mn and Zn
  - Viking high in potassium
  - Atlas high in boron

Conclusions of Previous Regional Rootstock Trials

- Peach / almond hybrid rootstocks are excellent hosts for ring nematode and are extremely susceptible to bacterial canker

- Lovell, Viking and Guardian are more resistant than Nemaguard