2023

THE ALMOND CONFERENCE

Connecting the Dots

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Replanting an Almond Orchard in Today’s Financially Challenging World

Moderator: Sebastian Saa (ABC)

Speakers: Brent Holtz (UC ANR), Matt Cox (Capay Farms), Greg Browne (USDA ARS), Roger Duncan (UC ANR)

Session Details

REPLANTING AN ALMOND ORCHARD IN TODAY`S FINANCIALLY CHALLENGING WORLD

Moderator
Sebastian Saa, ABC, Session Moderator

Speakers
Brent Holtz, UCCE, San Joaquin County

Mathew Cox, Capay Farms

Greg Browne, USDA-ARS

Roger Duncan, UCCE Stanislaus County

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Proper Tree Planting After Whole Orchard Recycling

Proper Tree Planting After Whole Orchard Recycling

by

Brent A. Holtz, Ph.D.

The Almond Conference

December 7th, 2023

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Agriculture and Natural Resources

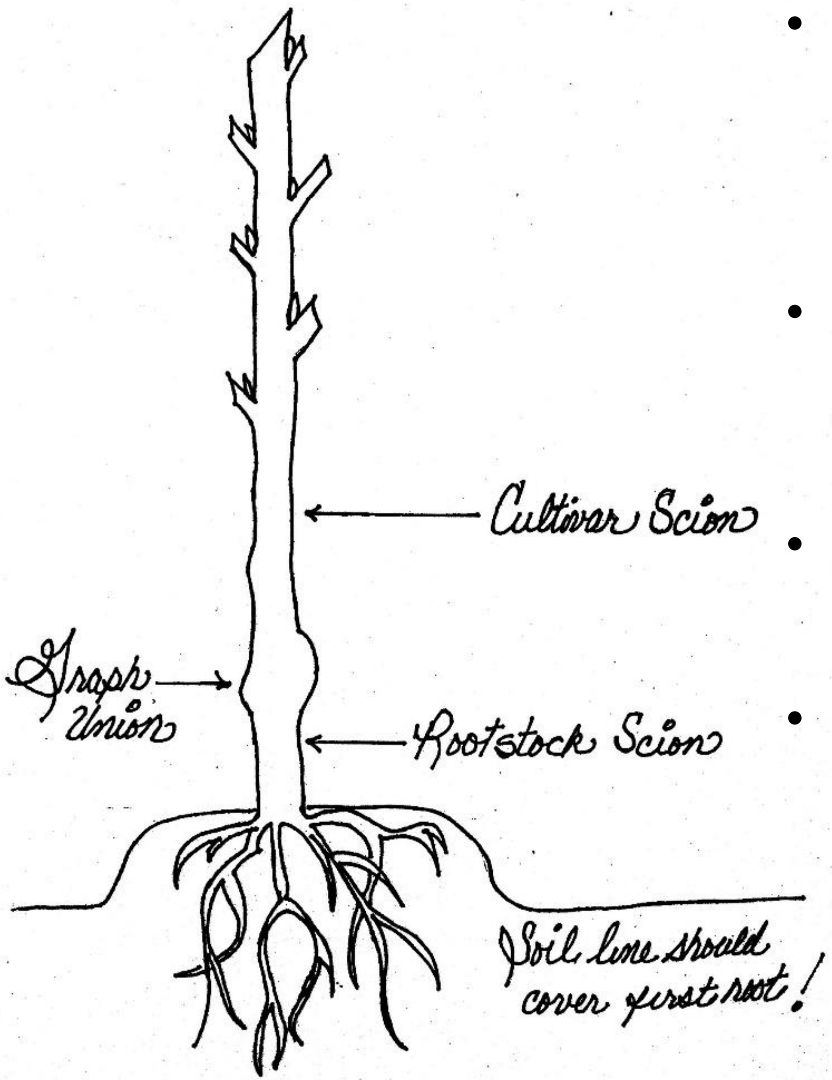
Proper almond tree planting

- Small root hairs of dormant bareroot trees can dry out quickly: keep roots protected from the air as much as possible
- Roots store carbohydrates needed to support new growth
- Do not heavily prune roots (only damaged roots)

Proper almond tree planting

- prevent crown gall infections by treating roots before planting with Galltrol *Agrobacterium radiobacter* (Strain 84) (www.agbiochem.com)

- Dig a hole deep and wide enough so the roots are spread out and not cramped
- Allow for 3-6 inches of settling in the planting hole
- Plant high on a berm
- Pull berms up before planting not afterwards



- Plant trees so the nursery soil line is above the current soil line
- Plant the highest root slightly above soil line, cover it with extra dirt
- Do not plant too deep!
- Be careful not to break any roots!

Prevention: Proper almond tree planting

- After planting, trees should be watered in with 1 to 3 gallons of water, even if the soil is moist

- ABC is producing a tree planting video that will be out soon.

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Irrigation system and nutrient efficiency

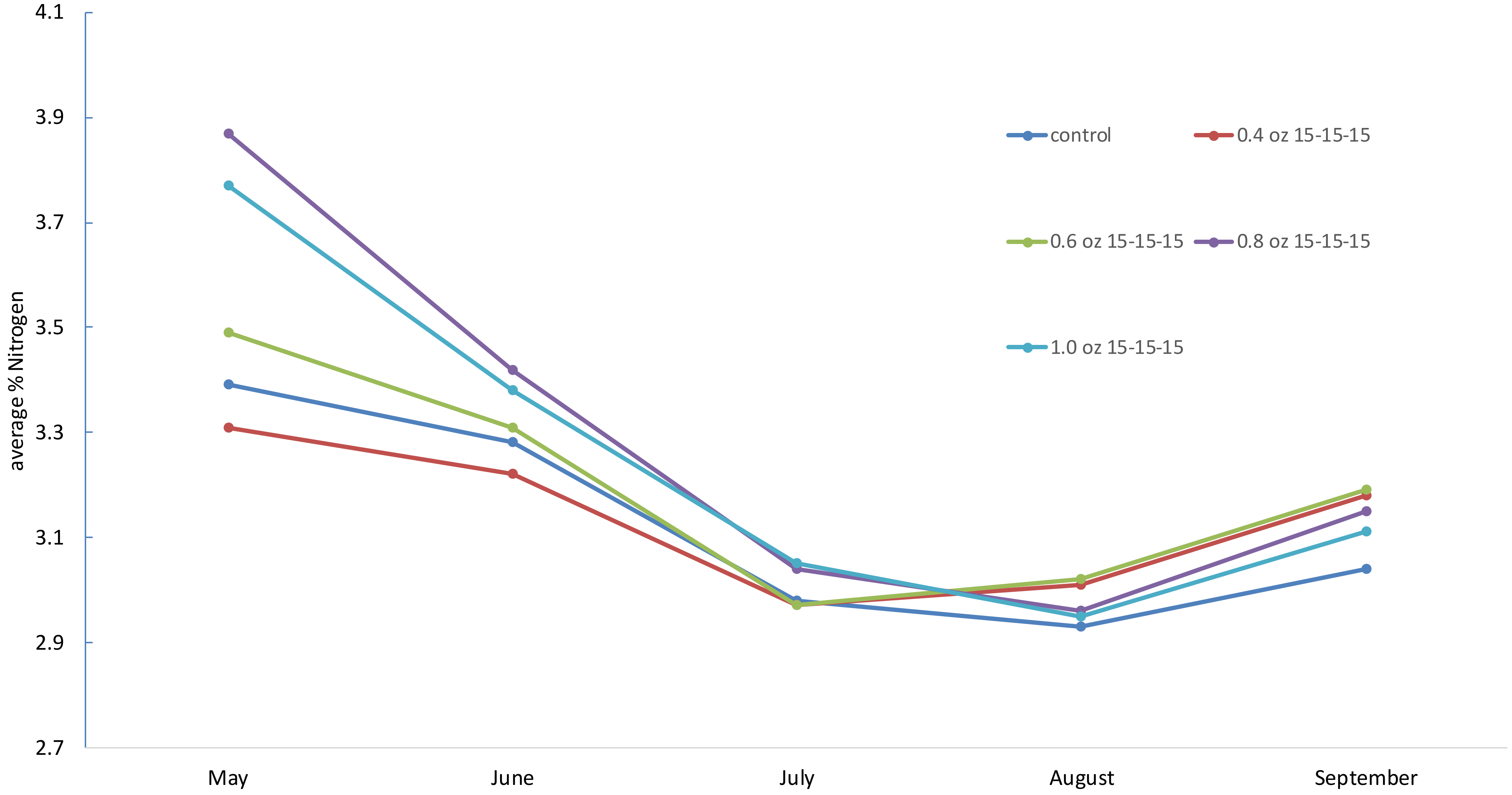
64 tons per acre caused initial tree stunting and total weed suppression. The C:N ratio was out of balance.

We doubled our nitrogen applications through fertigation in order to get the desired growth.

Northwest tiller was used to finish incorporating woodchips

Control

0.8 oz of N applied in March



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Control

70 tons per acre rate

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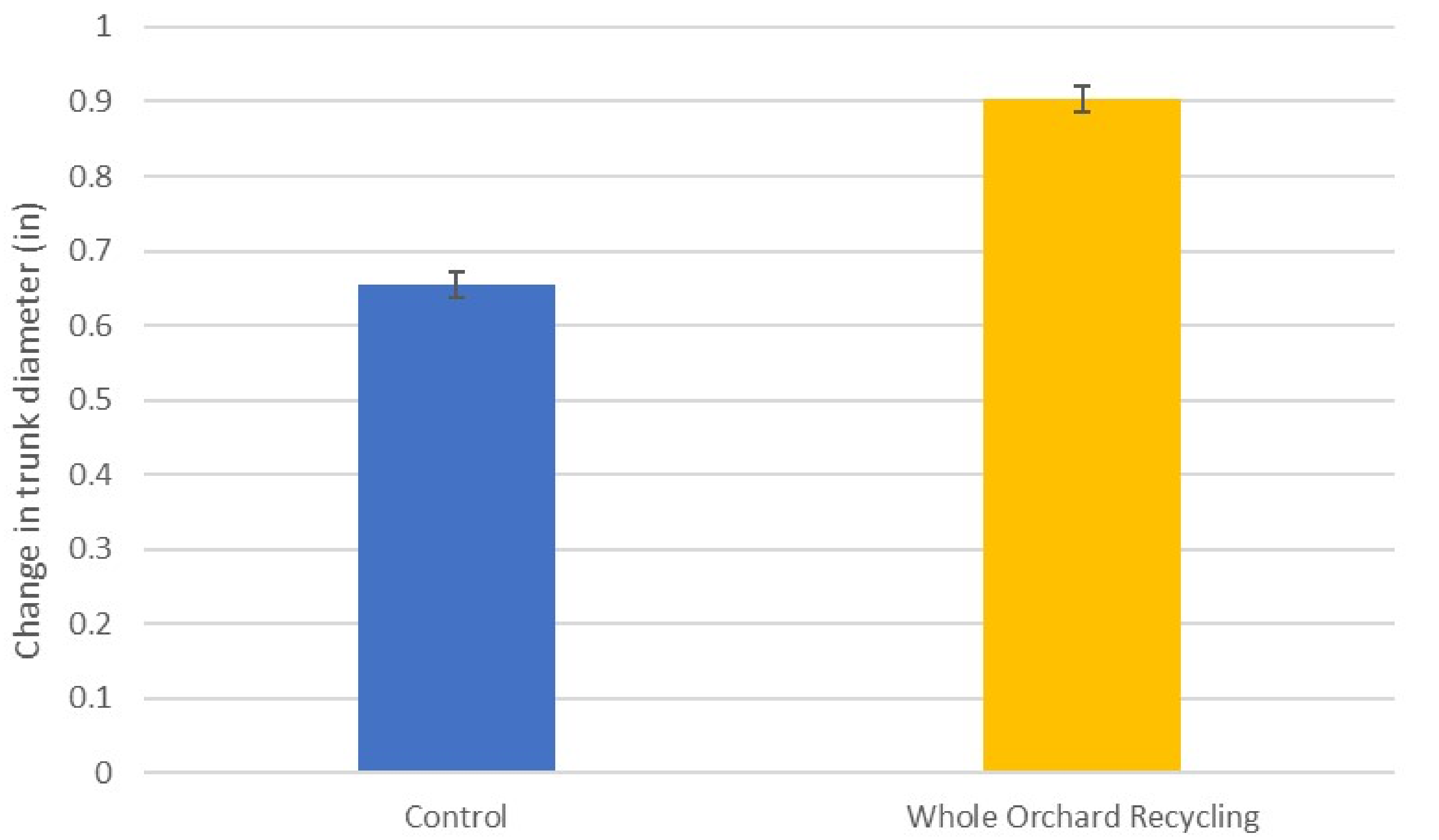
Both treatments received 4.5 oz of N per tree

Control

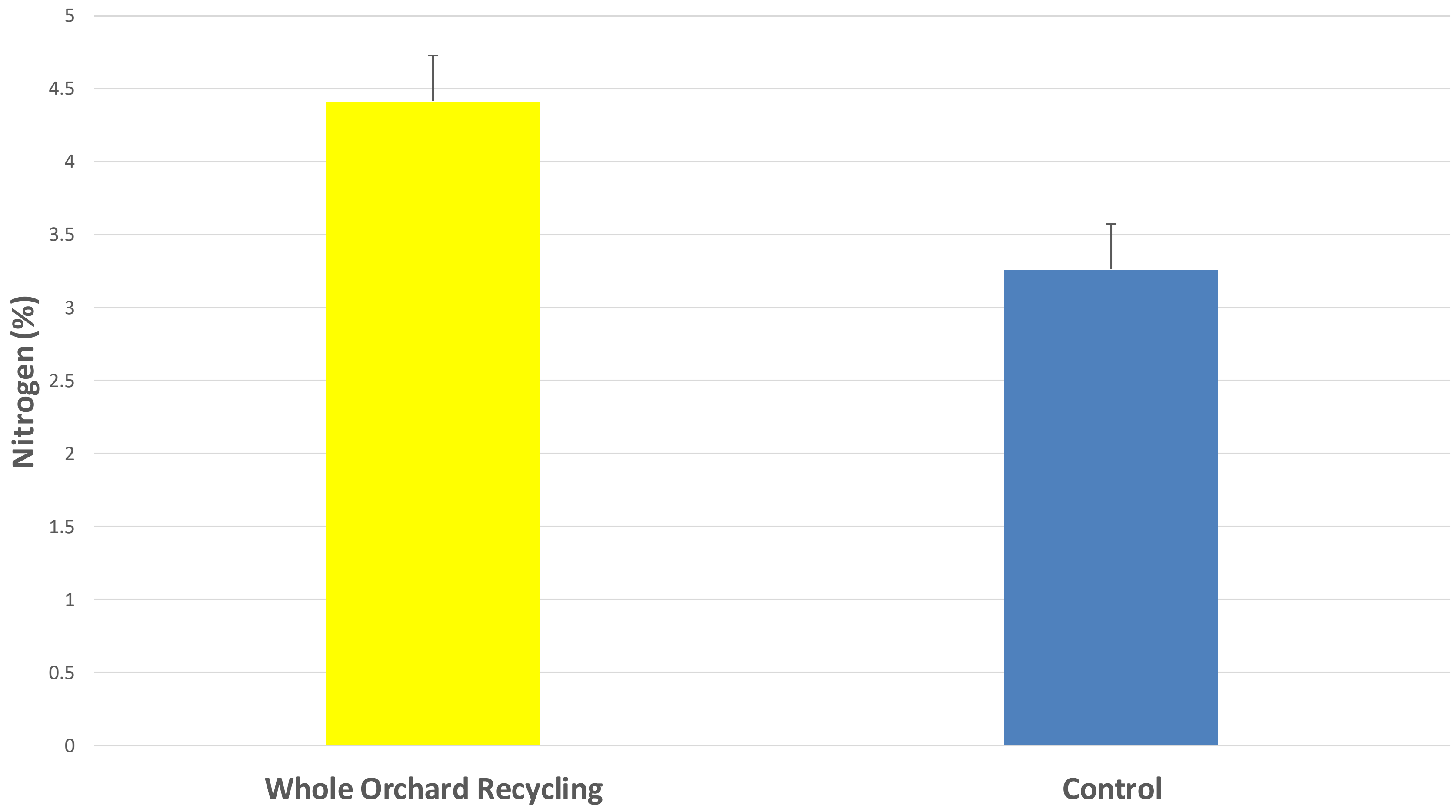
70 tons per acre rate

Both treatments received 45 lbs N/acre



Both treatments received 45 lbs N/acre (5 oz N per tree)

Leaf Petiole Analysis



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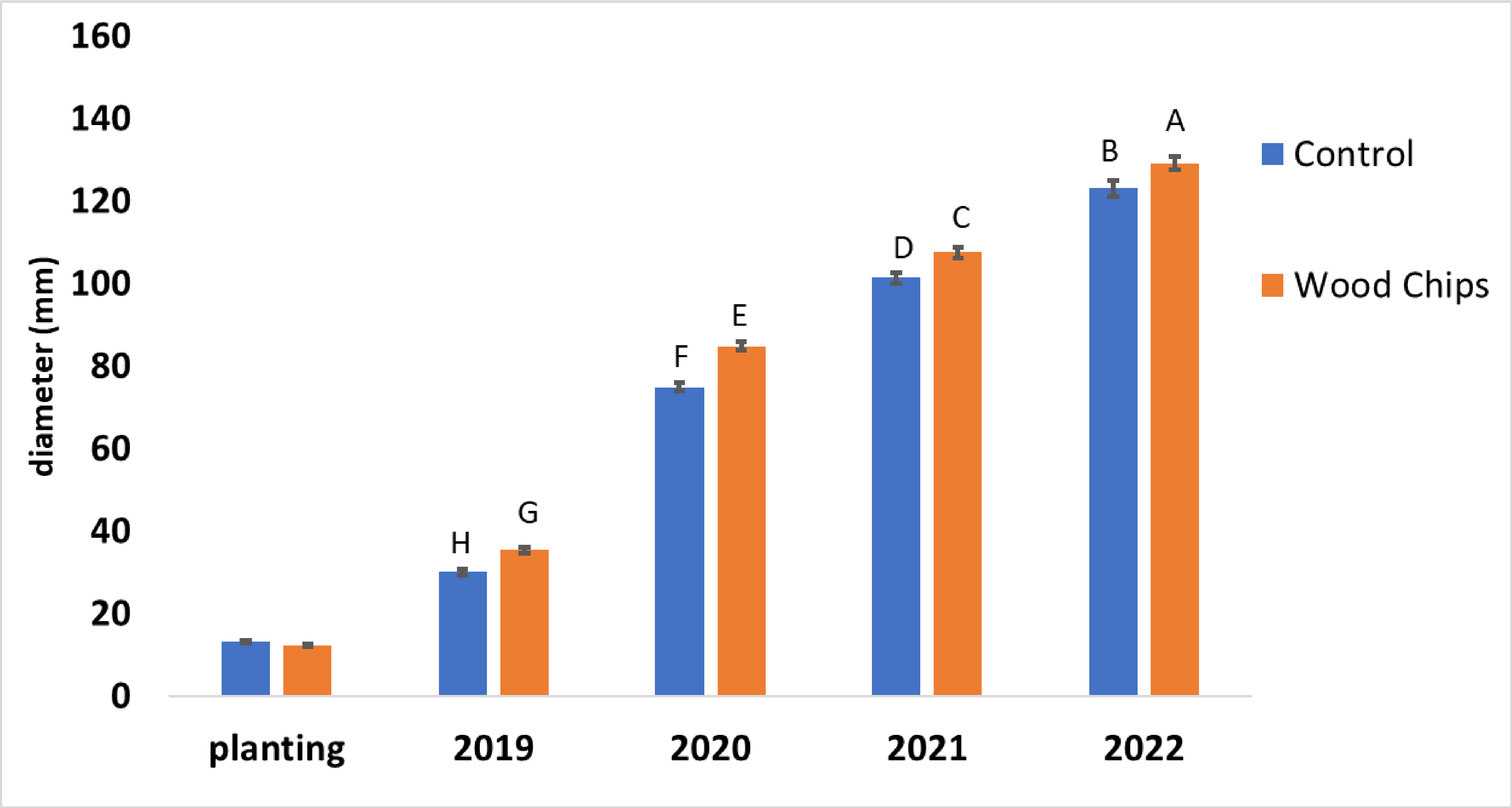
Both received 45 lbs N/acre (5 oz N per tree)

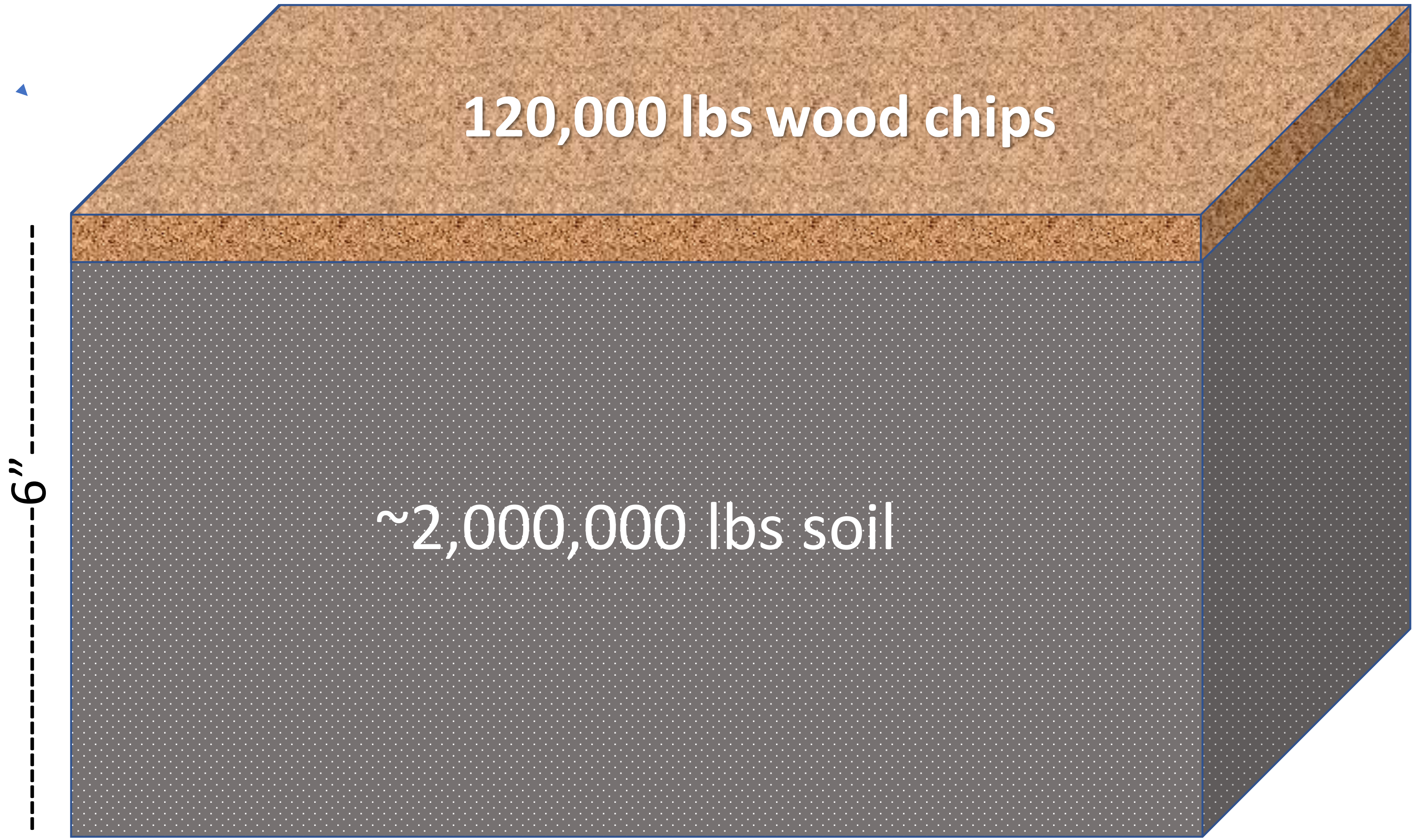

160
140
120
100
80
60
40
20
0
diameter (mm)
H
G
F
E
D
C
B
A
Control
Wood Chips
planting
2019
2020
2021
2022

When 64 tons of wood chips are returned to the soil per acre:
N= 0.31 %, 396 lbs/ac
K= 0.20 %, 256 lbs/ac
Ca= 0.60 %, 768 lbs/ac
C= 50 %, 64,000 lbs/ac

The nutrients will be released gradually and naturally

Can we return this organic matter to the soil without negatively impacting the next crop?

60-ton dry wt. wood chip application
= 6% of soil mass in the top 6" of soil



A plow is best at incorporating wood chips

Christine Gemperle's plow

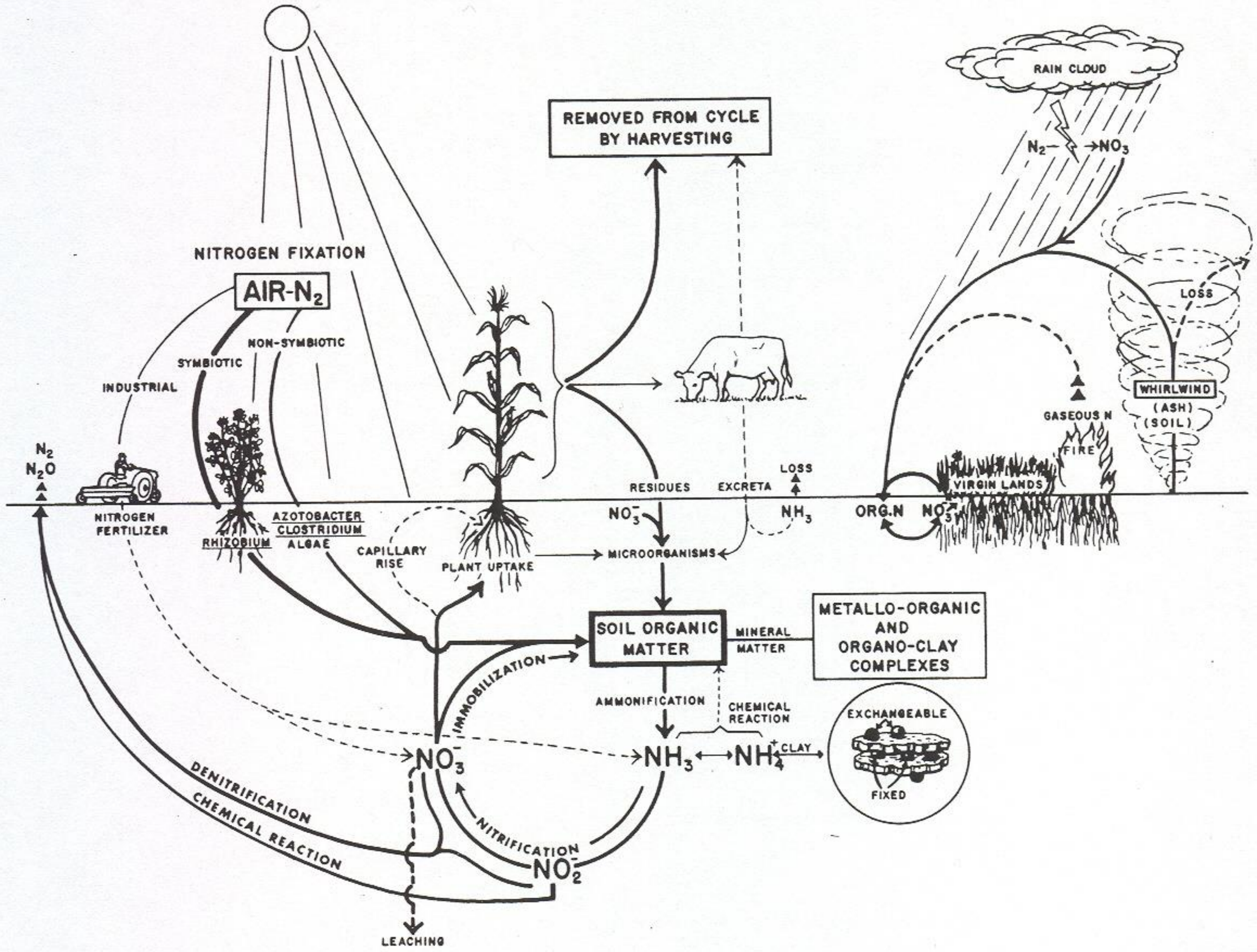


Figure 8.1. Nitrogen cycle in soil. (From Stevenson, 1982.)

2000 barrel experiment:

Almond prunings were chipped with a Brush Bandit wood chipper

sandy loam soil was mixed with wood chips, 1/3 chips to 2/3 soil

I thought this rate would be similar to whole orchard recycling?

It turned out to be much greater— a 300 tons per acre rate

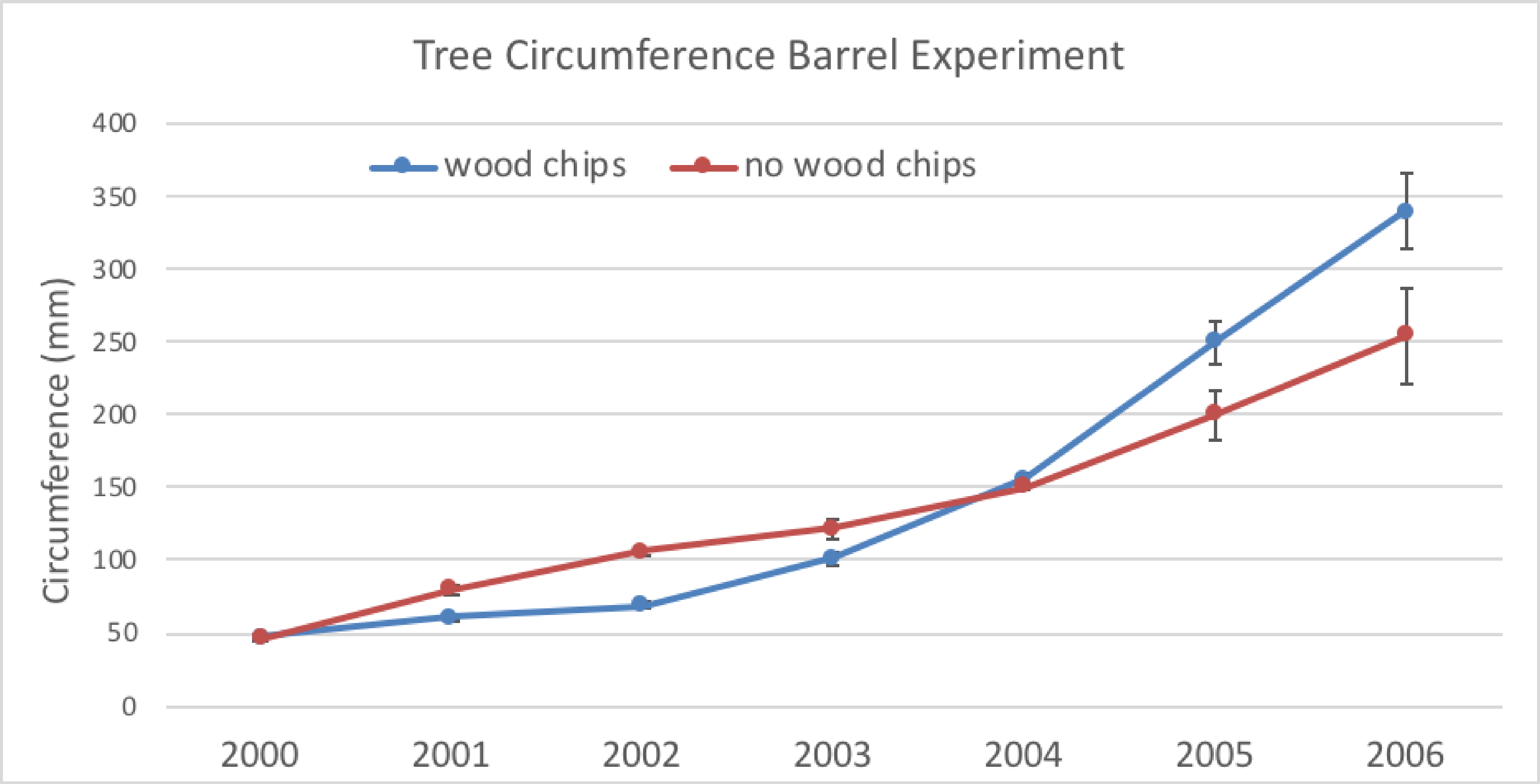
- 1/3 part wood chips were mixed with 2/3 parts soil
- Placed in 35 gallon containers

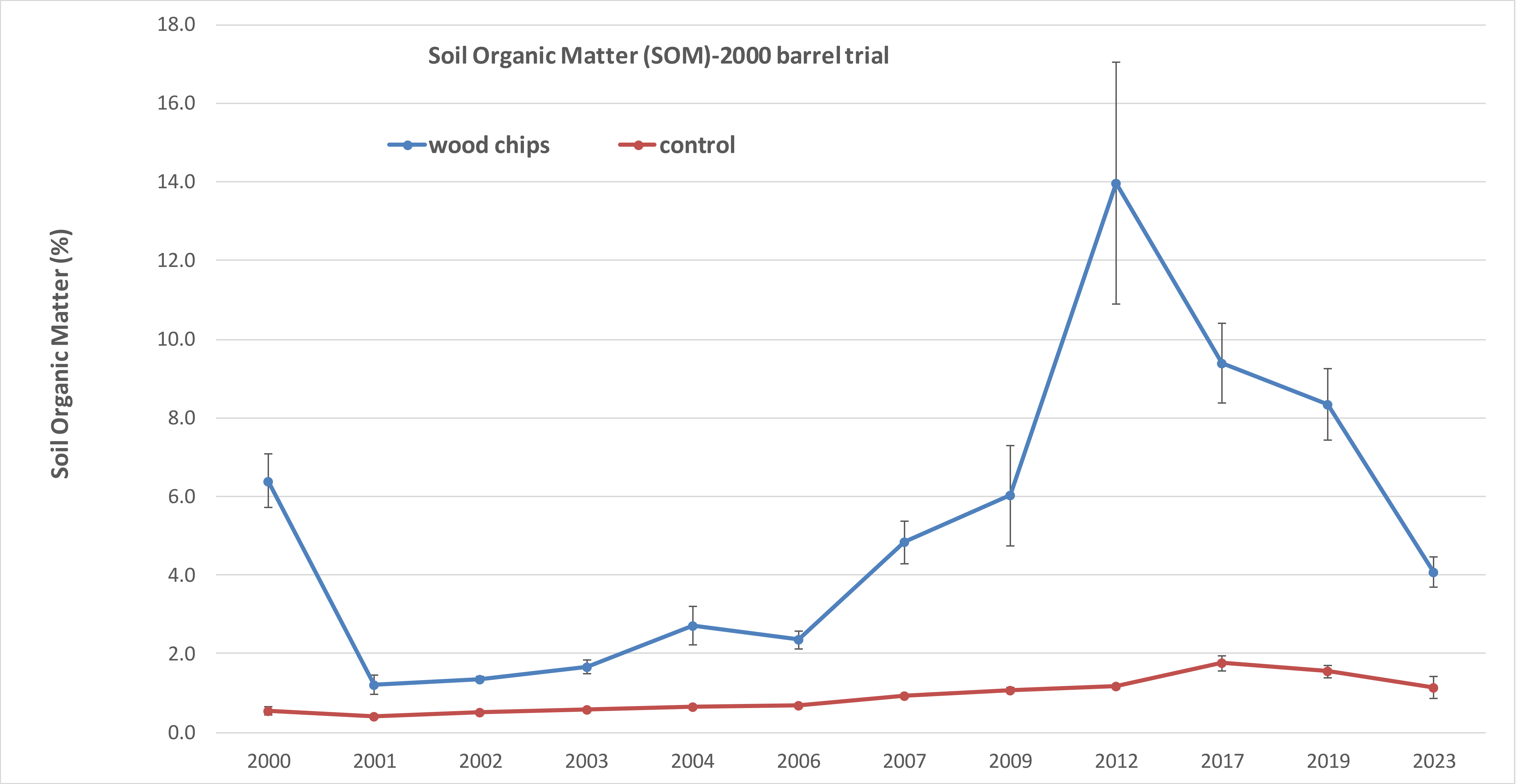
- One almond tree was planted per barrel

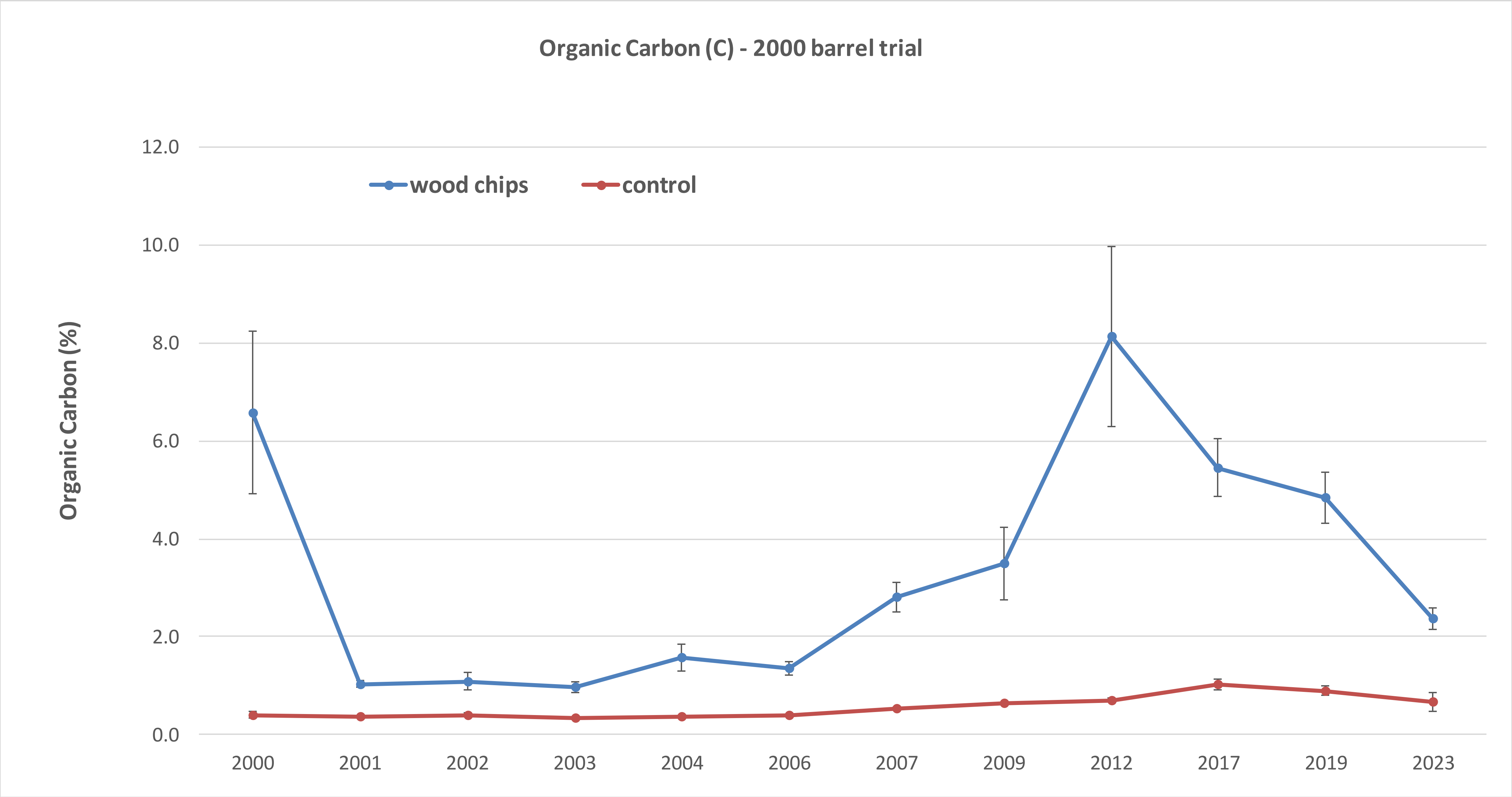
49 ppm Nitrate in the water

- Ten barrels received the wood chip and soil mixture while another 10 just received soil

- Mushrooms were found frequently after rainfall and irrigations in the chipped plots


Tree Circumference Barrel Experiment
wood chips
no wood chips
Circumference (mm)
400
350
300
250
200
150
100
50
0
2000
2001
2002
2003
2004
2005
2006


Soil Organic Matter (SOM)-2000 barrel trial
wood chips
control
Soil Organic Matter (%)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2000
2001
2002
2003
2004
2006
2007
2009
2012
2017
2019
2023



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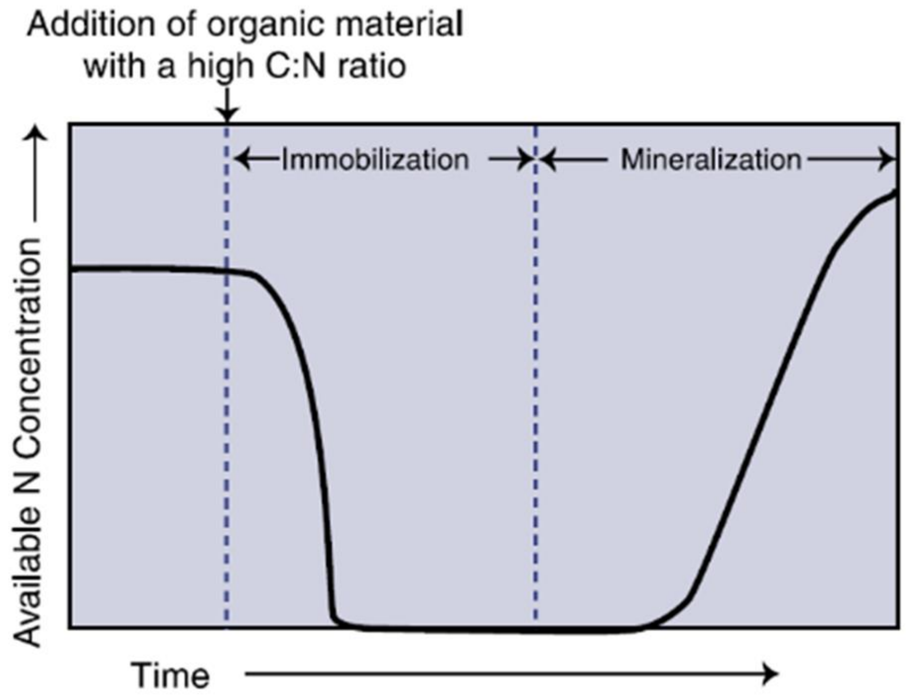
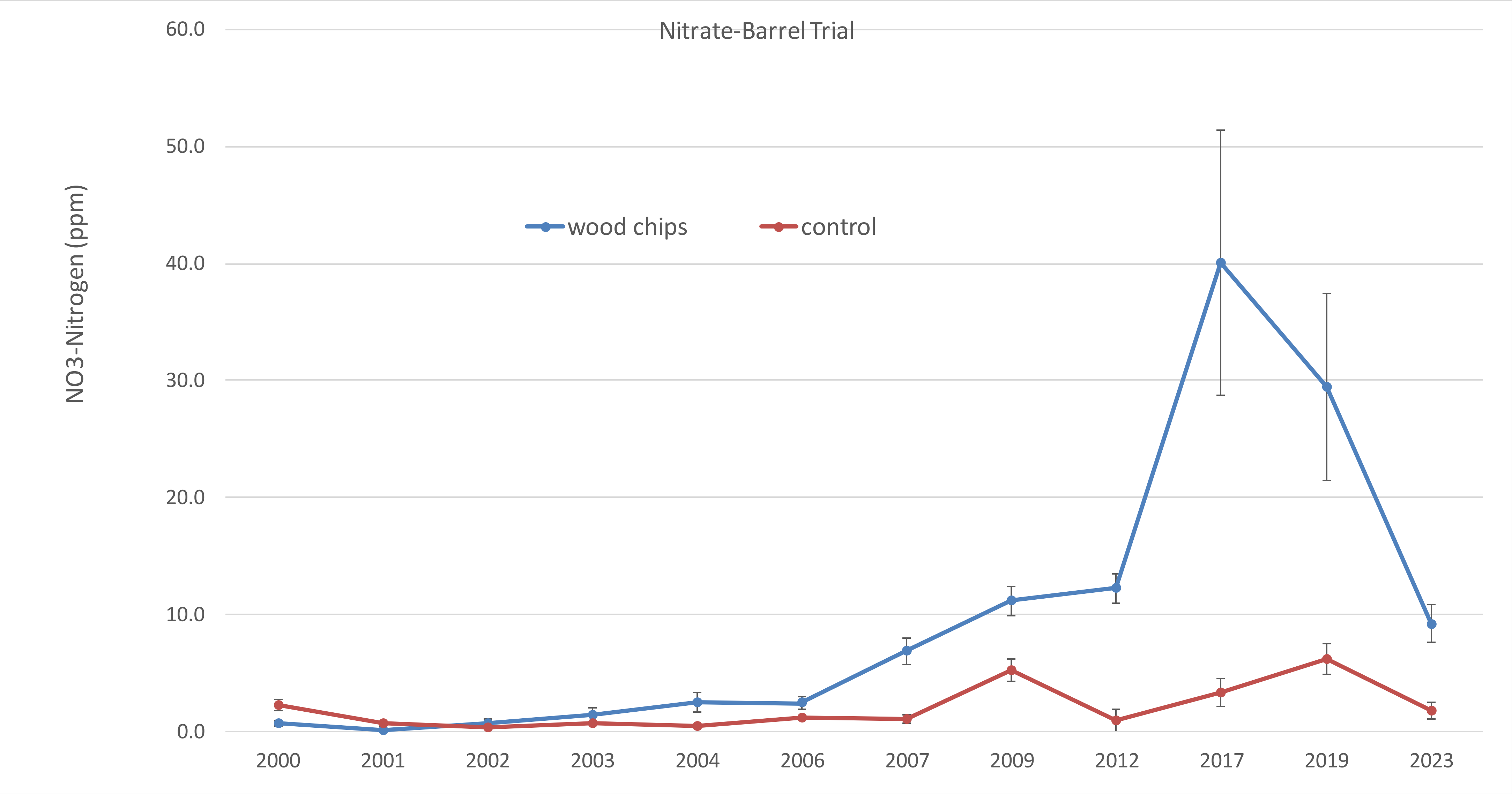
Available N for newly planted crop changes following addition of high C:N material like wood chips

- High C content stimulates microbial N immobilization, as organic material decomposes and microbial communities shift, N is mineralized and available for plant uptake over time
- How long does this process take?

Figure 2. Available N changes following addition of high C:N organic material.





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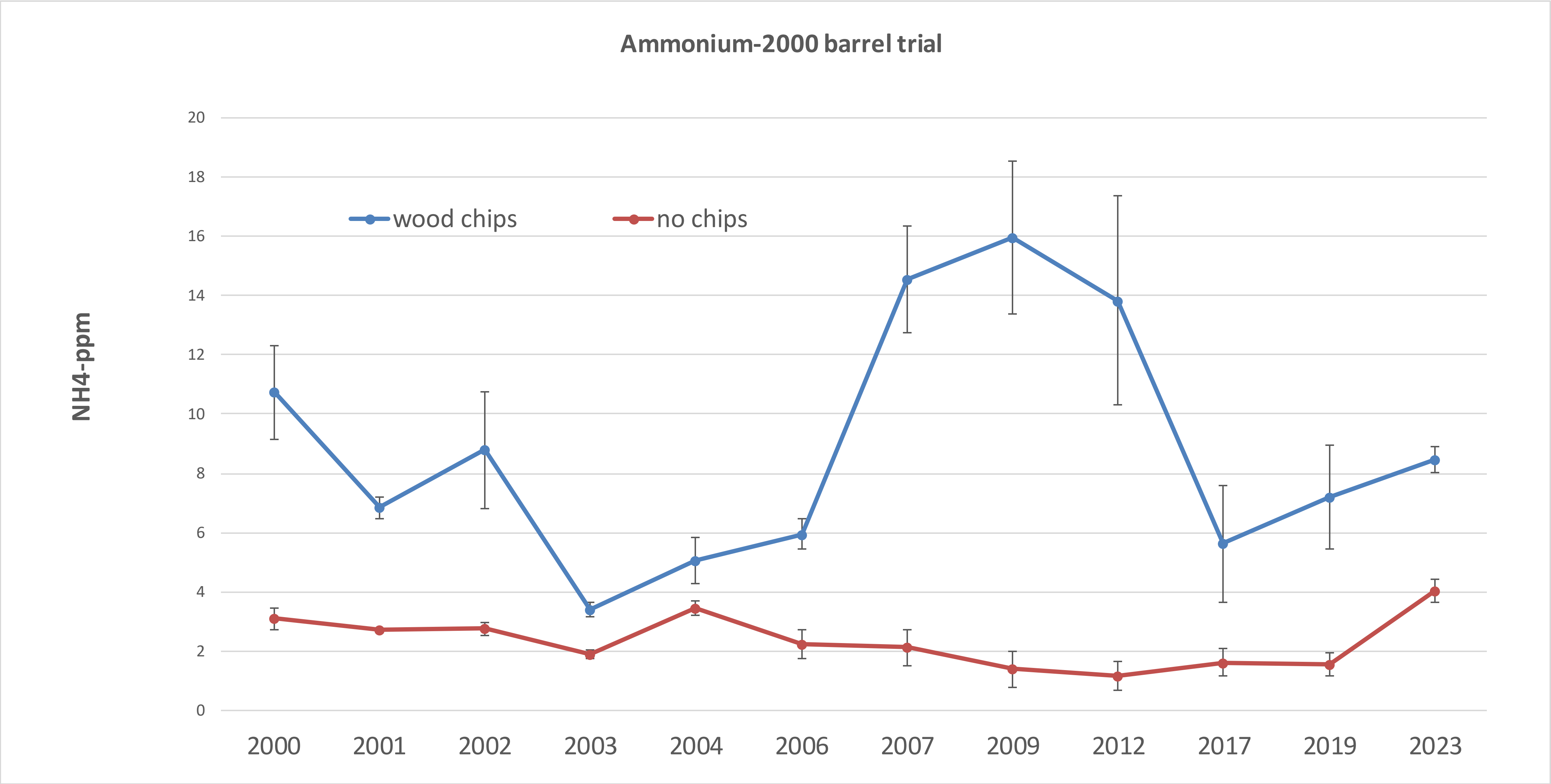

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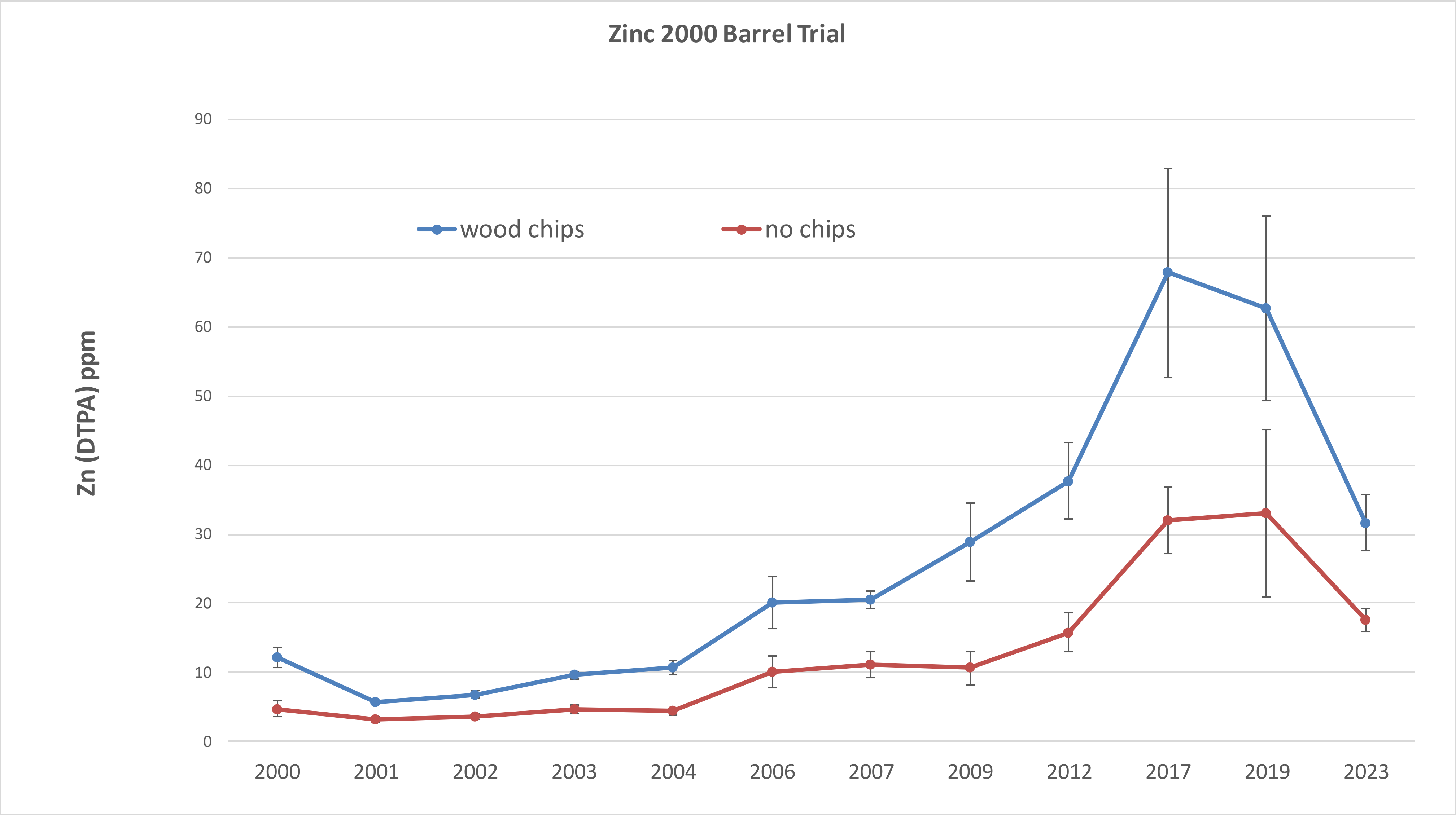
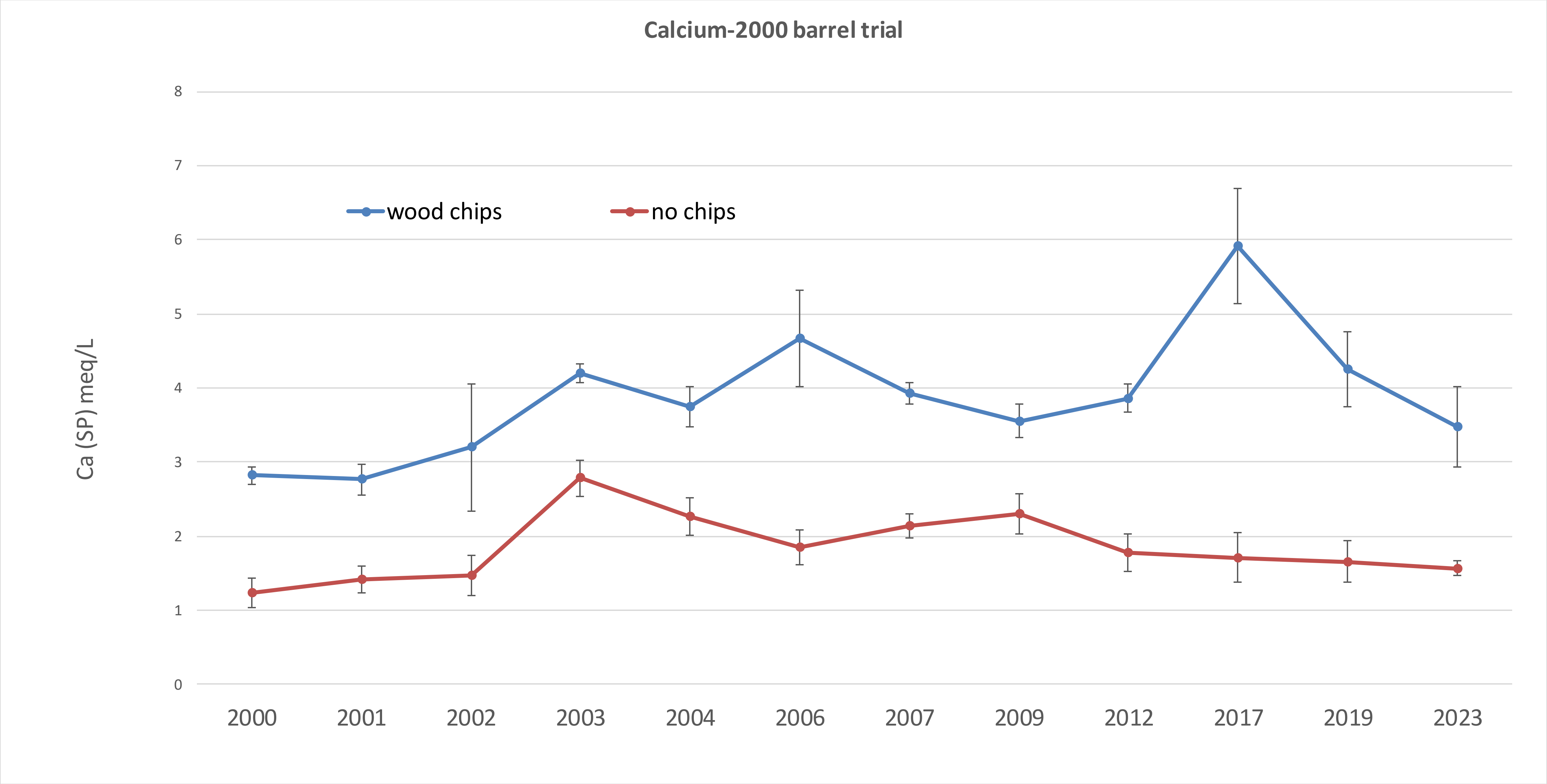
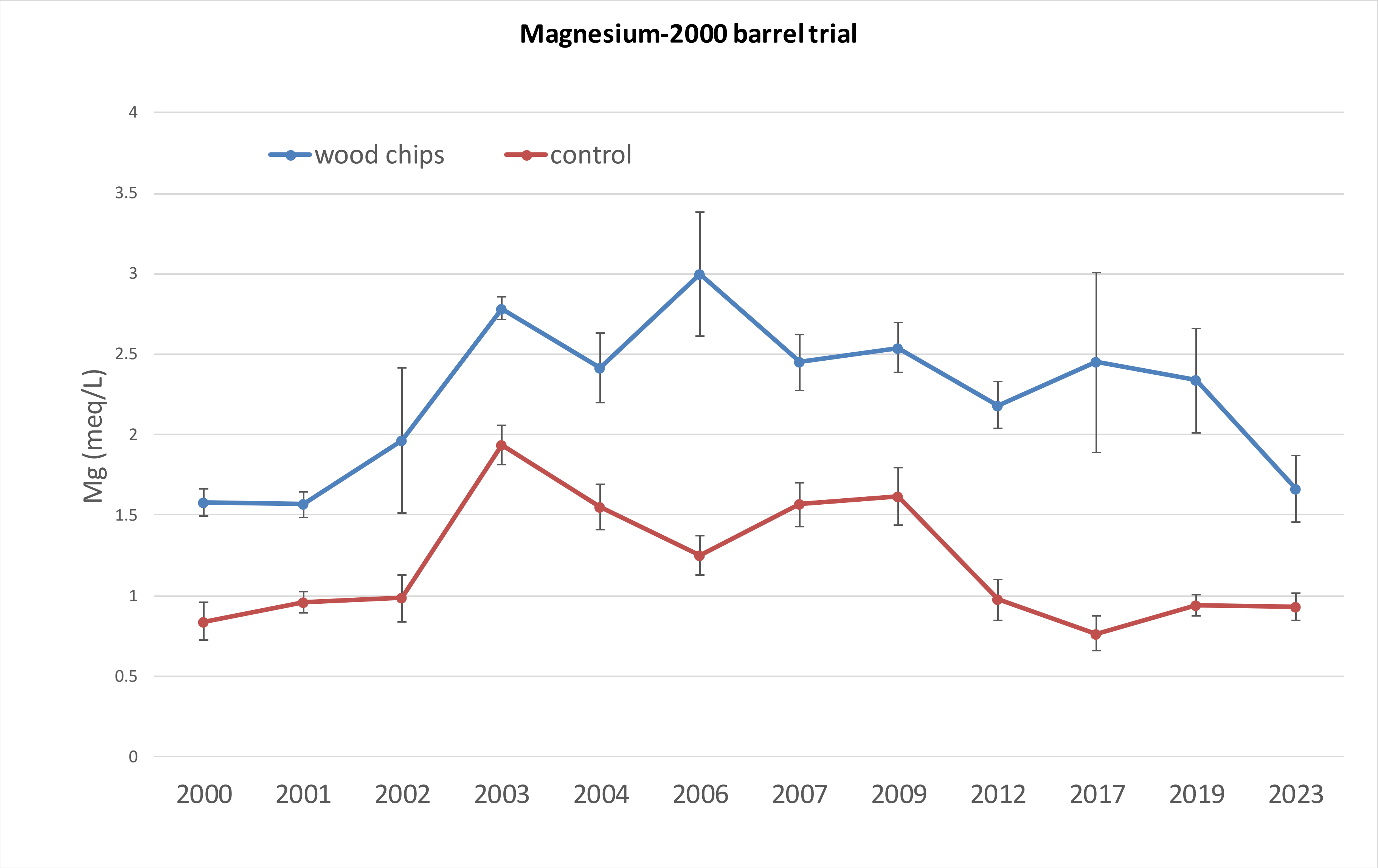
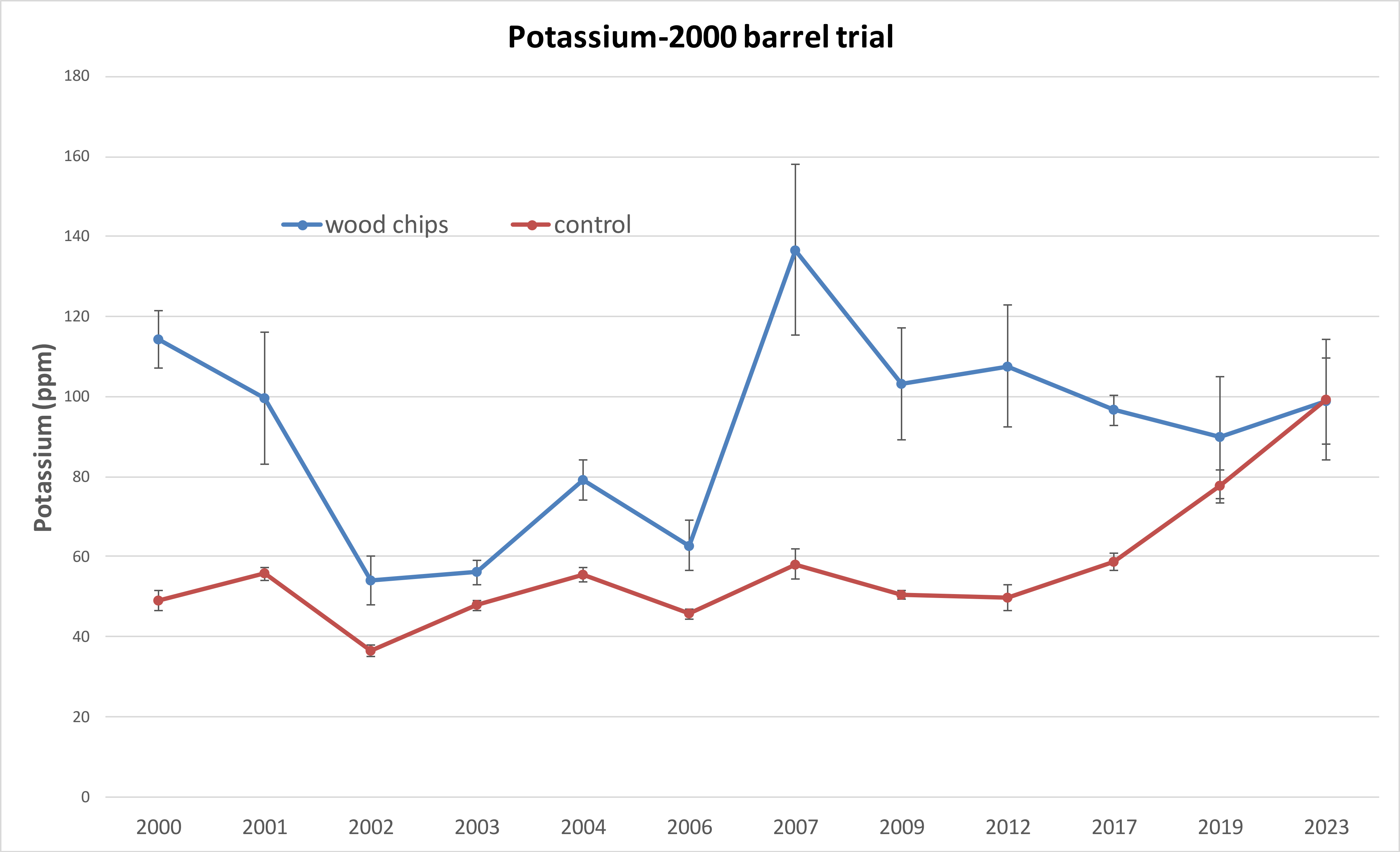


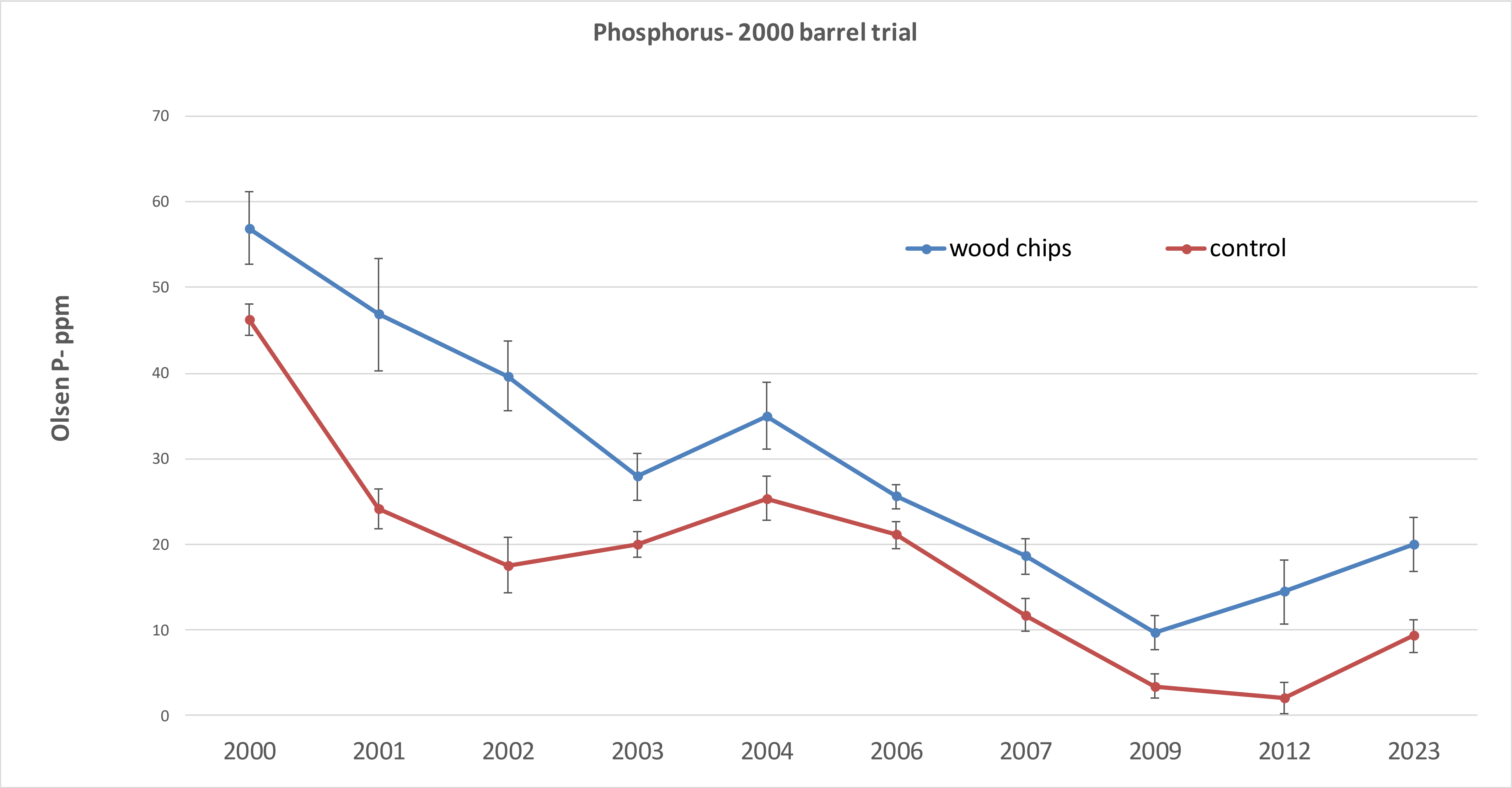
Zinc 2000 Barrel Trial
Zn (DTPA) ppm
wood chips
no chips
0
10
20
30
40
50
60
70
80
90
2000
2001
2002
2003
2004
2006
2007
2009
2012
2017
2019
2023



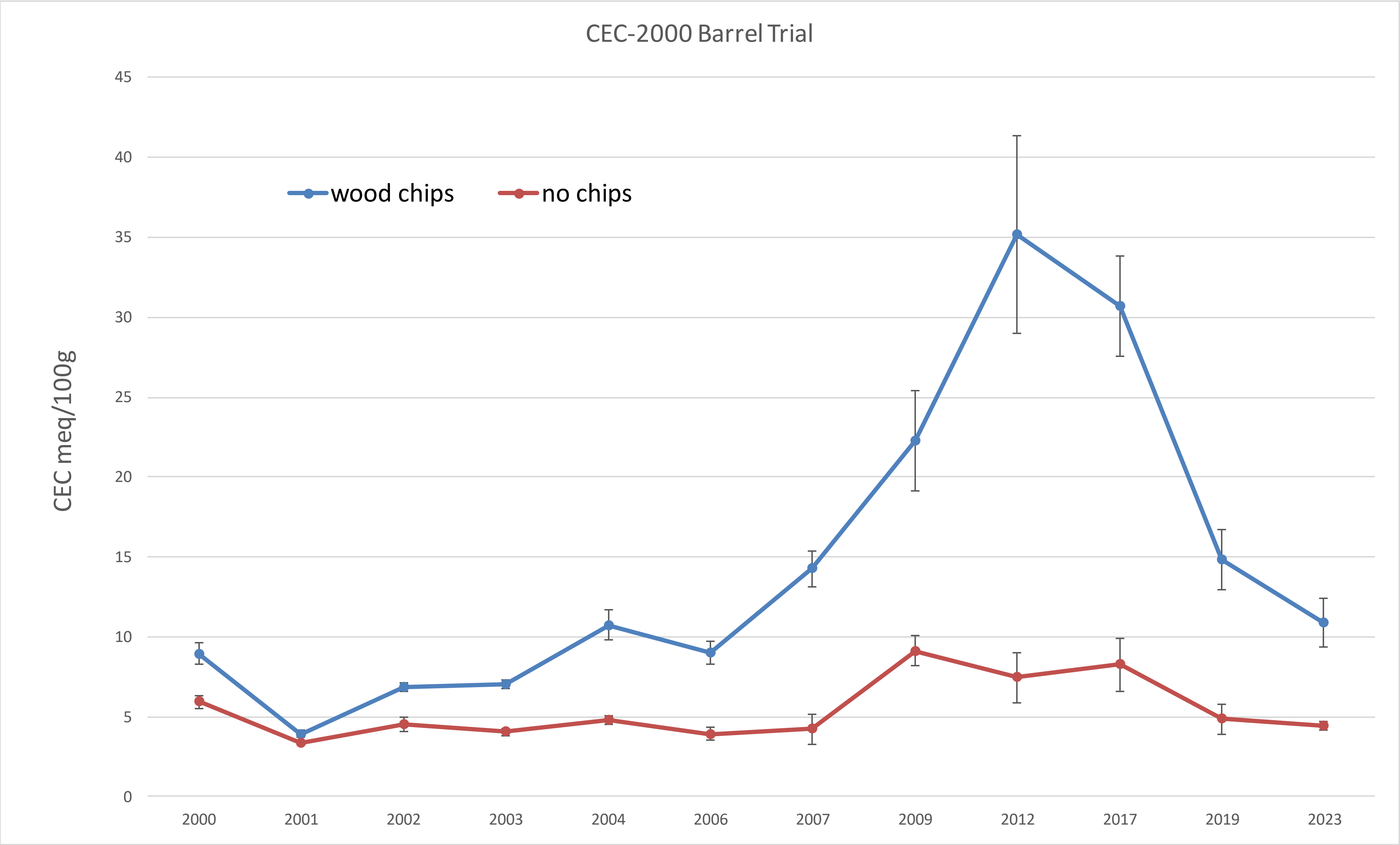
Calcium-2000 barrel trial
wood chips
no chips
Ca (SP) meq/L
0
1
2
3
4
5
6
7
8
2000
2001
2002
2003
2004
2006
2007
2009
2012
2017
2019
2023


Magnesium-2000 barrel trial
wood chips
control
Mg (meq/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
2000
2001
2002
2003
2004
2006
2007
2009
2012
2017
2019
2023


Potassium-2000 barrel trial
Potassium (ppm)
wood chips
control
0
20
40
60
80
100
120
140
160
180
2000
2001
2002
2003
2004
2006
2007
2009
2012
2017
2019
2023



Phosphorus- 2000 barrel trial
Olsen P- ppm
70
60
50
40
30
20
10
0
wood chips
control
2000
2001
2002
2003
2004
2006
2007
2009
2012
2023



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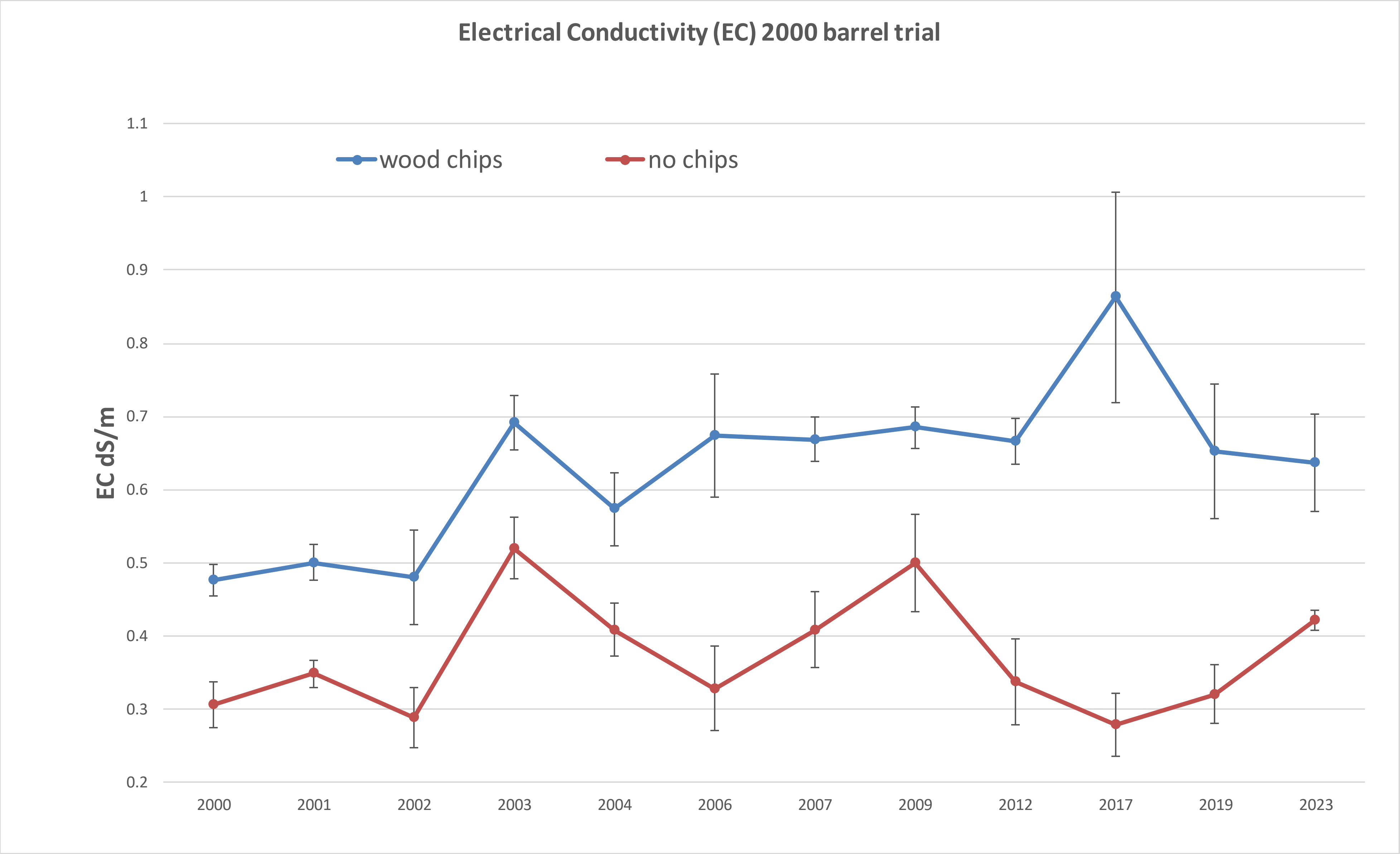

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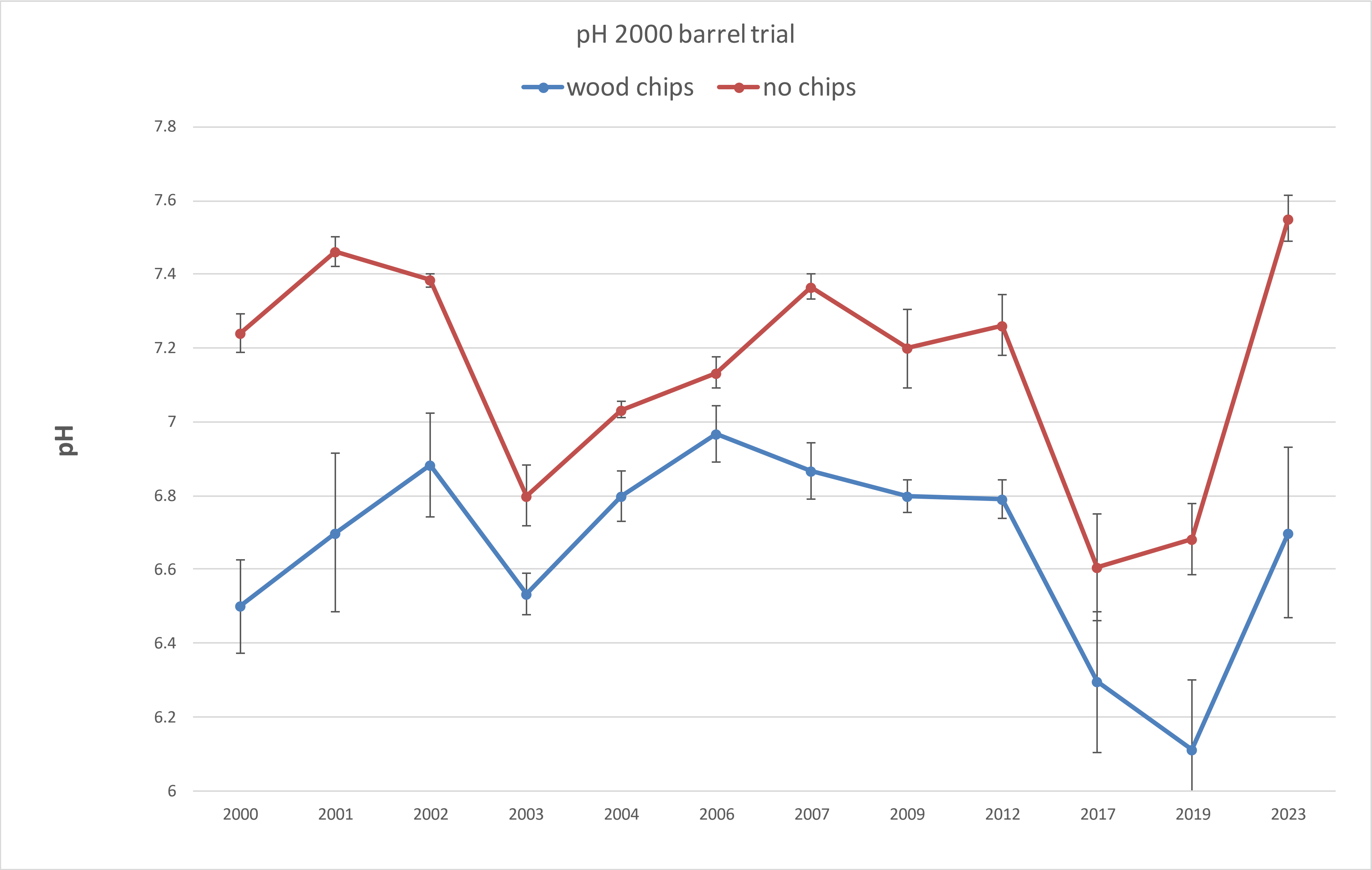

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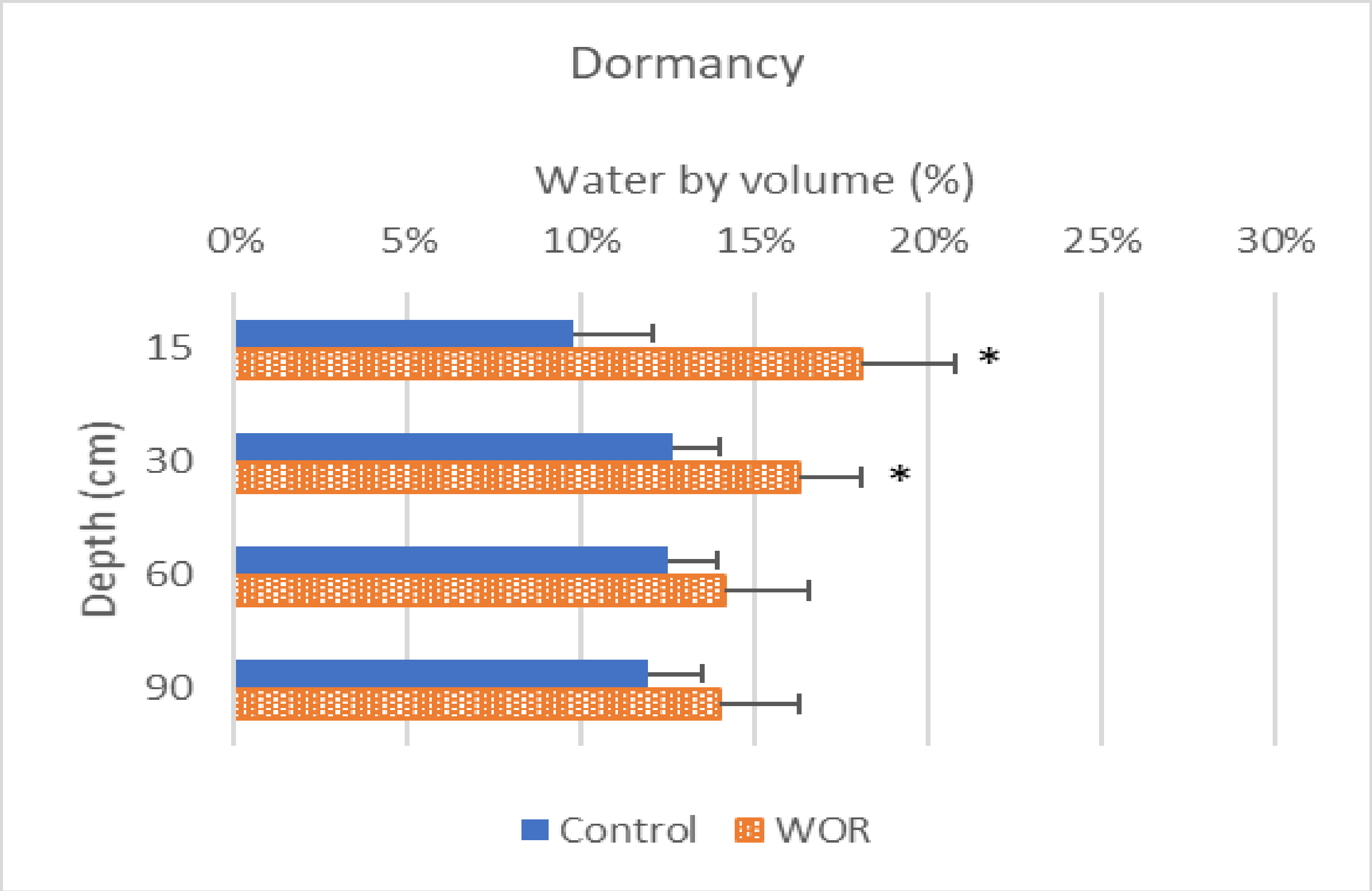
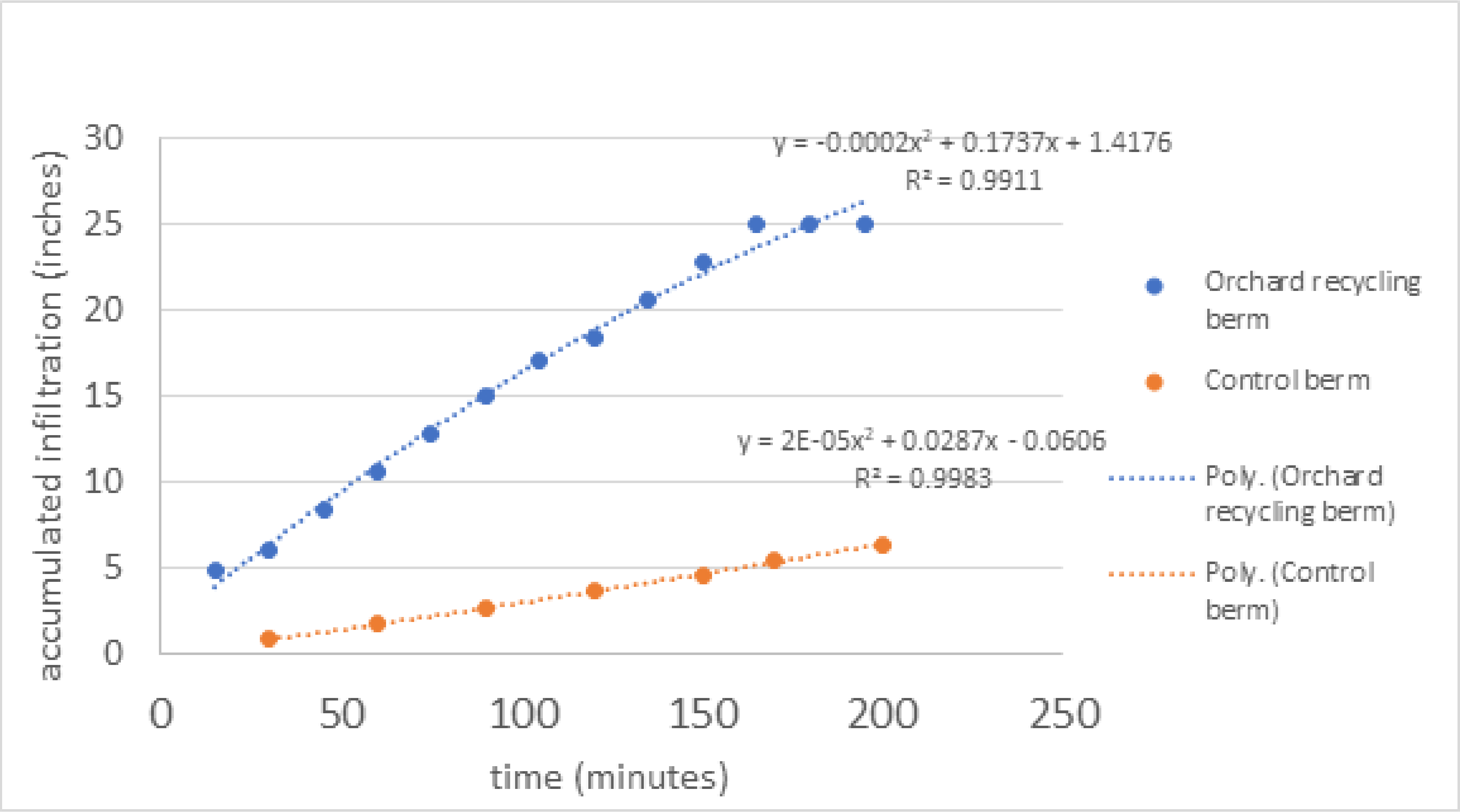
After 23 years in the barrels, the soil amended with the wood chips had become visually different from the control soil



A 42% increase in soil moisture by volume was observed in WOR treatments (17% VWC) compared to the control (11% VWC) during the 2019-2020 dormant period in the top 30 cm



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San Joaquin Valley Air Pollution Control District

$185 million since 2018

Table 2: State Funding Executed 9/1/2021 - Present

Category	Total Funding Available	Total Funding Executed	Total Funding Remaining
New Equipment Purchase	$30,000,000	$29,634,243	$365,757
Alternative Practices	$137,062,500	$80,277,119	$57,151,138
Totals:	**$167,062,500***	**$109,911,362**	**$57,516,895**

*total project funds available

Since inception, the program has resulted in the deployment of alternative practices at over 162,000 acres of orchard and vineyard removals, for nearly 4,500,000 tons of agricultural materials, resulting in the reduction of 8,791 tons of NOx, 16,212 tons of PM and 13,702 tons of ROG emissions as compared to open burning. Table 3 below illustrates program participation details by crop type.

Table 3: Participation by Crop Type (All Time)

Crop Type	Executed Projects	Acres	Tons of Material	Tons of Material (% Valley Total)
Almonds	1,313	105,303	3,159,103	71%
Grapes	611	26,916	403,741	9%
Walnuts	287	11,028	330,841	7%
Citrus	185	4,876	146,271	3%
Plums	142	3,629	108,876	2%
Peaches	165	3,225	96,753	2%
Cherry	78	2,090	62,706	1%
Nectarines	98	1,630	48,897	1%
Olives	49	1,319	39,570	1%
Apricots	33	1,159	34,767	1%
Other	58	1,600	47,351	1%
Total	**3,019**	**162,775**	**4,478,874**	**100%**

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CDFA's Healthy Soils Program has approved Whole Orchard Recycling as a practice that growers can receive incentives for practicing. www.cdfa.ca.gov

USDA-Natural Resources Conservation Services' (NRCS) Environmental Quality Incentives Program (EQIP) has implemented mulching and soil incorporation as program to help growers implement WOR.

In July 19, 2022, Governor Newsom signed AB 2101 (Flora) California Carbon Sequestration and Climate Resiliency Project Registry: Whole Orchard Recycling Projects. An additional $178 M was approved for WOR.

WOR Co-Investigators:

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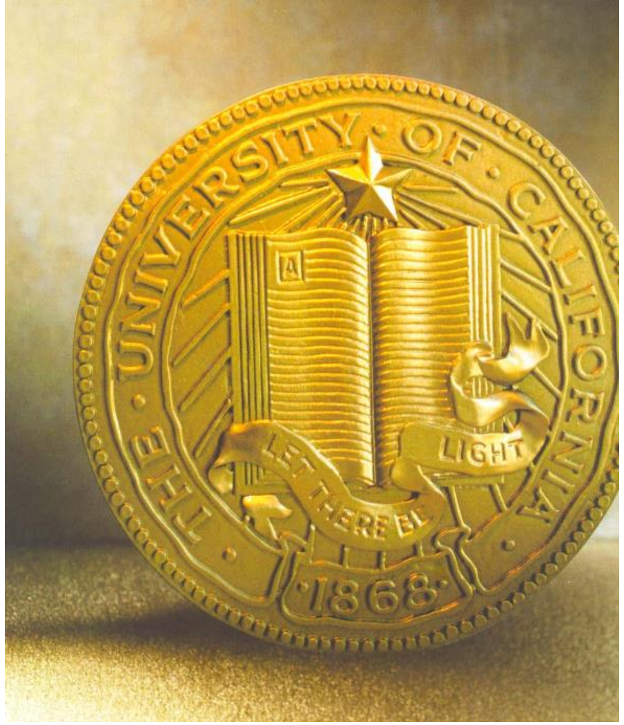


Thank You!

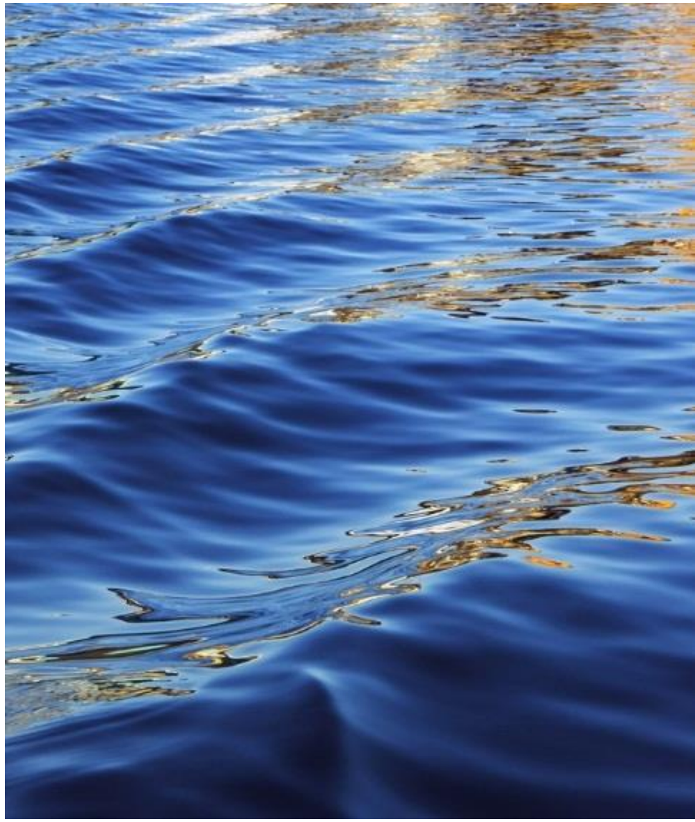
cdfa
CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

california almonds
AlmondBoard.com

USDA
ars

Irrigation Infrastructure

Development and Redevelopment in a Financially Challenging World



Irrigation Infrastructure – 3 important questions

What are we working with?	• Mainline, Pumps, Emitters, Technology, Soils
What are we trying to do?	• Irrigate, Fertilizer injection, Frost control, Ground water recharge
Are you going to use it?	• If you don't use it, why would you buy it

Water Source

Wells or Surface water

Wells – Information to Gather

Test Pump

- GPM, SWL, PWL, Sand (PPM)

Well Completion Report

- Depth, Diameter, Blank- Perforated Pipe, No Casing, Reductions

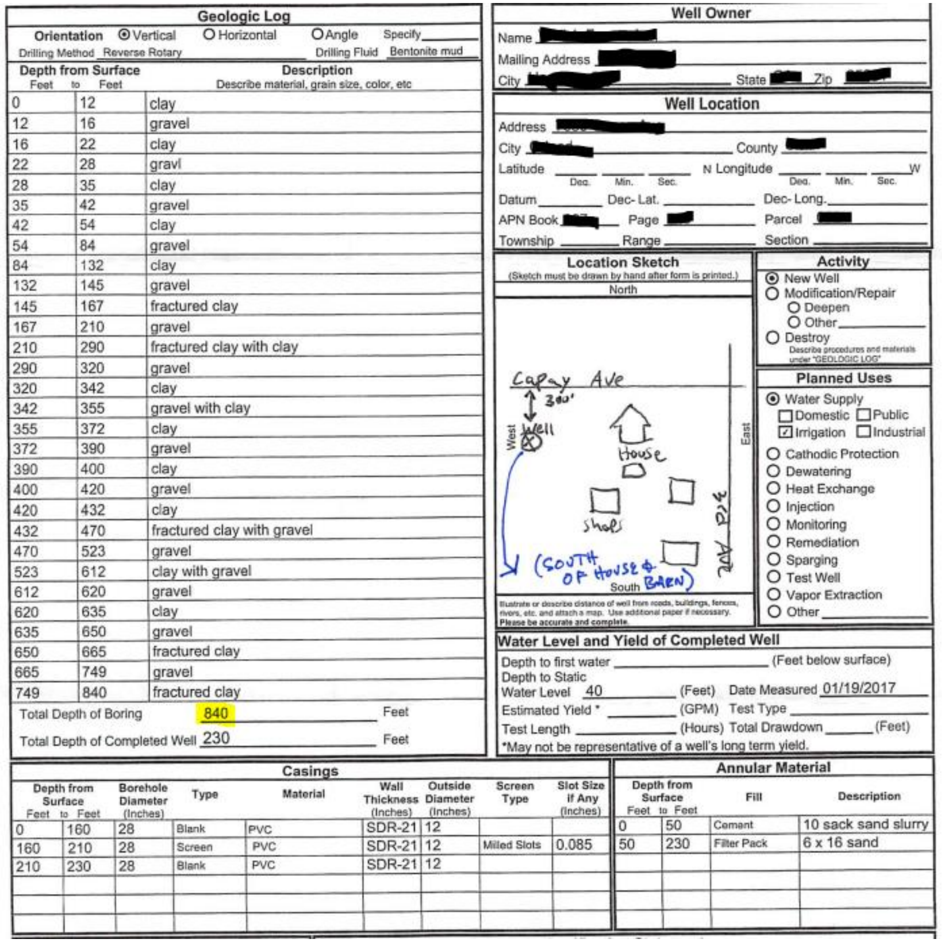
Videos

- Condition of Casing
  - Bent, Separated at the joints, Holes, Plugged Perforations, Rust
  - Cleaning (Brush, Acid, Pump, Blast,…)
  - Soft Bottom

Historical PWL

- Soundings or Level Transducer

Well Completion Report & Well Schematic



Geologic Log

Orientation ⦿ Vertical ○ Horizontal ○ Angle Specify ____
Drilling Method Reverse Rotary Drilling Fluid Bentonite mud

Depth from Surface Feet	to Feet	Description (Describe material, grain size, color, etc)
0	12	clay
12	16	gravel
16	22	clay
22	28	gravl
28	35	clay
35	42	gravel
42	54	clay
54	84	gravel
84	132	clay
132	145	gravel
145	167	fractured clay
167	210	gravel
210	290	fractured clay with clay
290	320	gravel
320	342	clay
342	355	gravel with clay
355	372	clay
372	390	gravel
390	400	clay
400	420	gravel
420	432	clay
432	470	fractured clay with gravel
470	523	gravel
523	612	clay with gravel
612	620	gravel
620	635	clay
635	650	gravel
650	665	fractured clay
665	749	gravel
749	840	fractured clay

Total Depth of Boring 840 Feet
Total Depth of Completed Well 230 Feet

Well Owner

Name [redacted]
Mailing Address [redacted]
City [redacted] State [redacted] Zip [redacted]

Well Location

Address [redacted]
City [redacted] County [redacted]
Latitude ____ Deg. Min. Sec. N Longitude ____ Deg. Min. Sec. W
Datum ____ Dec- Lat. ____ Dec- Long. ____
APN Book [redacted] Page [redacted] Parcel [redacted]
Township ____ Range ____ Section ____

Location Sketch
(Sketch must be drawn by hand after form is printed.)
North
Capay Ave
300'
Well
House
Shops
(SOUTH OF HOUSE & BARN)
West East South
RD 24
Illustrate or describe distance of well from roads, buildings, fences, rivers, etc. and attach a map. Use additional paper if necessary. Please be accurate and complete.

Activity
⦿ New Well
○ Modification/Repair
○ Deepen
○ Other ____
○ Destroy
Describe procedures and materials under "GEOLOGIC LOG"

Planned Uses
⦿ Water Supply
☐ Domestic ☐ Public
☑ Irrigation ☐ Industrial
○ Cathodic Protection
○ Dewatering
○ Heat Exchange
○ Injection
○ Monitoring
○ Remediation
○ Sparging
○ Test Well
○ Vapor Extraction
○ Other ____

Water Level and Yield of Completed Well

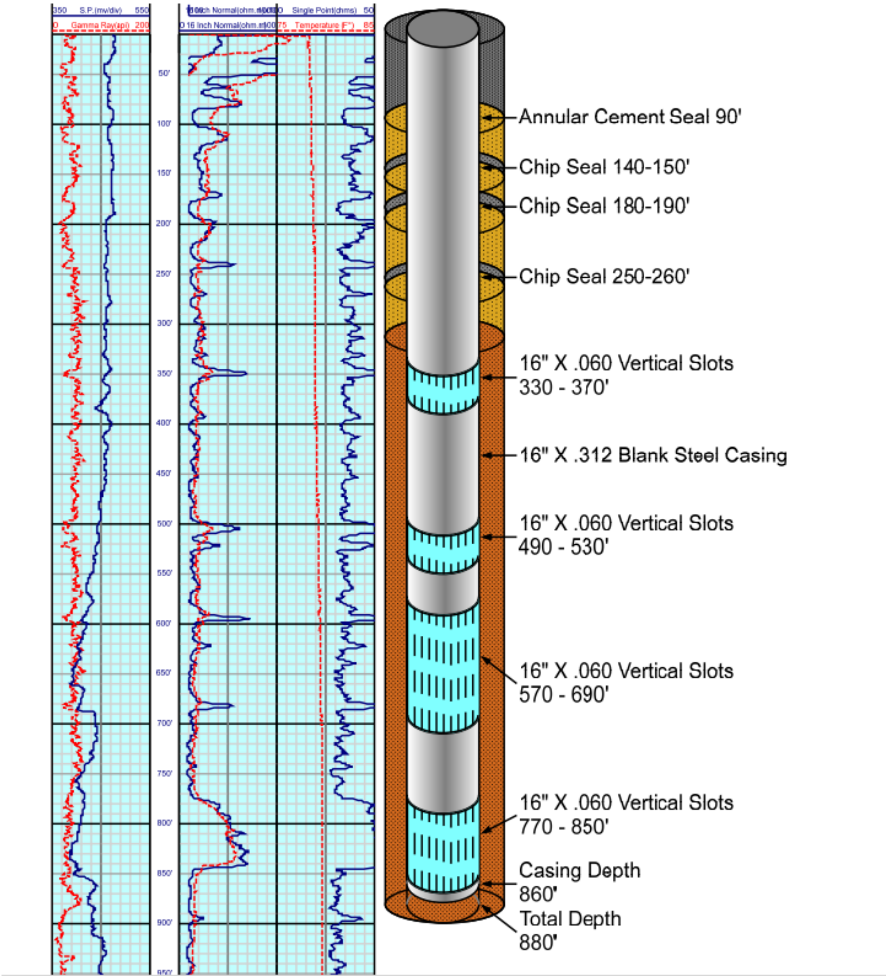
Depth to first water ____ (Feet below surface)
Depth to Static Water Level 40 (Feet) Date Measured 01/19/2017
Estimated Yield * ____ (GPM) Test Type ____
Test Length ____ (Hours) Total Drawdown ____ (Feet)
*May not be representative of a well's long term yield.

Casings

Depth from Surface Feet	to Feet	Borehole Diameter (Inches)	Type	Material	Wall Thickness (Inches)	Outside Diameter (Inches)	Screen Type	Slot Size if Any (Inches)
0	160	28	Blank	PVC	SDR-21	12		
160	210	28	Screen	PVC	SDR-21	12	Milled Slots	0.085
210	230	28	Blank	PVC	SDR-21	12		

Annular Material

Depth from Surface Feet	to Feet	Fill	Description
0	50	Cement	10 sack sand slurry
50	230	Filter Pack	6 x 16 sand



Surface Water – Information to Gather

Capacity of the Deliveries Outlet

- 1CFS = 448 GPM

Delivery Schedule

Capacity of Reservoir

Scheduled Cleanings

- Make sure the filters are ready

Water Quality & Plugging Potential

Inorganic	Organic	Weird Stuff
• Mineral (salts, bicarbonate, Iron precipitate,…) • Increasing as the water table drops • Acid or Chelating Agent	• Algae and Slime forming Bacteria • Seasonal timing due to water temperature • Acid, Chlorine, Copper, ……	• Ants, Spiders, Seeds,…. • Important to identify and keep notes, don’t just add more material

Water Quality Cont.

- **Plant Health**
  - Consult your CCA/PCA
  - Nutrient and spray considerations

Distribution System

Mainline, Valves, Emitters

Do you have an Irrigation Map?

Mainlines

- Do the GPM of the old system match what your current demands?
- **If reusing…**
  - Locate in the field and mark it
  - Have it surveyed and identified on the new design maps
  - Clearly mark it for the Ripping crews.

Valves

Above Ground or Below

Ability to Automate

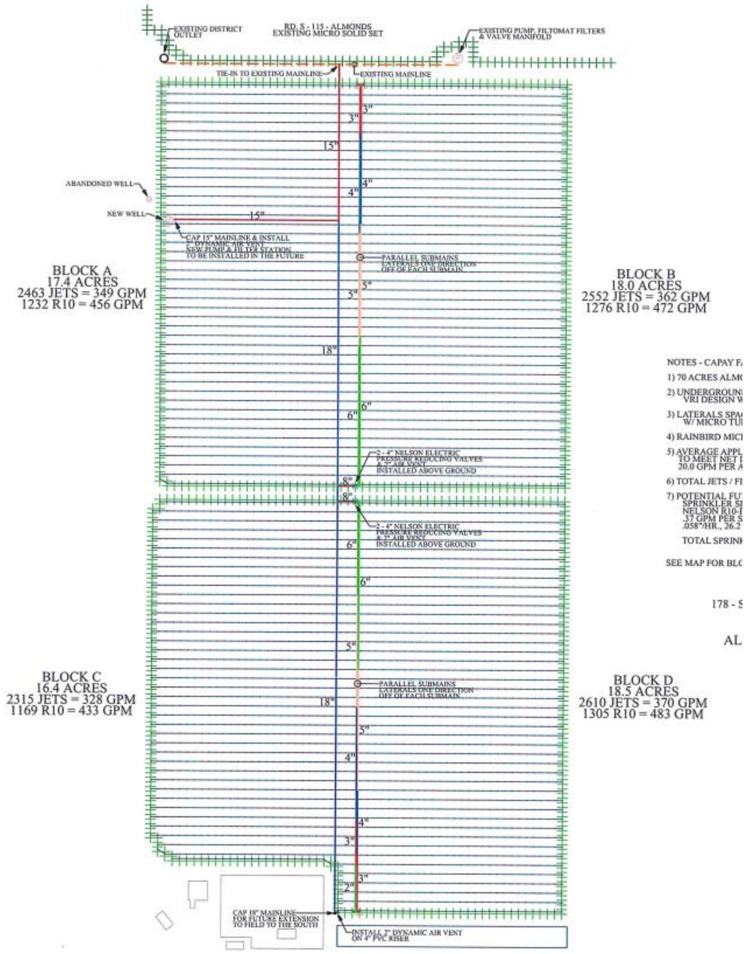
- Labor savings
- Pulse irrigate to match water infiltration
- Documentation with pressure switch

Pressure Reducing

- Operating pressures change by emitter type and desired flow

Submain and Lateral pipe

- If Reusing:
  - Reduced amount of tillage prior to planting
  - Spacing down the row can we adjusted
    - Dual system – Drip/Solid set
    - Solid set converted to above ground hose
  - If row spacing is too wide (walnuts to almonds), can you turn the field on an angle?



Water Distribution System

Who installed it?

- Modifications

How many hours to meet peak ETc for all the blocks?

- Can you do it and stay off of peak electrical time?

Cost of Operation

- Calculate the KWh per AcFt irrigated

Cost of Maintenance

- Size of hose = size of couplers
  - Less money to install but more to maintain
- Standard size for emitters/couplers
  - Make sure the system is easy to maintain or it won't be done.

Water Distribution System Cont.

How many other systems have been tied together?

- Do you have isolation valves on the mainline?

DU might be a challenge

High angle sprinklers might put water into the canopy causing leaf disease

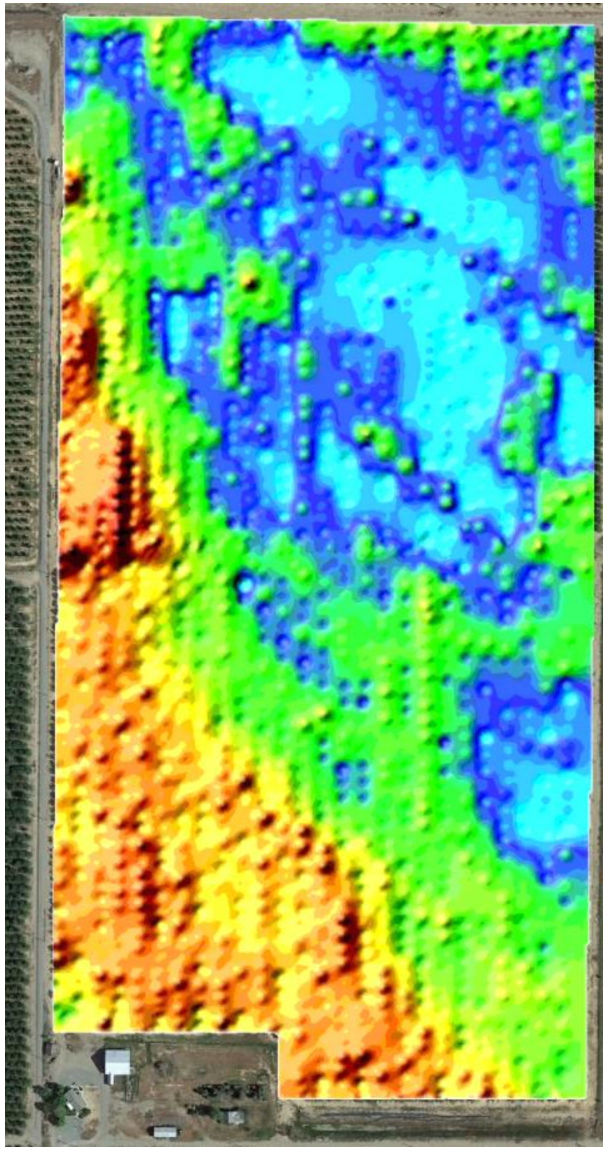
How much money are you really saving?

Do you have an old flood system that can be repurposed for Ground Water Recharge?

Soil Mapping

Soil Mapping

- Water holding capacity / Nutrient holding
  - Tying together Irrigation technology
    - Soil moisture and plant health devices
    - Aerial Imaging
  - Scouting the field for pest and nutrient problems



Soil Mapping Cont.

- Water infiltration rate
- Perched water tables or impermeable layering of soil types
- Once you have it, its good forever

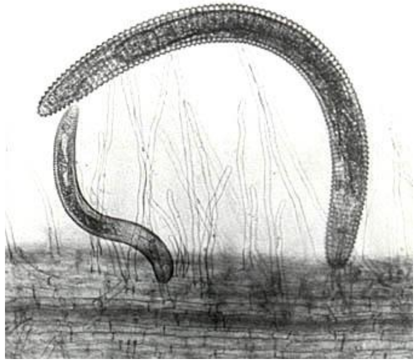
REPLANTING AN ALMOND ORCHARD… CONTINUED

ALTERNATIVES TO SOIL FUMIGATION

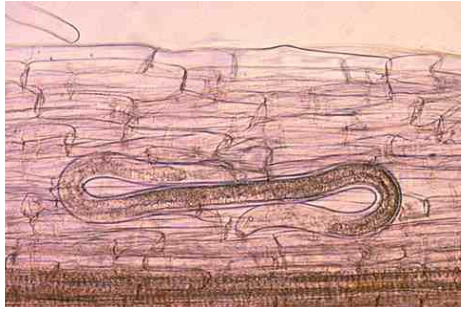
Greg Browne, USDA-ARS, Davis, CA

Key reasons for preplant soil fumigation (or alternative practices)

- **Plant-parasitic nematodes** (ring, lesion, root knot), not universal;



Ring nematode



Lesion nematode

- **Prunus replant disease (PRD)** Microbe-induced growth suppression; commonly occurs in *Prunus* after *Prunus;* severity varies

Severe case of PRD, Sacramento Valley

Healthy tree

RD-affected tree

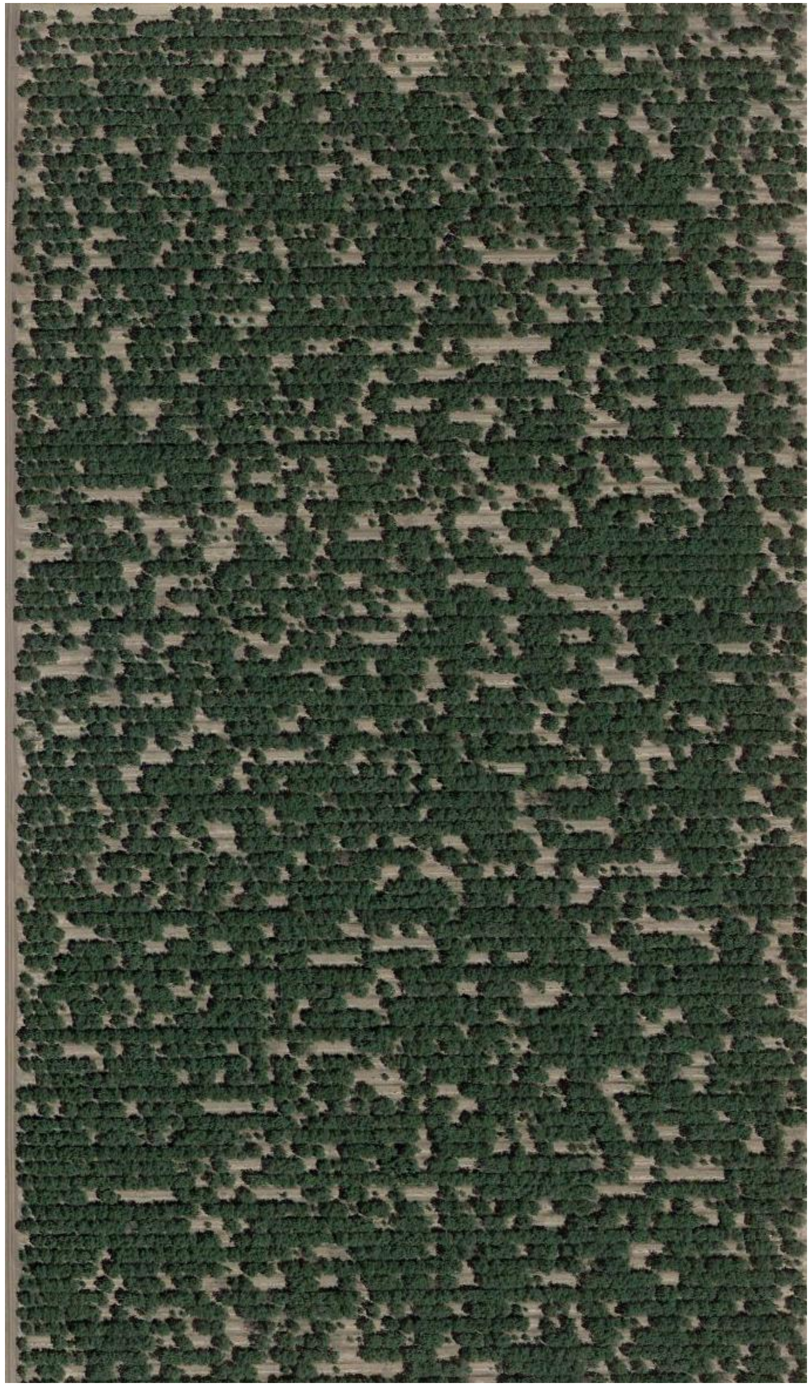
Key reasons for preplant soil fumigation (or alternative practices)

More typical case of PRD, San Joaquin Valley:

Alternatives to soil fumigation

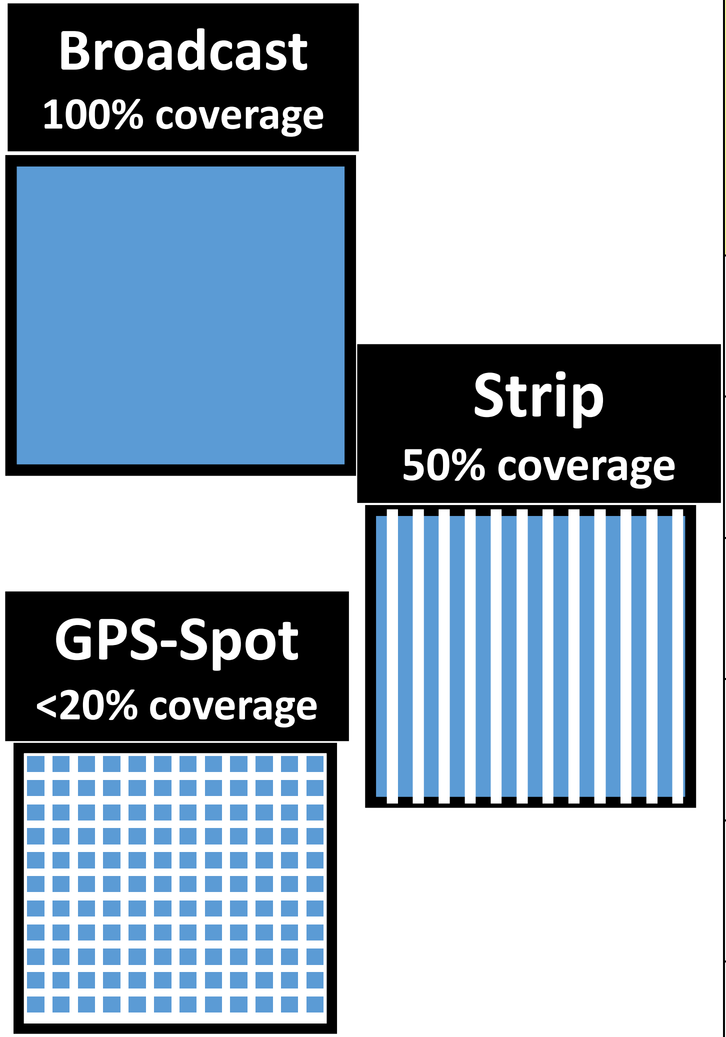
- Consider alternative treatments before removing old orchard…
- Consider whether a preplant soil treatment is needed…
- Phytopathogenic nematodes?
- History of replant disease in adjacent/similar soils and replant scenarios?
- Fallowing multiple years?
- Hybrid rootstock appropriate?

Connecting the Dots 2023



Example of a fumigation decision matrix for thinking about alternatives to soil fumigation, i.e., using a "dialed" approach

(After D. Doll)



Replant scenario	Shank fumigation treatment options considered advisable in CA*					
	No fumigation	Telone II Row-strip	Telone II Broadcast	Chloropicrin GPS-spot**	Chloropicrin Row-strip**	Co-application of Telone II (Str or BC) with Chloropicrin (spot or strip)**
No orchard history (fallowed $\geq$4 years); No PP-nematodes	X					
No Prunus history; w/ PP-nemaotdes		X -pop. dependent	X -pop. dependent			
Punus history; No PP-nematodes, Sandly loam or coarser soil texture				X	X	
Prunus history; No PP-nematodes, Silty clay loam texture or finer	X?			X -situation-dependent	X -situation-dependent	
Prunus history w/PP-Nematodes			X -population dependent			X -population dependent
Prunus history w/ aggressive pathogens				Some short-term benefit	Some short-term benefit	Some short-term benefit

Anaerobic soil disinfestation (ASD), components and steps






Assessing cost and value of ASD and its components, 2020-present, Kearney Agricultural Extension and Research Center

<u>Treatments</u>:

1. Ctl
2. Ctl+WT
3. Rb9
4. Rb9+WT
5. Ahs9
6. Ahs9+WT
7. Fum 1,3-D +Pic, shank

(Each trt. applied to 4 blocks of 12-tree mainplots)

Assessing cost and value of ASD and its components, continued...

Estimated costs, fumigation vs. rice bran alternatives

Treatment abbreviation (and description)	Cost item	Cost/unit ($)	Unit	Units / treated acre	Cost / treated acre	Proportion of orchard acre to which cost applies	Cost / orchard acre
Fum:	1,3-dichloropropene	40	gal	33	$1,340	0.5	$670
(Strip fumigation, shank, 1.3-D + chloropicrin)	Chloropicrin	6.6	lb	200	$1,320	0.5	$660
	Fumigant application	113	acre	1	$113	1	$113
						TOTAL :	***$1,443***
Rb9:	Rice bran	210	ton	9	$1,890	0.5	$945
(Strip amendment with rice bran only)	Hauling (200 mi)	28	ton	9	$252	1	$252
	Spreading	12	ton	9	$108	0.5	$54
	Incorporation	20	acre	1	$20	1	$20
						TOTAL:	***$1,271***
Rb9+WT:	Rice bran	210	ton	9	$1,890	0.5	$945
(Strip ASD with rice bran, water and tarp)	Hauling (200 mi)	28	ton	9	$252	1	$252
	Spreading	12	ton	9	$108	0.5	$54
	Incorporation	20	acre	1	$20	1	$20
	Irrigation system	325	acre	1	$325	1	$325
	TIF	890	acre	1	$890	0.5	$445
	Tarp disposal	150	acre	1	$150	1	$150
						TOTAL:	***$2,191***

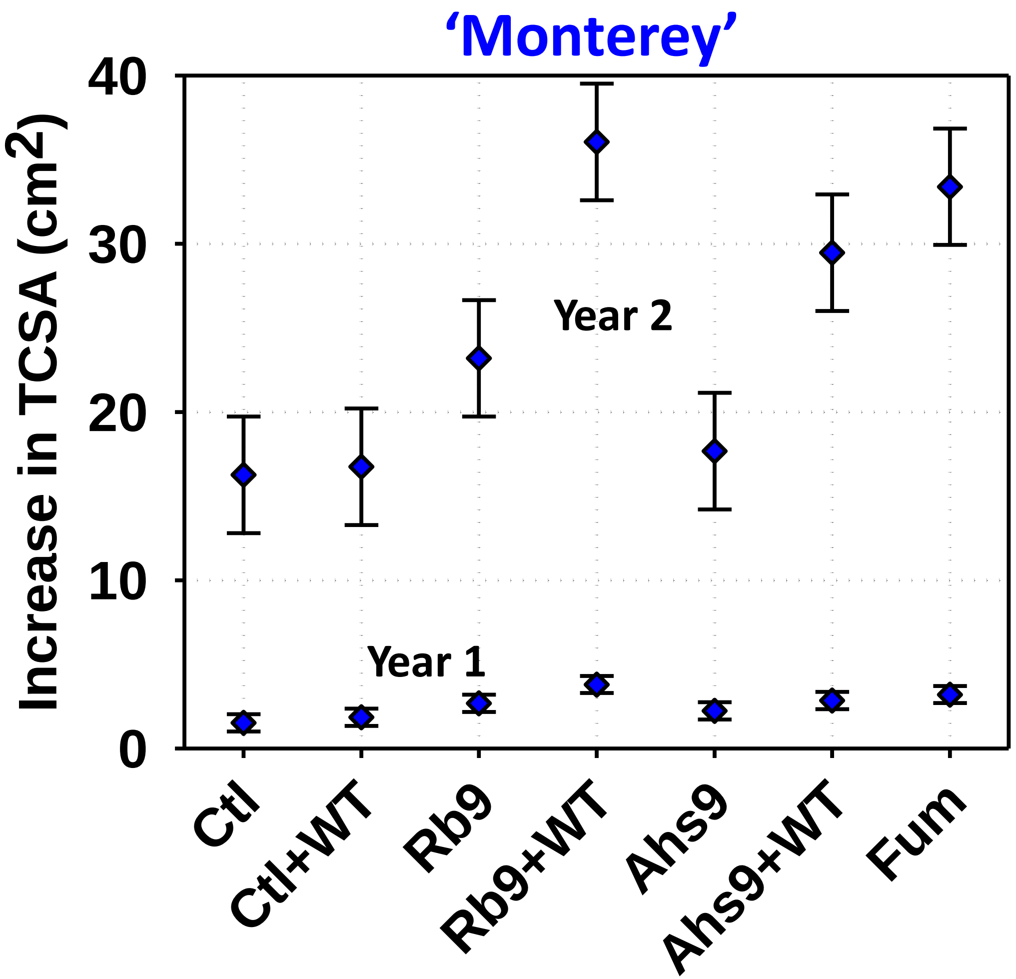
Assessing cost and value of ASD and its components, continued…

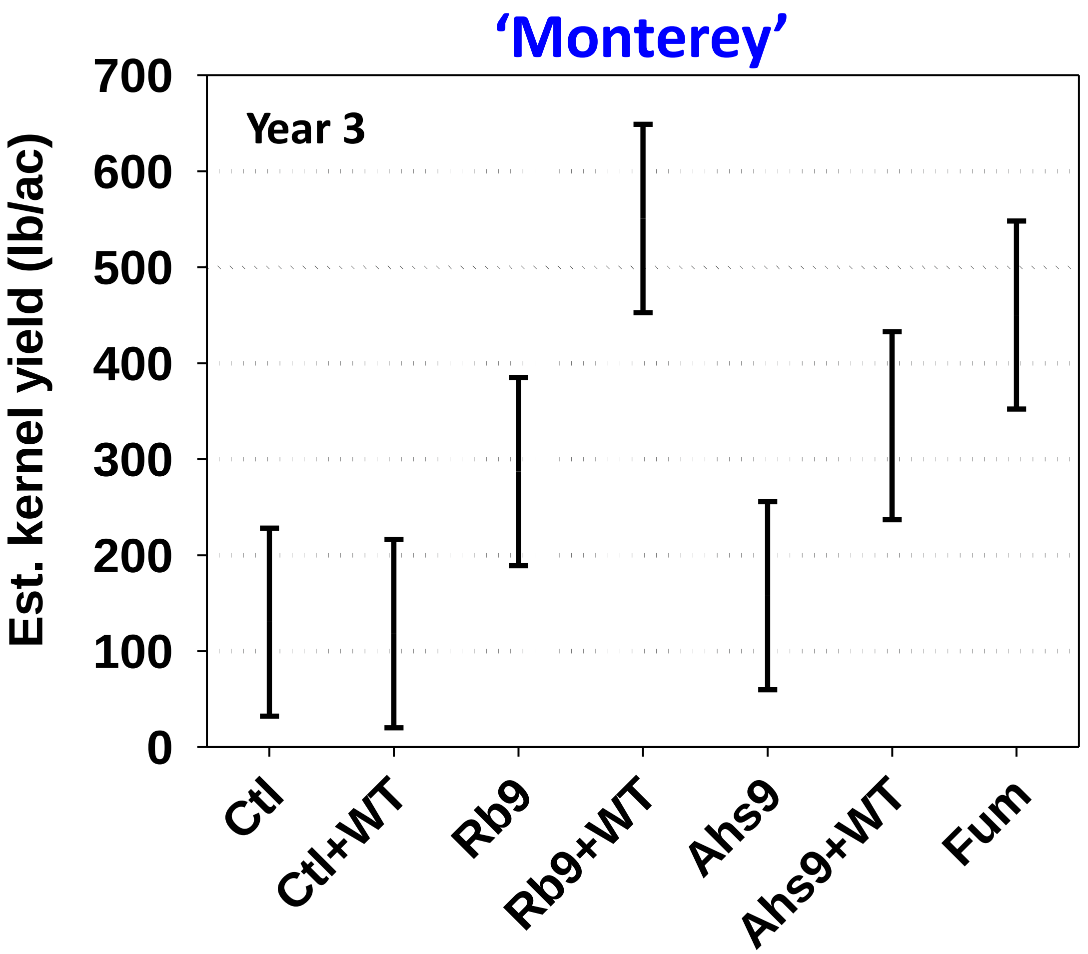
Estimated costs, fumigation vs. ground almond hull and shell alternatives

Treatment abbreviation (and description)	Cost item	Cost/unit ($)	Unit	Units / treated acre	Cost / treated acre	Proportion of orchard acre to which cost applies	Cost / orchard acre
Fum:	1,3-dichloropropene	40	gal	33	$1,340	0.5	$670
(Strip fumigation, shank, 1.3-D + chloropicrin)	Chloropicrin	6.6	lb	200	$1,320	0.5	$660
	Fumigant application	113	acre	1	$113	1	$113
						TOTAL :	***$1,443***
Ahs9:	Ground Ahs	120	ton	9	$1,080	0.5	$540
(Strip amendment with ground almond hull and shell only)	Hauling (200 mi)	28	ton	9	$252	1	$252
	Spreading	12	ton	9	$108	0.5	$54
	Incorporation	20	acre	1	$20	1	$20
						TOTAL:	***$866***
Ahs9+WT:	Ground Ahs	120	ton	9	$1,080	0.5	$540
(Strip ASD with ground almond hull and shell, water and tarp)	Hauling (200 mi)	28	ton	9	$252	1	$252
	Spreading	12	ton	9	$108	0.5	$54
	Incorporation	20	acre	1	$20	1	$20
	Irrigation system	325	acre	1	$325	1	$325
	TIF	890	acre	1	$890	0.5	$445
	Tarp disposal	150	acre	1	$150	1	$150
						TOTAL:	***$1,786***

Assessing cost and value of ASD and its components, continued

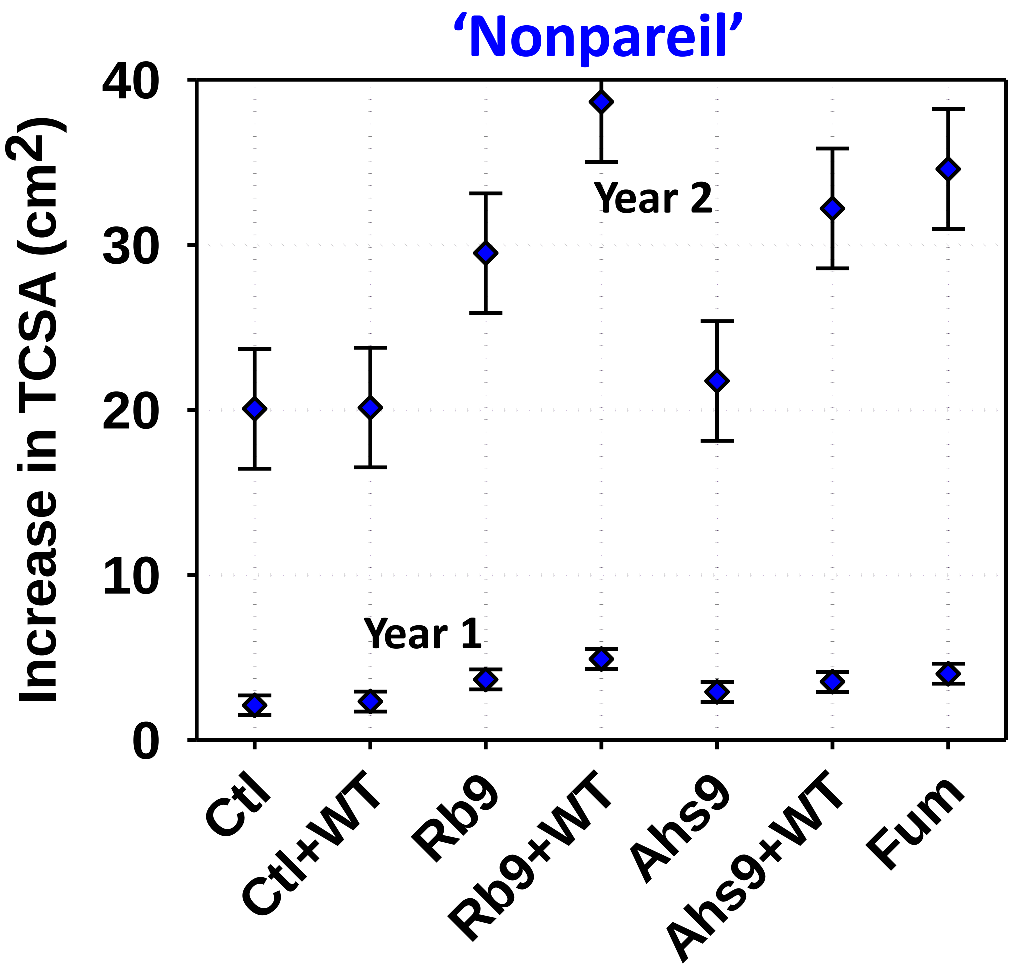
Growth and yield benefits KARE trial planted 2021

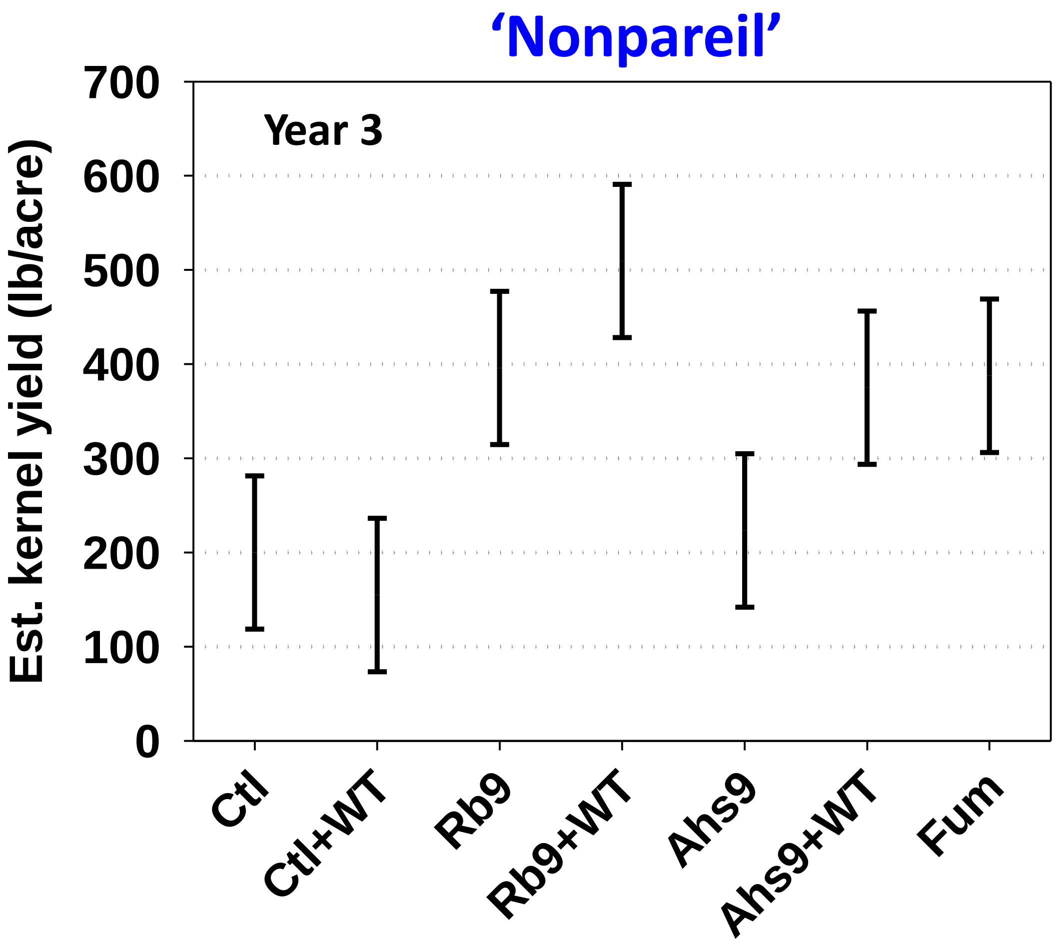




Assessing cost and value of ASD and its components, continued

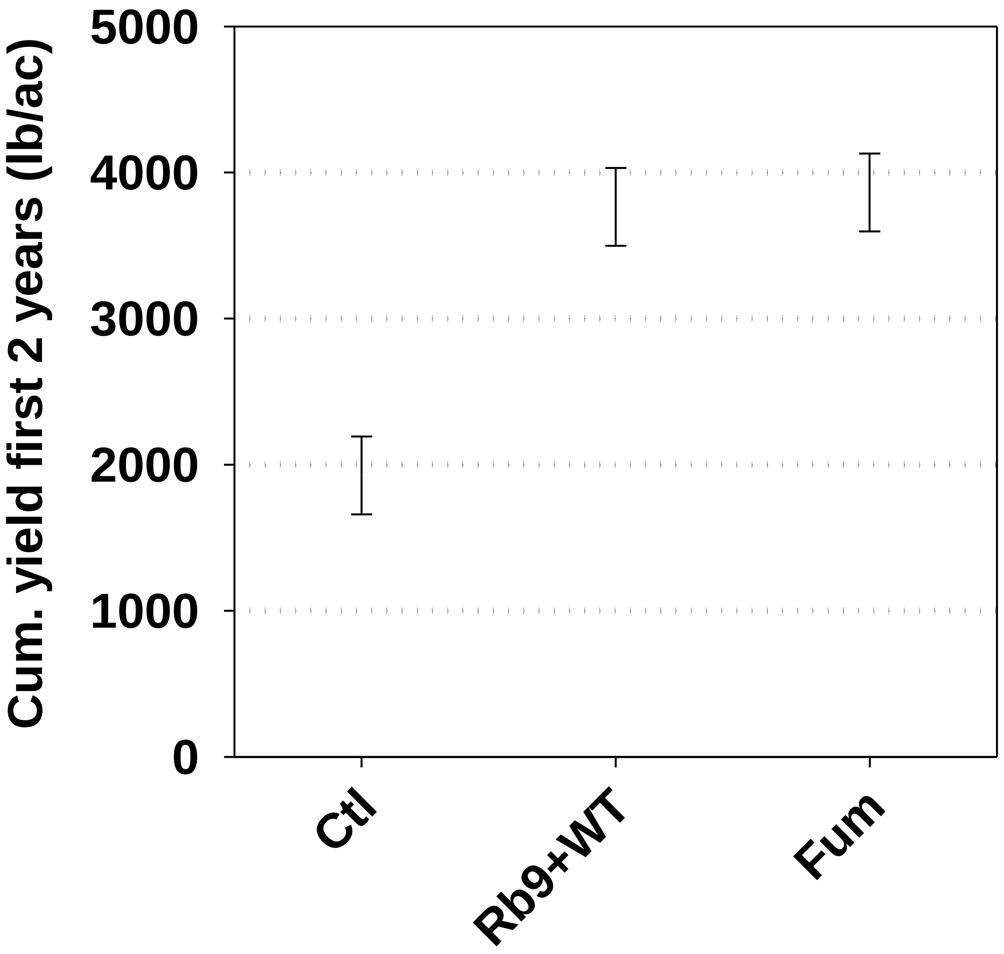
Growth and yield benefits KARE trial planted 2021



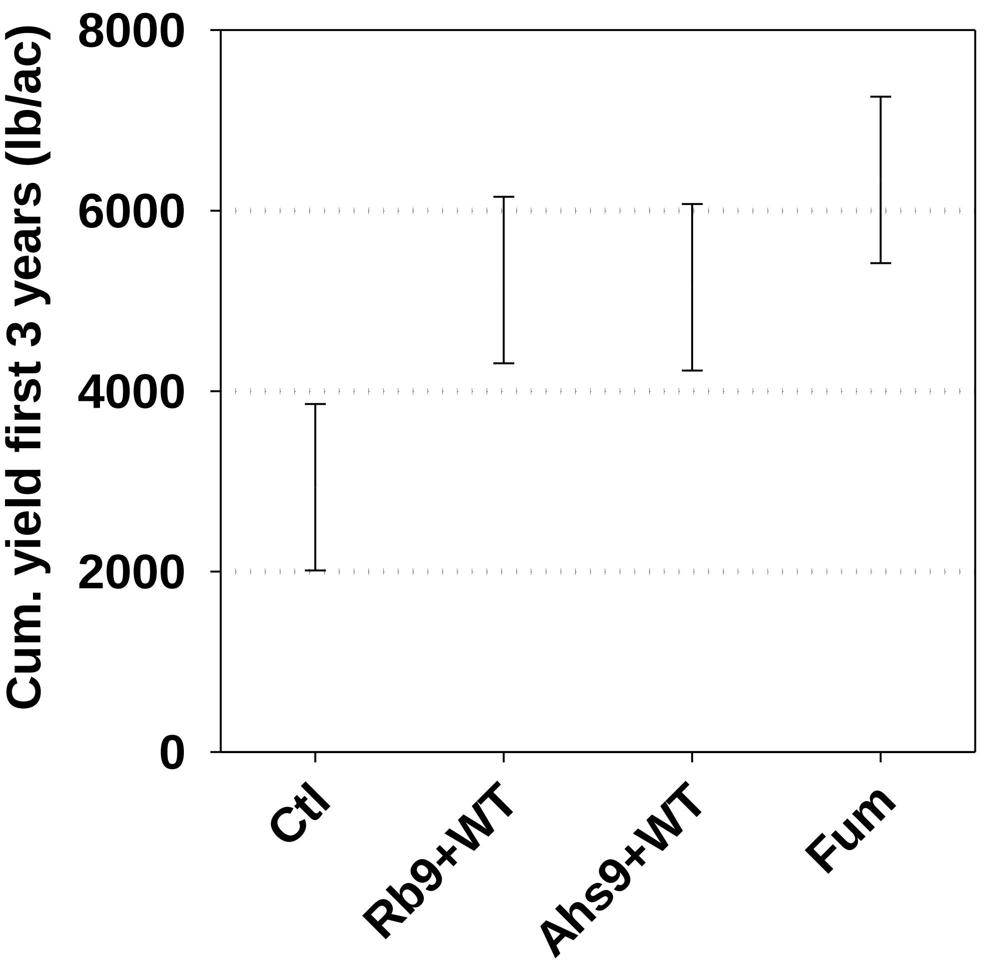


Comment: yield benefits of ASD were ~consistent among trials

KARE trial with B.N. self-fruitful, yields 2016-2017



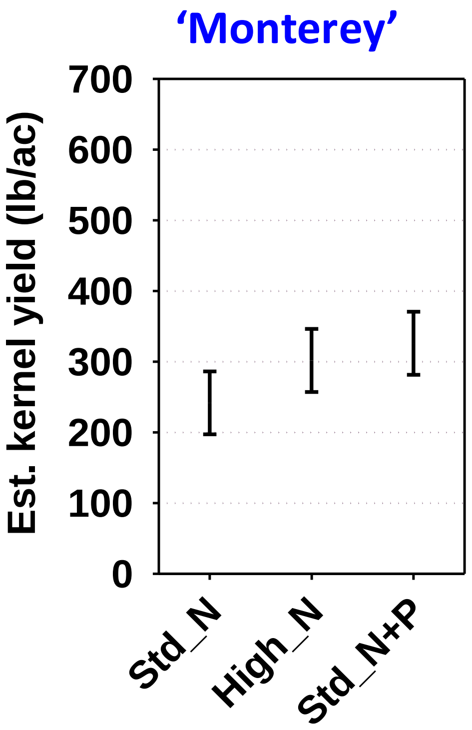
CSUF trial with ‘Shasta’, yields 2020-2022

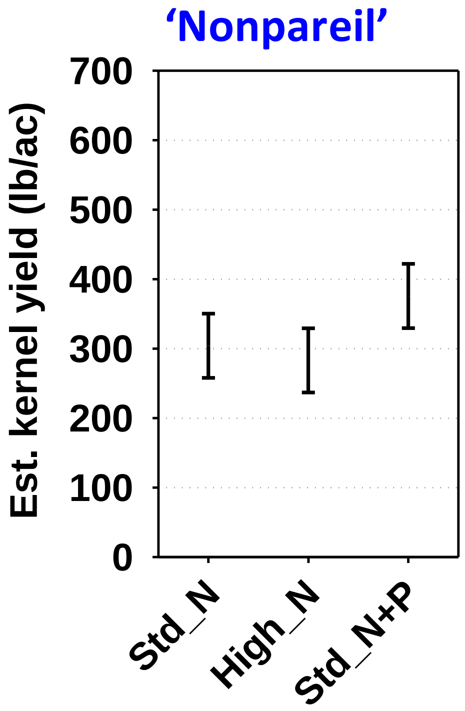


Comment: ASD treatments were compatible with WOR and worked best with ammonium sulfate added before initiation

(Statement based tree growth responses of ‘Shasta’ in CSUS trial, 2018-2022)

Comment: phosphate fertilization in first growing season can improve tree growth and yield in replanted almond orchards w/ and w/o preplant soil treatments





Key points:

- Preplant soil amendment with RB alone may provide adequate & economical prevention of PRD.
- Preplant ASD driven by RB or Ahs are most technically effective alternatives to fumigation but currently have high expense.
- Amendment & ASD benefits consistent and compatible with WOR and optimal fertilization.
- Commercial trialing , proving, & innovation may be beneficial

Thank you!

california almonds
Almond Board of California

Almond Rootstock Resources

Roger Duncan

Orchard Crops Advisor

University of California

Cooperative Extension

Stanislaus County

University of California
Agriculture and Natural Resources

Over 40 Years of UC Almond Rootstock Field Trials

- Rick Buchner
- Joe Connell
- Carolyn Debuse
- David Doll
- Roger Duncan
- John Edstrom
- Lonnie Hendricks
- Katherine Jarvis-Shean
- Warren Micke
- Mario Viveros
- Paul Verdegaal
- Mohammad Yaghmour

- Northern Merced County (1989)
- 1996-97 regional trials (4 sites)
- Stanislaus:
  - Gemperle trial 2003
  - Superior Fruit Ranch ORF trial 2007
  - Del Don Westside trial (2011)
  - Rootstock vs fumigation (2015)
  - Dwarfing rootstocks (Kearney)
- Butte County (2010)
- Yolo County boron trial (2011)
- Kern County (2019)

Rootstock Influences Many Things

- Nematode tolerance
- Soil-borne disease tolerance
- Soil / water chemistry tolerance
- Vigor
- Date of maturity
- Bloom time
- Nutrition
- Drought tolerance

Rootstock Significantly Affects Potassium Uptake

- Clay Loam, Westley , CA

Peach x almond hybrids may accumulate more leaf potassium than standard peach rootstocks

	July Leaf K (%)
FxA	2.48 a
Brights 5	2.46 a
Cadaman	2.44 a
BB 106	2.40 a
Hansen	2.22 ab
GF 677	2.15 ab
HM2	2.14 ab
Empyrean 1	1.95 abc
Atlas	1.94 abc
Viking	1.90 abcd
Nemaguard	1.85 abcd
HBOK 50	1.63 bcd
Rootpac R	1.57 bcd
Krymsk 86	1.39 cd
Lovell	1.38 cd

Comparison of Rootstocks for Salt Accumulation in July-Sampled Leaves

- Sandy loam soil;
- Gemperle Farms, Keyes. CA

University of California
Agriculture and Natural Resources

Relative Salt Tolerance of Almond Rootstocks

	% Sodium	% Chloride
Nemaguard	**0.99**	**0.51**
Lovell	**0.70**	**0.50**
Guardian	**0.76**	**0.41**
Cadaman	**0.38**	0.25
Empyrean 1	0.09	0.07
Hansen	0.09	0.07
GF 677	0.04	0.05
Cornerstone	0.04	0.05
Viking	0.29	0.21
Atlas	**0.94**	0.29
Krymsk 86	**0.60**	**0.32**
Penta	**0.30**	**0.41**
Julior	**0.35**	0.16
Adesoto	0.06	0.04
Critical Level	0.25	0.30

Pathogenic Nematodes in 17th-leaf, Unfumigated, Sandy Loam Soil. Gemperle Rootstock Trial, Keyes, CA. March 2019. Nematodes per 250 cc soil.

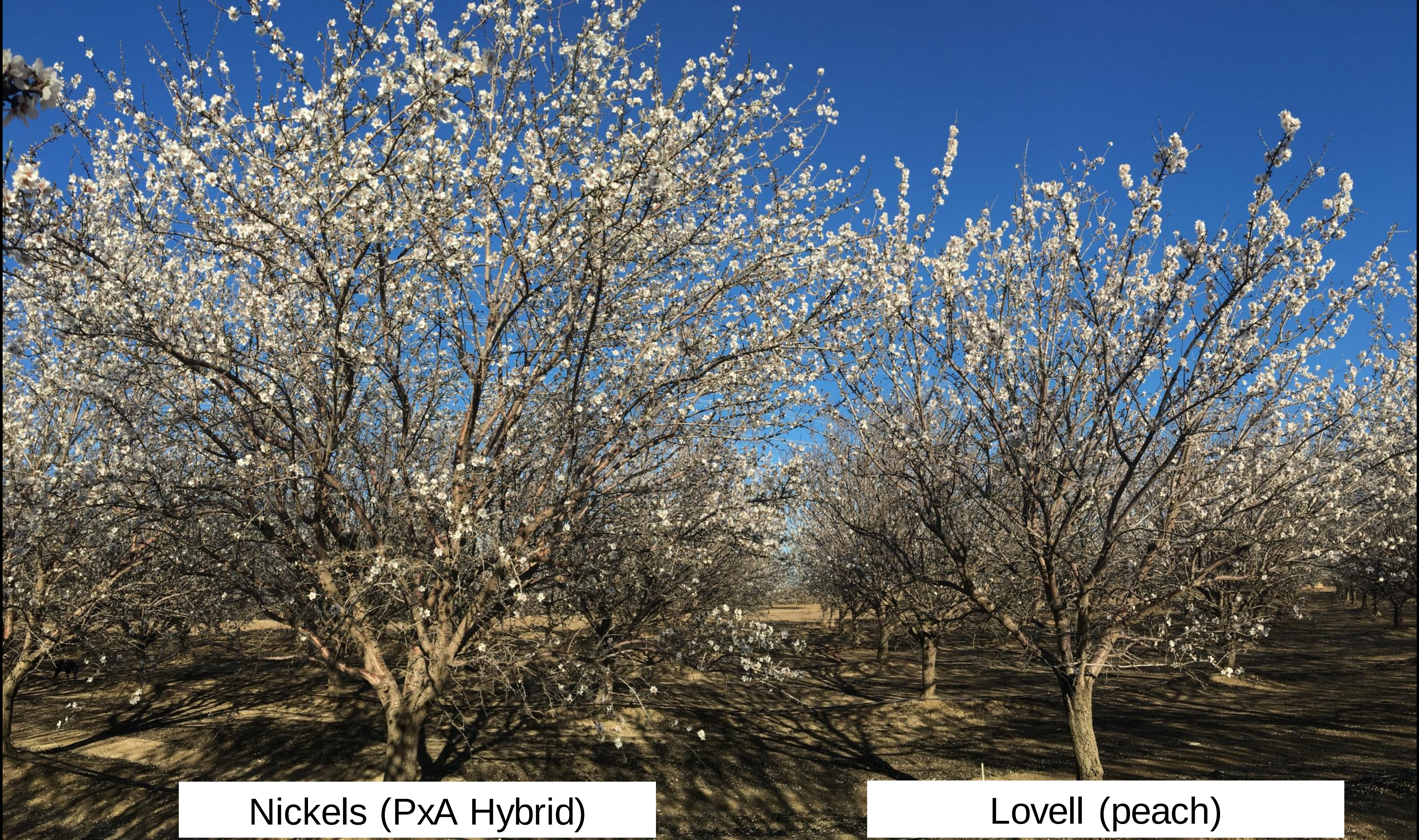
	Ring (*Mesocriconema xenoplax*)	Root Lesion (*Pratylenchus vulnus*)
Nickels	1,438 a	34 a
Cornerstone	1,176 a	2 a
Hansen	1,396 a	37 a
Adesoto	257 b	112 a
Cadaman	156 b	22 a
Nemaguard	137 b	69 a
GF 677	118 b	103 a
Atlas	97 b	35 a
Lovell	19 b	36 a
Krymsk 86	10 b	0 a
Empyrean 1	1 b	13 a
Guardian	0 b	38 a
Viking	0 b	18 a

Phytophthora Root & Crown Rot

Rootstock	Phytophthora Rating
Guardian	Mod Susceptible
Lovell	Mod Susceptible
Nemaguard	Mod Susceptible
Cadaman	Mod Susceptible
Empyrean 1	Mod Susceptible
Brights 5	Highly Susceptible
Cornerstone	Highly Susceptible
F x A	Unknown
Hansen 536	Highly Susceptible
Nickels	Highly Susceptible
Titan SG1, Titan II, etc.	Mod Susceptible
Krymsk 86	Resistant
Marianna 40	Assumed resistant
Marianna 2624	Resistant
Rootpac 20	Resistant
Rootpac R	Resistant
Atlas	Highly Susceptible
Viking	Highly Susceptible

Anchorage

Rootstock	Anchorage
Guardian	Fair
Lovell	Fair
Nemaguard	Good
Cadaman	Good
Empyrean 1	Fair
Brights 5	Good
Cornerstone	Good
F x A	Excellent
Hansen 536	Excellent
Nickels	Very Good
Titan SG1, Titan II, etc.	Good
Krymsk 86	Excellent
Marianna 40	Very Good
Marianna 2624	Good
Rootpac 20	Unknown
Rootpac R	Good
Atlas	Fair
Viking	Excellent


Nickels (PxA Hybrid)
Lovell (peach)

Rootstock Vigor

- Peach / Almond hybrids (Titan hybrids, Hansen, Nickels, Bright's 5, Cornerstone, FxA, etc.), Empyrean 1
- Interspecifics (Viking, Atlas)
- Peach (Nemaguard, Guardian, Lovell)
- Plum / plum hybrids (Krymsk 86, Rootpac R, Marianna 2624, etc.)

Most Vigorous

Least Vigorous

Rootstock Effect on Yield

Westside Stanislaus County 2022

	2022 Yield per Acre (11th leaf)	Cum Yield (4th – 7th), 9th & 11th leaf
BB 106	3201 ab	19,495
Flordaguard x Alnem	3356 ab	18,802
Brights 5	3116 ab	18,539
HM2	3447 a	18,255
Hansen	3095 ab	18,111
Empyrean 1	2759 bcd	17,316
Rootpac R	2373 cde	15,786
Paramount (GF 677)	2844 abc	15,507
PAC9908-02	2067 e	15,453
Atlas	2223 cde	15,355
Viking	2823 abc	15,318
HBOK 50	2131 de	13,658
Nemaguard	2002 e	13,626
Krymsk 86	1925 e	13,265
Lovell	1883 e	11,603

Rootstock Effect on Gross Income (six harvests)

Westside Stanislaus County 2022

	2022 Yield per Acre (11th leaf)	Cum Yield (4th – 7th), 9th & 11th leaf	Difference in Gross Income over Nemaguard*
BB 106	3201 ab	19,495	$11,738
Flordaguard x Alnem	3356 ab	18,802	$10,352
Brights 5	3116 ab	18,539	$9,826
HM2	3447 a	18,255	$9,258
Hansen	3095 ab	18,111	$8,970
Empyrean 1	2759 bcd	17,316	$7,380
Rootpac R	2373 cde	15,786	$4,320
Paramount (GF 677)	2844 abc	15,507	$3,762
PAC9908-02	2067 e	15,453	$3,654
Atlas	2223 cde	15,355	$3,458
Viking	2823 abc	15,318	$3,384
HBOK 50	2131 de	13,658	$64
Nemaguard	2002 e	13,626	--
Krymsk 86	1925 e	13,265	-$722
Lovell	1883 e	11,603	-$4,046

*Gross income calculated at $2.00 / lb

Rootstock Effect on Yield Efficiency

West side Stanislaus County 2022 Yields

Peach x almond hybrids not just larger, but more yield efficient in this trial

	2022 Yield per Acre (11th leaf)	2022 Yield Efficiency (lb / % PAR)
BB 106	3201 ab	38.8 b
Flordaguard x Alnem	3356 ab	40.7 ab
Brights 5	3116 ab	39.1 b
HM2	3447 a	44.8 a
Hansen	3095 ab	38.0 bc
Empyrean 1	2759 bcd	36.9 bcd
Rootpac R	2373 cde	34.0 cde
Paramount (GF 677)	2844 abc	37.3 bc
PAC9908-02	2067 e	28.4 f
Atlas	2223 cde	32.4 def
Viking	2823 abc	40.0 b
HBOK 50	2131 de	32.0 ef
Nemaguard	2002 e	28.8 f
Krymsk 86	1925 e	30.5 ef
Lovell	1883 e	31.9 ef

Rootstock Cumulative Yield and Income – Yolo County. K. Jarvis-Shean

	Yolo County Clay Loam			
Rootstock	Cumulative Yield (lb. / acre) 3rd-11th leaf	2021 PAR	2021 Yield Efficiency lb. / % PAR	Difference in Gross Income per acre Compared to Lovell 9 harvests[1]
Nickels	21,504 a	87 a	33 ab	$22,350
Titan SG1	20,551	80	20	$20,444
Flordaguard x Alnem (FxA)	19,992 ab	88 a	29 b	$19,326
Brights 5	18,982 b	80 B	36 ab	$17,306
Hansen	15,911 c	82 ab	32 30 ab	$11,164
Viking	15,240 c	68 C	40 a	$9,822
Rootpac R	12,429 d	68 C	25 b	$4,200
Krymsk 86	12,032 de	54 65 c	27 b	$3,406
Lovell	10,329 e	58 d	33 ab	--

[1]Calculated at $2.00 per pound

UCCE Butte County Rootstock Trial – Joe Connell

Rootstock	3rd Leaf	4th Leaf	5th Leaf	6th Leaf	7th Leaf	8th Leaf	9th Leaf	10th Leaf	Accumulated Total Yield
'Lovell'	74	1,042	1,426	2,208	1,978	3,211	3,572	2,083	15,595
'Krymsk 86'	105	1,018	1,524	2,435	2,923	3,279	3,786	2,459	17,529
'Atlas'	113	1,190	2,060	2,826	3,252	4,111	4,486	2,722	20,759
'Empyrean 1'	69	1,321	2,183	3,378	3,289	4,231	4,425	3,758	22,654
'Nickels'	96	1,162	2,157	3,332	3,642	4,019	4,602	3,645	22,655
'Rootpac-R'	90	1,025	1,553	1,714	1,526	2,434	2,818	1,381	12,541

Table 3. Accumulated 'Nonpareil' yield, kernel pounds per acre @ 113 trees/ac.

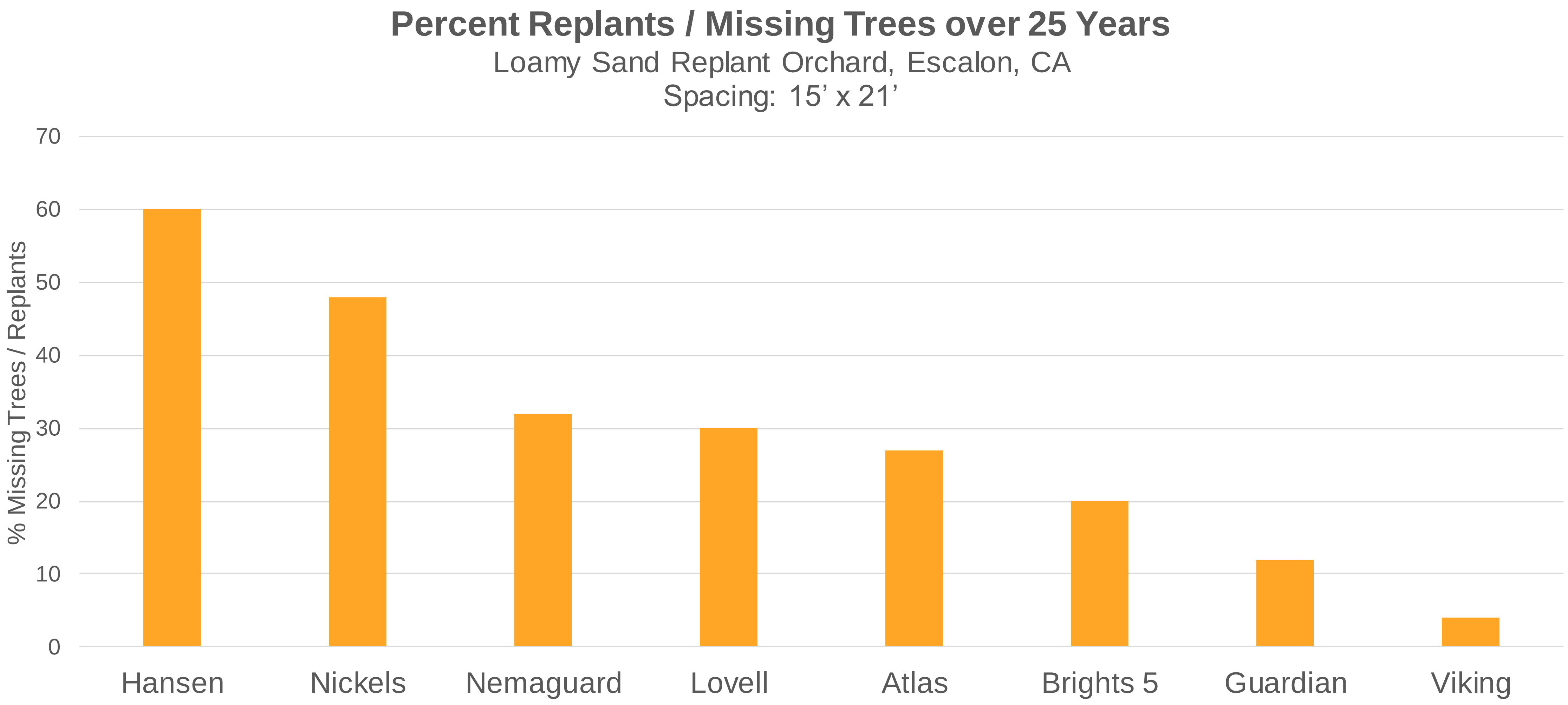
Nickels & Empyrean 1: $10,252 more than Krymsk 86 and $14,000 more per acre than Lovell through 10th leaf @ $2.00 / pound

Rootstock Effect on Kernel Size

Higher vigor rootstocks frequently have larger kernels

	Kernel Size 2022 (g / kernel)
Flordaguard x Alnem	1.31 a
BB 106	1.23 ab
Paramount (GF 677)	1.23 ab
Brights 5	1.21 ab
HM2	1.17 bc
Hansen	1.16 bc
Empyrean 1	1.11 bcd
Atlas	1.06 cde
Viking	1.06 cde
PAC9908-02	1.03 de
Krymsk 86	1.01 def
Nemaguard	0.99 def
HBOK 50	0.98 def
Rootpac R	0.95 ef
Lovell	0.90 f

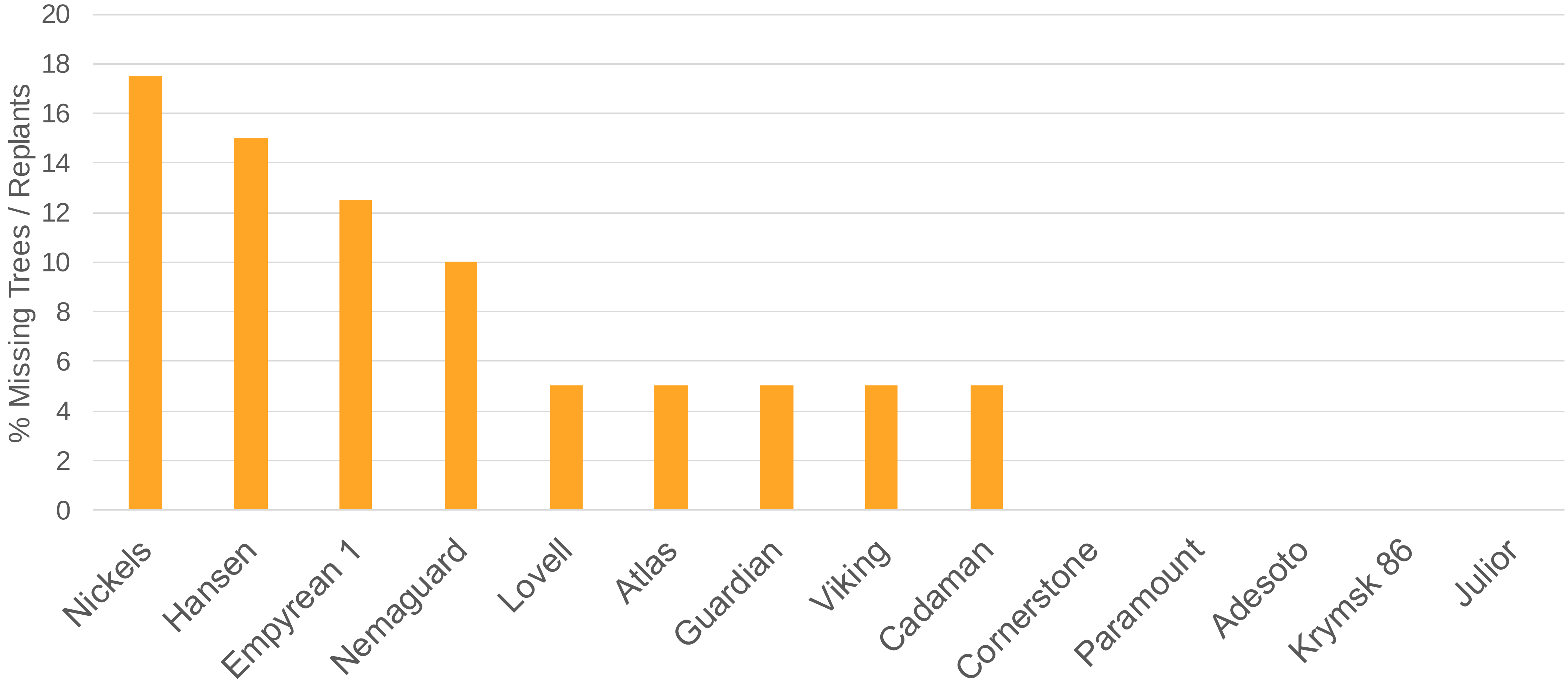
Orchard Longevity – 1997 Rootstock Trial, Escalon



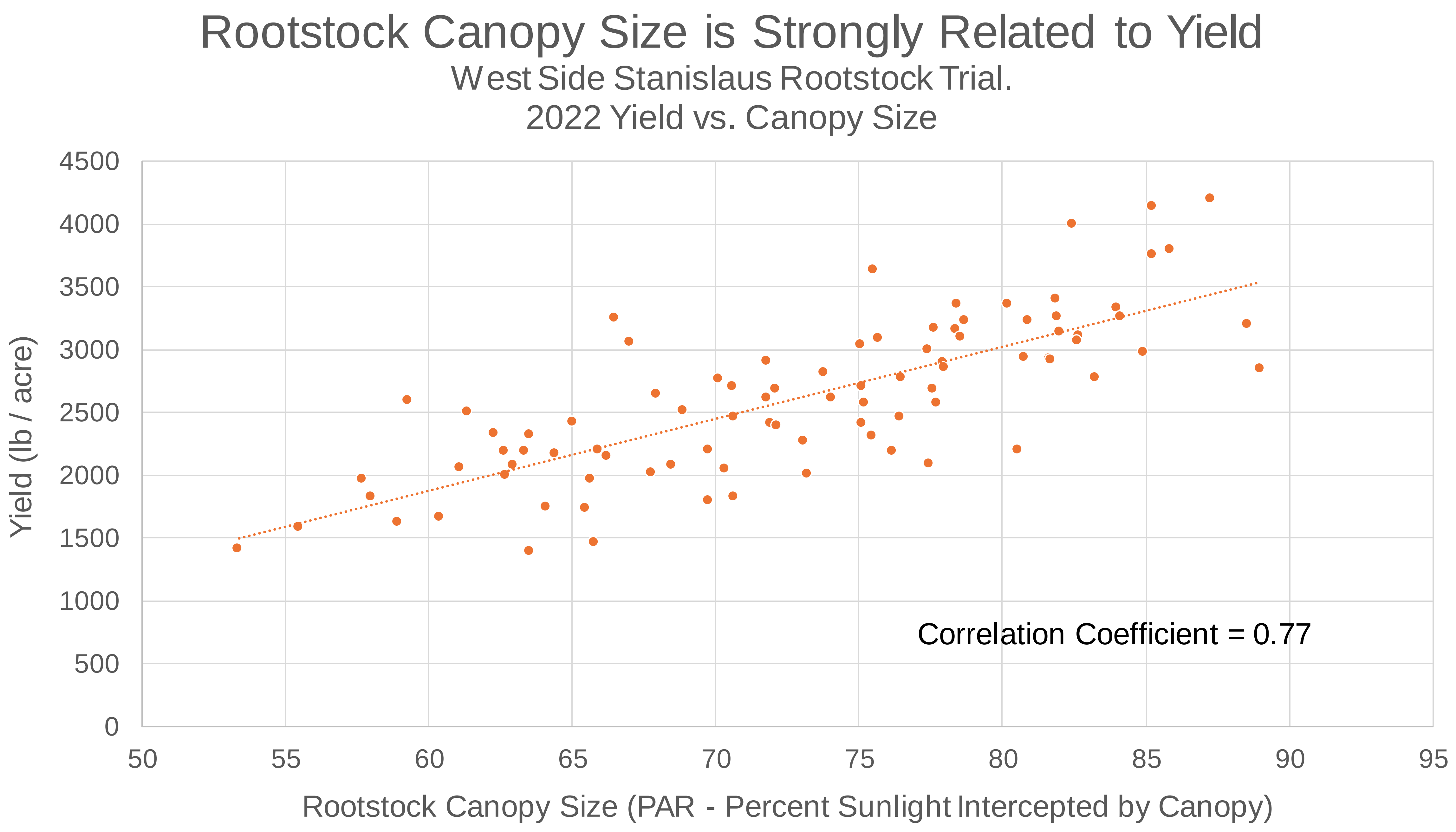
Most trees missing from early bacterial canker or late-life blow over due to wood decay

Percent Replants / Missing Trees after 20 Years

Sandy Loam Replant Orchard. Ceres, CA
Spacing 17’ x 21’



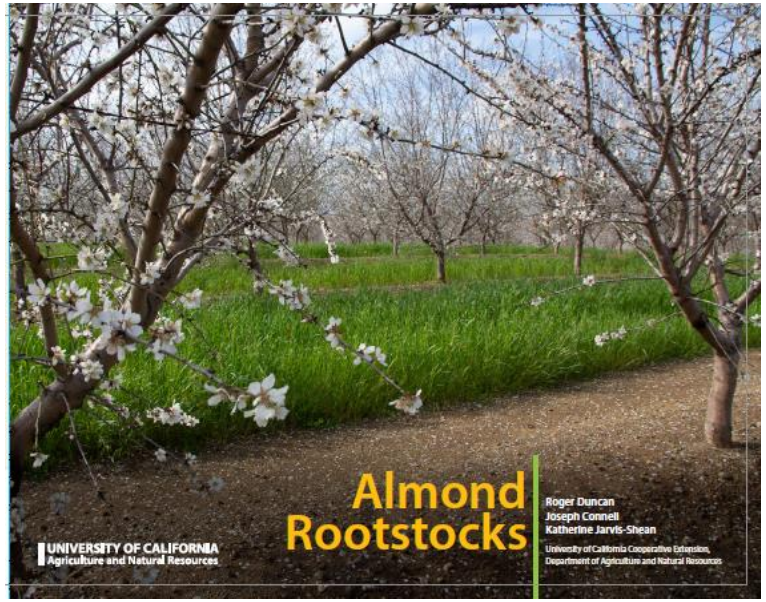
Most trees missing from scaffold failure or late-life blow over due to wood decay


Rootstock Canopy Size is Strongly Related to Yield
West Side Stanislaus Rootstock Trial.
2022 Yield vs. Canopy Size
Yield (lb / acre)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
50
55
60
65
70
75
80
85
90
95
Rootstock Canopy Size (PAR - Percent Sunlight Intercepted by Canopy)
Correlation Coefficient = 0.77

What does this mean for use of high-density systems with dwarfing rootstocks?

- Can you fully compensate by planting lower vigor rootstocks more densely?

New Tri-fold Rootstock Comparison Chart



SCAN ME

Parentage	Rootstock	Genetic Background[1]	Comments
Peach	Guardian®	P. persica	Similar to Nemaguard but with good resistance to ring nematode and bacterial canker.
	Lovell®	P. persica	Historical standard in Sacramento Valley heavier soils due to perceived better asphyxia tolerance than Nemaguard. Susceptible to rootknot nematode.
	Nemaguard®	P. persica	Historical standard rootstock for the San Joaquin Valley in well-drained soil. Being replaced by newer, better-suited rootstocks. Prone to zinc deficiency.
Peach Hybrids	Cadaman®	P. persica x P. davidiana	Similar to Nemaguard but better tolerance of alkaline and saline conditions.
	Empyrean 1® (Barrier 1®)	P. persica x P. davidiana	High vigor and salt tolerance similar to peach x almond hybrids but less susceptible to ring nematode. Fair anchorage may limit use in windy areas.
Peach x Almond Hybrids	Brights 5®	P. dulcis x P. persica	Similar to Hansen but with more moderate vigor.
	Cornerstone®	P. dulcis x P. persica	Similar to Hansen but with more moderate vigor.
	Flordaguard x Alnem (FxA®)	P. dulcis x P. persica	Similar to Hansen. New release by USDA-ARS. Limited experience.
	Hansen 536®	P. dulcis x P. persica	Standard peach x almond hybrid rootstock developed by the University of California. High vigor, excellent anchorage, high salt and alkalinity tolerance. Highly susceptible to ring nematode and bacterial canker.
	Nickels®	P. dulcis x P. persica	Similar to Hansen but better adapted to nursery propagation and storage practices. More tolerant of wet spring soils due to higher chilling requirement.
	Titan Hybrids (Titan II®, SG 1®, etc.)	P. dulcis x P. persica	More vigorous than Hansen with possibly better wet-soil tolerance.
Plum Hybrids	Krymsk 86® (plum x peach)	P. cerasifera x P. persica	Excellent anchorage and general tolerance to root diseases. Lower vigor in sandy soil. Susceptible to sodium, chloride, boron, and all nematodes. Incompatible with Independence.
	Marianna 40® (plum x plum)	P. cerasifera x P. munsoniana	Better vigor and anchorage and less suckering than Marianna 2624. Assumed resistance to oak root fungus and Phytophthora but experience is limited.
	Marianna 2624® (plum x plum)	P. munsoniana x P. cerasifera	Standard in soils infested with oak root fungus and Phytophthora. Incompatible with Nonpareil and Independence. Root suckering and low vigor are common.
	Rootpac 20® (plum x sand cherry)	P. besseyi x P. cerasifera	Dwarfing rootstock (about 65% of Nemaguard) used in Super High-Density plantings in Spain. Limited experience in California.
	Rootpac R® (plum x almond)	P. cerasifera x P. dulcis	Best suited for alkaline, heavy soils high in chloride. Not well suited for sandy soils (low vigor) or where excess sodium and boron are a problem. Performance has been variable in UC trials.
Complex Hybrids (peach, almond, plum, apricot)	Atlas®	P. persica x (P. dulcis x (P. cerasifera x P. mume))	Similar to Nemaguard but may have higher yield efficiency. Intolerant to cold storage or dehydration when planted bare root.
	Viking®	P. persica x (P. dulcis x (P. cerasifera x P. mume))	Slightly more vigorous than Nemaguard but good tolerance to ring nematode, bacterial canker, salt, and alkaline conditions. Excellent anchorage.

	Horticultural Characteristics				Abiotic Conditions				
Rootstock	Compatibility	Anchorage	Vigor[2]	Suckering	Excessive Sodium	Excessive Chloride	Lime-induced Chlorosis	Excessive Boron	In-season Waterlogging[3]
Guardian®	Good	Fair	Moderately high	Low	Susceptible	Susceptible	Susceptible	Susceptible	Sensitive
Lovell®	Good	Fair	Moderate	Low	Susceptible	Highly susceptible	Susceptible	Highly susceptible	Sensitive
Nemaguard®	Good	Good	Moderately high	Low	Highly susceptible	Susceptible	Susceptible	Susceptible	Sensitive
Cadaman®	Good (limited experience)	Good	Moderately high	Low	Moderately tolerant	Moderately tolerant	Moderately tolerant	Highly susceptible	Sensitive
Empyrean 1® (Barrier 1®)	Good (limited experience)	Fair	Very high	Low	Tolerant	Moderately tolerant	Moderately tolerant	Susceptible	Sensitive
Brights 5®	Good	Good	High	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive
Cornerstone®	Good (limited experience)	Good	Very high	Low	Tolerant	Tolerant	Moderately tolerant	Assumed Moderately tolerant	Sensitive
Flordaguard x Alnem (FxA®)	Good (limited experience)	Excellent	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Unknown
Hansen 536®	Good	Excellent	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive
Nickels®	Good	Very good	Very high	Low	Moderately tolerant	Moderately tolerant	Tolerant	Moderately tolerant	Sensitive
Titan Hybrids (Titan II®, SG 1®, etc.)	Good	Good	Very high	Low	Tolerant	Tolerant	Tolerant	Moderately tolerant	Sensitive
Krymsk 86® (plum x peach)	Good with Nonpareil. Incompatible with Independence.[8] Marginal with Monterey and Shasta	Excellent	Moderate	Low / Moderate	Susceptible	Highly susceptible	Susceptible	Susceptible	Tolerant[3]
Marianna 40® (plum x plum)	Assumed similar to M 2624	Very good	Moderate	Low	Unknown	Unknown	Unknown	Assumed susceptible	Tolerant[3]
Marianna 2624® (plum x plum)	Incompatible with Nonpareil and Independence. Marginal with Monterey	Good	Moderately low	High (variable)	Tolerant	Tolerant	Susceptible	Susceptible	Tolerant[3]
Rootpac 20® (plum x sand cherry)	Variable (limited experience)	Unknown	Very low	High	Unknown	Unknown	Unknown	Assumed susceptible	Unknown
Rootpac R® (plum x almond)	Good with Nonpareil (limited experience)	Good	Moderate to low	Moderate	Susceptible	Tolerant	Tolerant	Susceptible	Tolerant[3]
Atlas®	Good	Fair	Moderately high	Low	Susceptible	Susceptible	Moderately tolerant	Highly susceptible	Sensitive
Viking®	Good	Excellent	Moderately high	Low	Moderately tolerant	Moderately tolerant	Moderately tolerant	Moderately tolerant	Sensitive

	Diseases						Nematodes		
Rootstock	Oak Root Fungus	Crown Gall	Phytophthora	Verticillium Wilt	Replant Disease	Bacterial Canker	Rootknot[4]	Ring[5]	Root Lesion[6]
Guardian®	Susceptible	Susceptible	Moderately susceptible	Susceptible	Unknown	Tolerant	Resistant	Tolerant	Susceptible
Lovell®	Susceptible	Susceptible	Moderately susceptible	Highly susceptible	Highly susceptible	Tolerant	Susceptible	Tolerant	Susceptible
Nemaguard®	Susceptible	Moderately susceptible	Moderately susceptible	Susceptible	Highly susceptible	Susceptible	Resistant	Susceptible	Susceptible
Cadaman®	Susceptible	Unknown	Moderately susceptible	Highly susceptible	Unknown	Moderately tolerant	Resistant	Susceptible	Highly susceptible
Empyrean 1® (Barrier 1®)	Susceptible	Unknown	Moderately susceptible	Susceptible	Low susceptibility	Assumed tolerant[7]	Resistant	Tolerant	Highly susceptible
Brights 5®	Susceptible	Moderately susceptible	Highly susceptible	Susceptible	Low susceptibility	Highly susceptible	Resistant	Highly susceptible	Susceptible
Cornerstone®	Susceptible	Highly susceptible	Highly susceptible	Susceptible	Unknown	Assumed susceptible	Resistant	Highly susceptible	Susceptible
Flordaguard x Alnem (FxA®)	Unknown	Highly susceptible	Unknown	Highly susceptible	Unknown	Unknown	Unknown	Unknown	Unknown
Hansen 536®	Highly susceptible	Highly susceptible	Highly susceptible	Highly susceptible	Low susceptibility	Highly susceptible	Resistant	Highly susceptible	Moderately tolerant
Nickels®	Susceptible	Highly susceptible	Highly susceptible	Susceptible	Unknown	Highly susceptible	Resistant	Highly susceptible	Susceptible
Titan Hybrids (Titan II®, SG 1®, etc.)	Susceptible	Unknown	Moderately susceptible	Susceptible	Unknown	Highly susceptible	Resistant	Unknown	Unknown
Krymsk 86® (plum x peach)	Moderately Resistant	Susceptible	Resistant	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible
Marianna 40® (plum x plum)	Resistant	Unknown	Assumed resistant	Unknown	Unknown	Assumed susceptible	Resistant	Susceptible	Susceptible
Marianna 2624® (plum x plum)	Resistant	Moderately tolerant	Resistant	Unknown	Highly susceptible	Highly susceptible	Resistant	Susceptible	Susceptible
Rootpac 20® (plum x sand cherry)	Unknown	Susceptible	Resistant	Unknown	Unknown	Assumed susceptible	Unknown	Unknown	Unknown
Rootpac R® (plum x almond)	Unknown	Unknown	Resistant	Susceptible	Highly susceptible	Assumed susceptible	Resistant	Highly susceptible	Susceptible
Atlas®	Susceptible	Moderately tolerant	Highly susceptible	Tolerant	Unknown	Susceptible	Resistant	Susceptible	Highly susceptible
Viking®	Susceptible	Moderately tolerant	Highly susceptible	Susceptible	Unknown	Tolerant	Resistant	Tolerant	Susceptible

[1] As per Rubio-Cabetas, et al., 2017.

[2] Vigor of rootstocks with plum parentage is often significantly lower in sandy soil.

[3] Wet soil in-season can worsen incompatibility symptoms.

[4] Rootknot nematode resistance infers Meloidogyne incognita, M. arenaria, and M. javanica, not the peach rootknot nematode M. floridensis.

[5] Ring = (Mesocriconema (=Criconemella) xenoplax.

[6] Root lesion = Pratylenchus vulnus.

[7] Assumed susceptibility or resistance is based on other rootstocks with similar parentage, but insufficient data exists for confirmation.

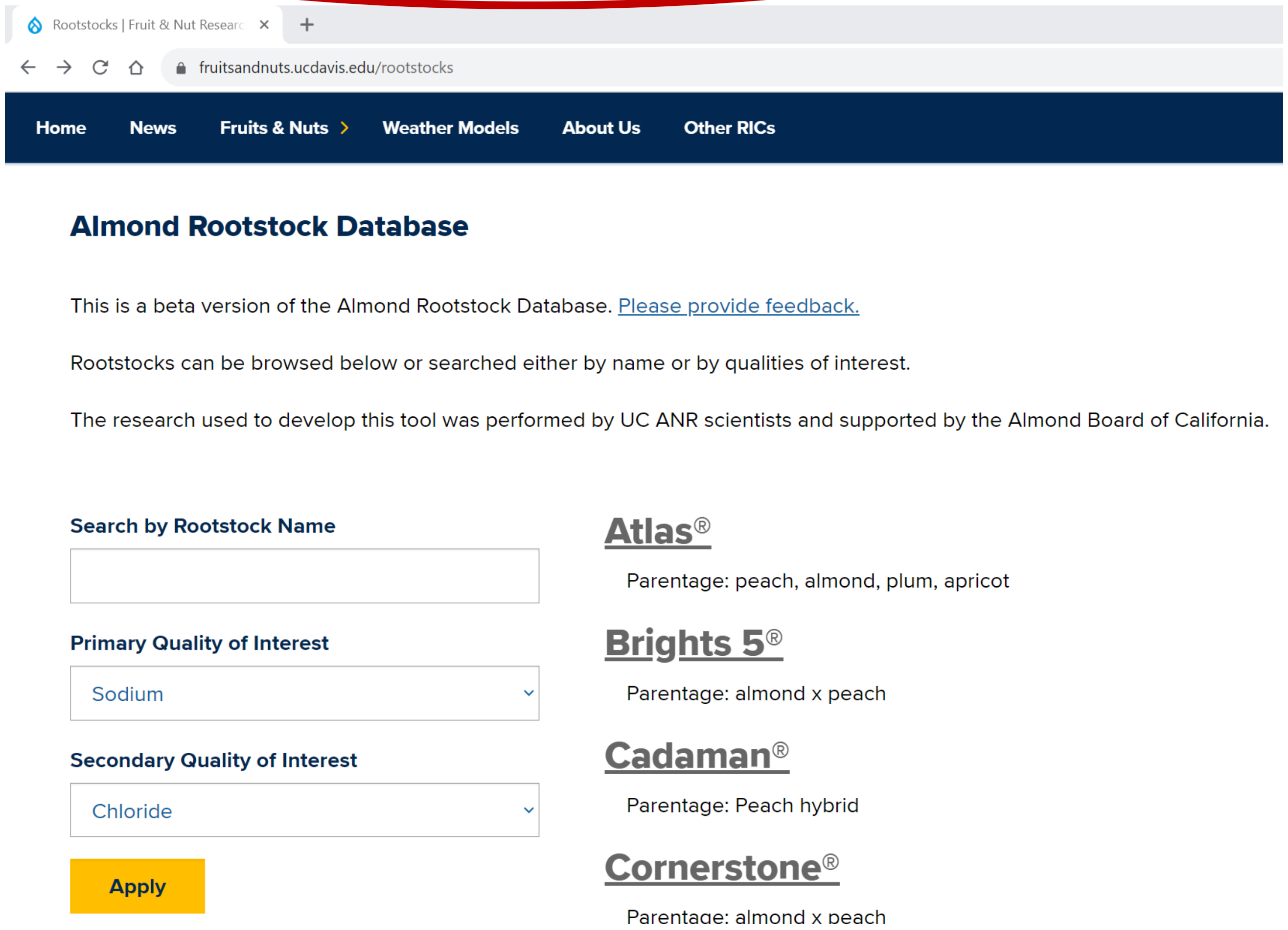
[8] Sporadic incompatibility symptoms have been observed with Independence on Krymsk 86, while some orchards have performed acceptably.

Video: Yolo County Rootstock Trial

Video: Westside Stanislaus Rootstock Trial

Online Rootstock Database – UC Fruit and Nut Center

- fruitsandnuts.ucdavis.edu/rootstocks


Rootstocks | Fruit & Nut Researc

fruitsandnuts.ucdavis.edu/rootstocks

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Almond Rootstock Database

This is a beta version of the Almond Rootstock Database. Please provide feedback.

Rootstocks can be browsed below or searched either by name or by qualities of interest.

The research used to develop this tool was performed by UC ANR scientists and supported by the Almond Board of California.

Search by Rootstock Name

Primary Quality of Interest

Sodium

Secondary Quality of Interest

Chloride

Apply

Atlas®

Parentage: peach, almond, plum, apricot

Brights 5®

Parentage: almond x peach

Cadaman®

Parentage: Peach hybrid

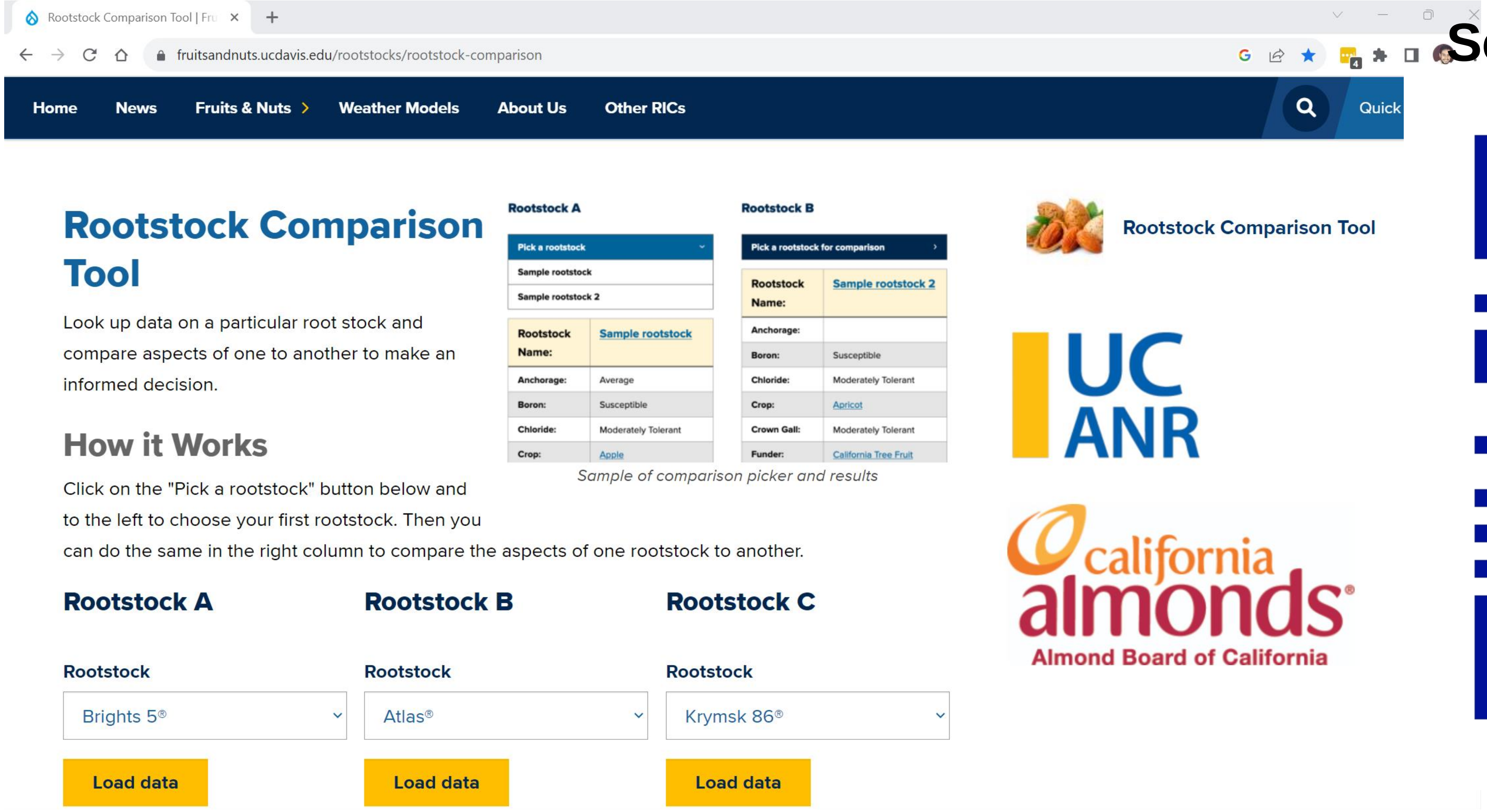
Cornerstone®

Parentage: almond x peach

Scan the QR code

Online Rootstock Comparison Tool

- https://fruitsandnuts.ucdavis.edu/rootstocks/rootstock-comparison



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Thank you!

Thank you to the Almond Board for funding several decades of rootstock research

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Thank you