Whole orchard recycling in the San Joaquin Valley, rebalancing the C:N ration, fertility management and disease considerations in next generation orchards

Brent A. Holtz, Ph.D.

Norther San Joaquin Valley Almond Day

January 21, 2025

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Can whole orchards be incorporated into the soil when they are removed and not burned in the field or in a co-generation plant?

Can we return this organic matter to our orchard soils without negatively effecting the next orchard that will be planted?

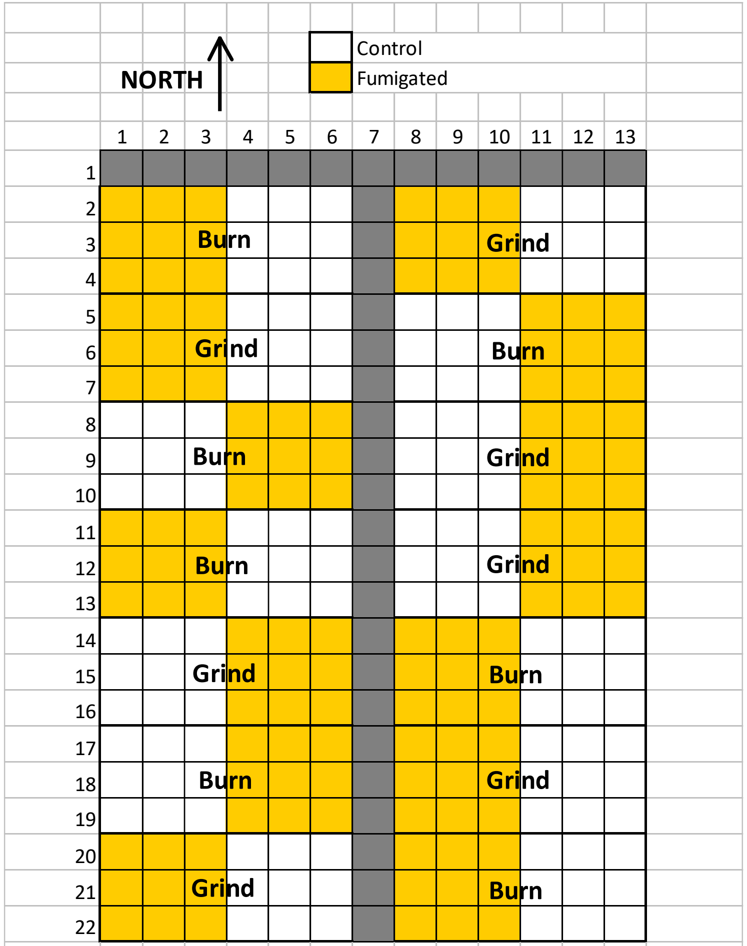
The Iron Wolf

The Iron Wolf
a 100,000 lb (45,000 kg)
rototiller

http://ucanr.edu/?blogpost=16603&blogasset=74534

Two Treatments:
Orchard Grinding with Iron Wolf
Pushing and Burning Trees

In a natural forest system– Tree nutrients come from either decomposing logs or ashes from forest fires.



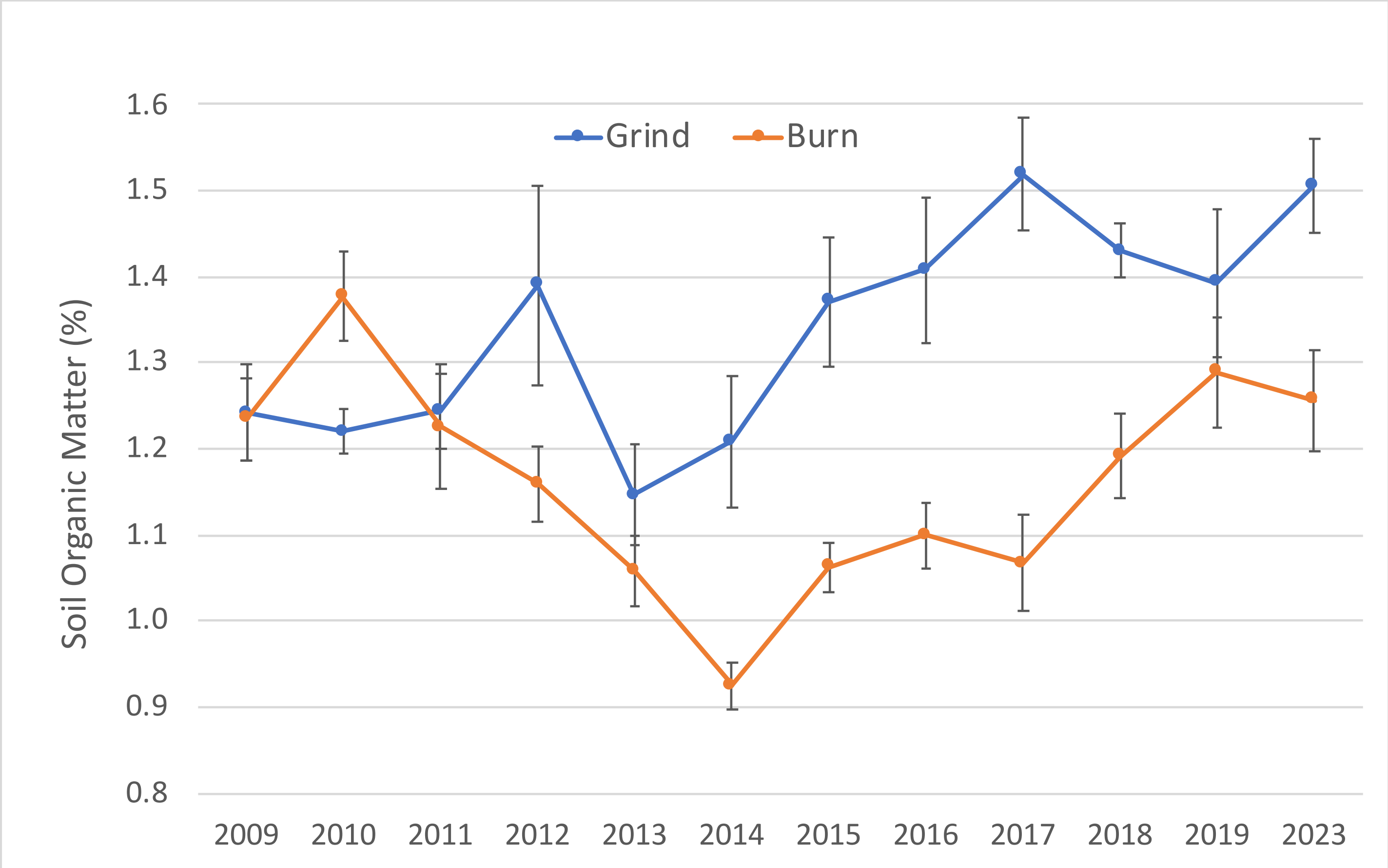
no of tree sites counting buffers: 286

2009 First leaf trees growing in grinding plot

2010 Second leaf trees

No difference in tree circumference

The Grinding did not stunt the second generation orchard



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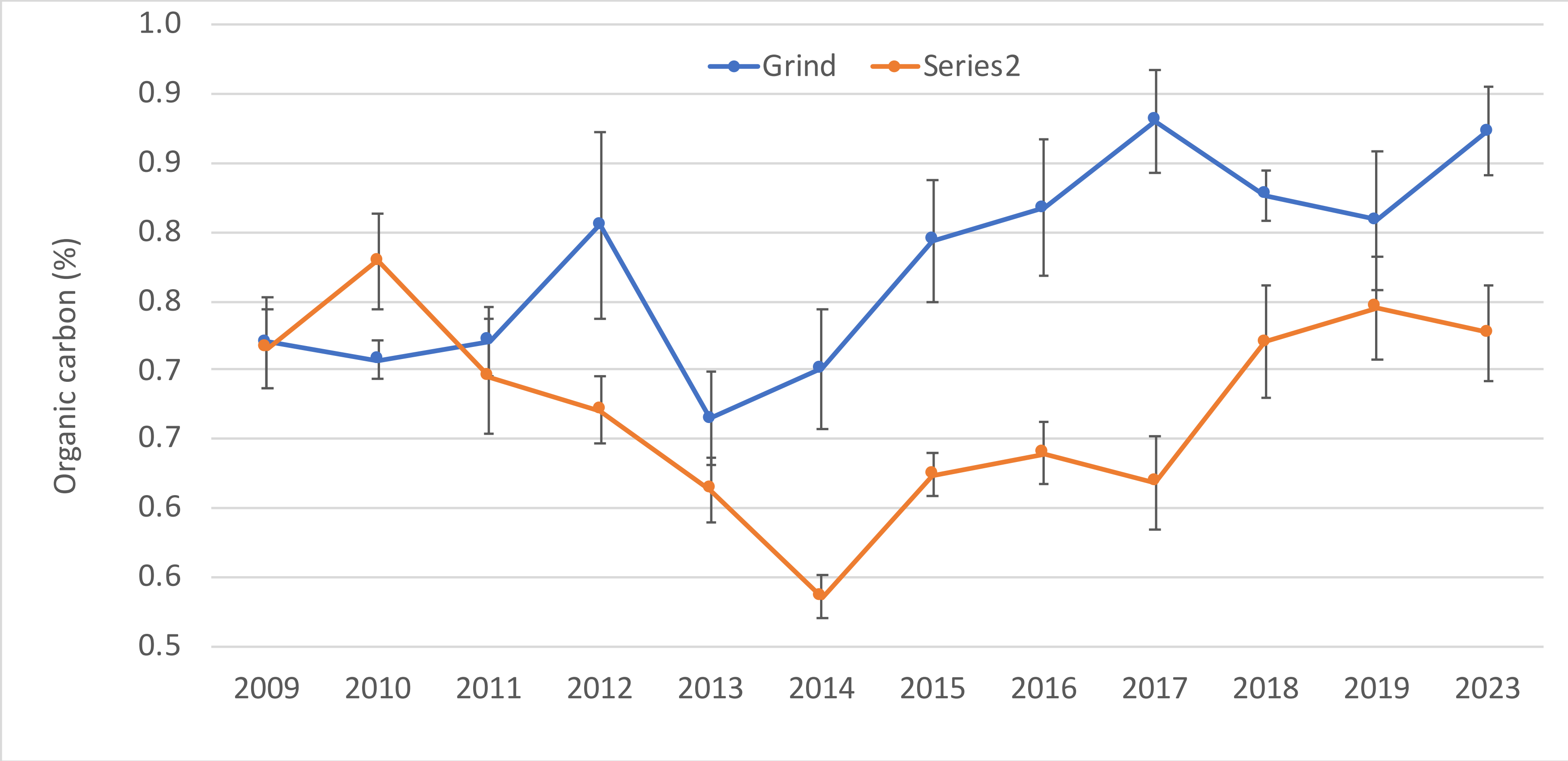

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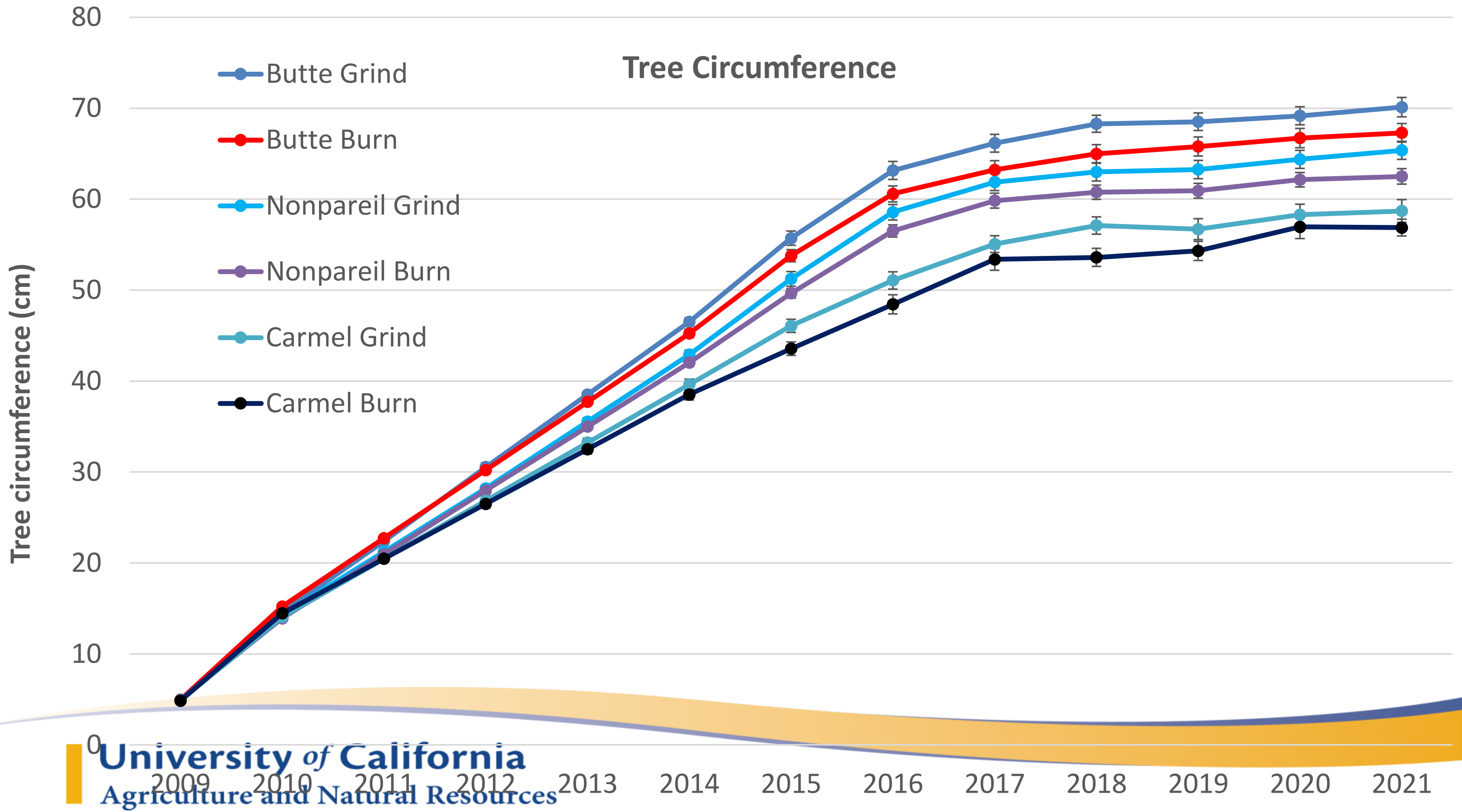

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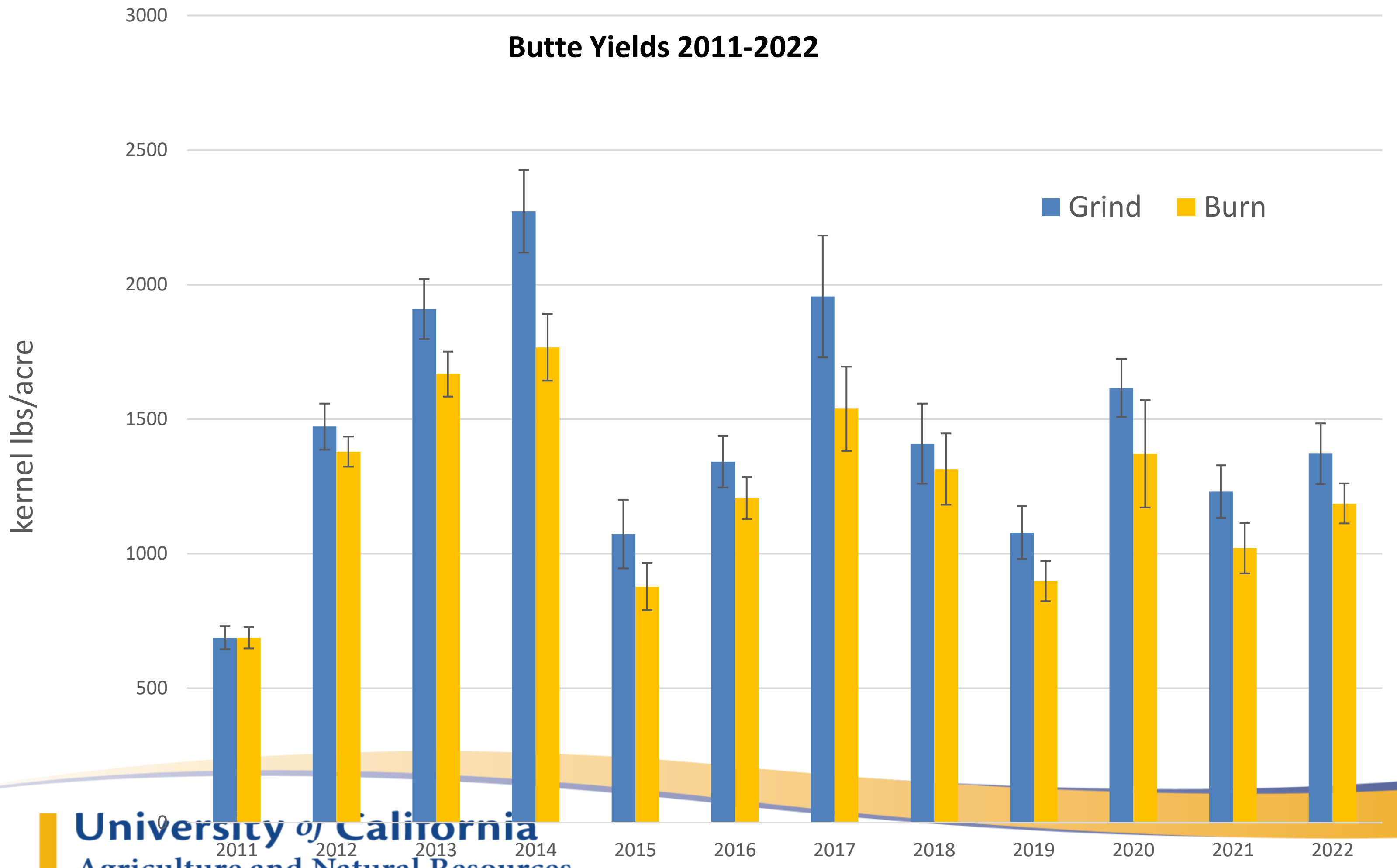

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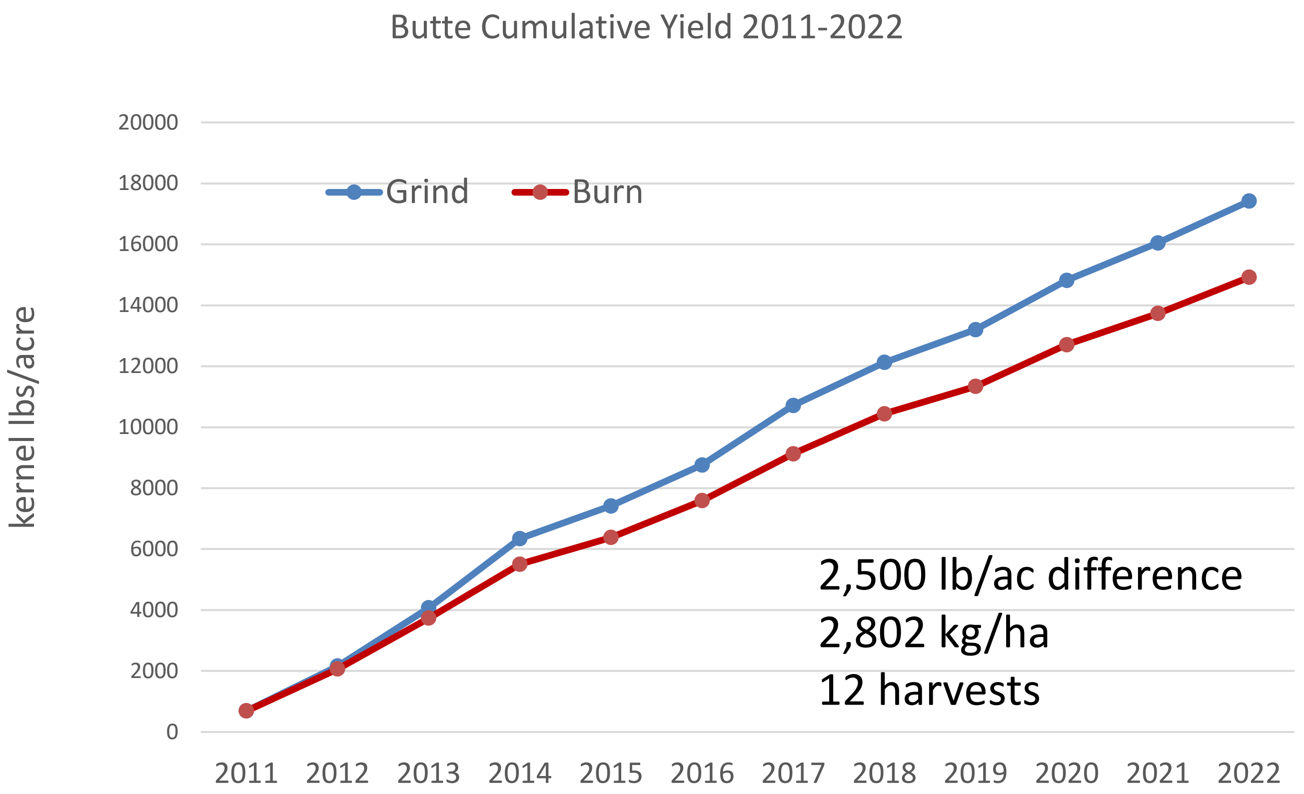

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Whole Orchard Recycling has:

- Increased soil organic matter
- Increased soil organic carbon
- Increased soil nutrients
- Increase soil microbial diversity
- Increased orchard productivity

PLOS ONE

RESEARCH ARTICLE

Orchard recycling improves climate change adaptation and mitigation potential of almond production systems

Emad Jahanzad[1], Brent A. Holtz[2], Cameron A. Zuber[2], David Doll[2], Kelsey M. Brewer[1], Sean Hogan[2], Amélie C. M. Gaudin[1]*

1 Department of Plant Sciences, University of California, Davis, California, United States of America,
2 University of California Agriculture and Natural Recourses, Davis, California, United States of America

* agaudin@ucdavis.edu

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Abstract

There is an urgent need to develop climate smart agroecosystems capable of mitigating climate change and adapting to its effects. In California, high commodity prices and increased frequency of drought have encouraged orchard turnover, providing an opportunity to recycle tree biomass *in situ* prior to replanting an orchard. Whole orchard recycling (WOR) has potential as a carbon (C) negative cultural practice to build soil C storage, soil health, and orchard productivity. We tested the potential of this practice for long term C sequestration and hypothesized that associated co-benefits to soil health will enhance sustainability and resiliency of almond orchards to water-deficit conditions. We measured soil health metrics and productivity of an almond orchard following grinding and incorporation of woody biomass vs. burning of old orchard biomass 9 years after implementation. We also conducted a deficit irrigation trial with control and deficit irrigation (-20%) treatments to quantify shifts in

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TECHNICAL REPORT

Groundwater Quality

Effects of whole-orchard recycling on nitrate leaching potential in almond production systems

Emad Jahanzad[1] | Kelsey M. Brewer[2] | Amisha T. Poret-Peterson[3] | Catherine M. Culumber[4] | Brent A. Holtz[4] | Amélie C. M. Gaudin[2]

[1]California Department of Food and Agriculture, Sacramento, CA 95814, USA

[2]Dep. of Plant Sciences, Univ. of California, Davis, CA 95616, USA

[3]USDA-ARS, Crops Pathology and Genetics Research Unit, Davis, CA 95616, USA

[4]Division of Agriculture and Natural Recourses, Univ. of California, Davis, CA 95616, USA

Correspondence
Amélie C. M. Gaudin, Dep. of Plant Sciences, Univ. of California, Davis, CA 95616, USA.
Email: agaudin@ucdavis.edu

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Abstract

Inefficient nitrogen (N) fertilization and irrigation have led to unhealthy nitrate levels in groundwater bodies of agricultural areas in California. Simultaneously, high commodity prices and drought have encouraged perennial crop growers to turnover less-productive orchards, providing opportunities to recycle tree biomass in situ and to use high-carbon (C) residues to conserve soil and water resources. Although climate change adaptation and mitigation benefits of high-C soil amendments have been shown, uncertainties remain regarding the benefits and trade-offs of this practice for N cycling and retention. We used established almond [*Prunus dulcis* (Mill.) D. A. Webb] orchard trials on Hanford fine sandy loam with short-term and long-term biomass recycling legacies to better understand the changes in N dynamics and retention capacity associated with this practice. In a soil column experiment, labeled N fertilizer was added and traced into various N pools, including microbial biomass and inorganic fractions in soil and leachate. Shifts in microbial communities were characterized using the abundance of key N cycling functional genes regulating nitrification and denitrification processes. Our findings showed that, in the short term, biomass recycling led to N immobilization within the orchard biomass incorpora-

Closure of more biomass plants reduces options

By Christine Souza

The closure or threatened closure of more California biomass power plants leaves farmers with fewer options for disposing of tree prunings or of trees uprooted during planned orchard removals.

"The last few projects that we've done,

In 2015 growers started using manure spreaders to spread wood chips back on the soil surface

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Horizontal grinders can chip 15-20 acres per day.

Orchard removal typically involves five machines. Horizontal grinders can chip up 15-20 acres per day. Two-inch screen sizes are recommended rather than four-inch screens to reduce chip size.

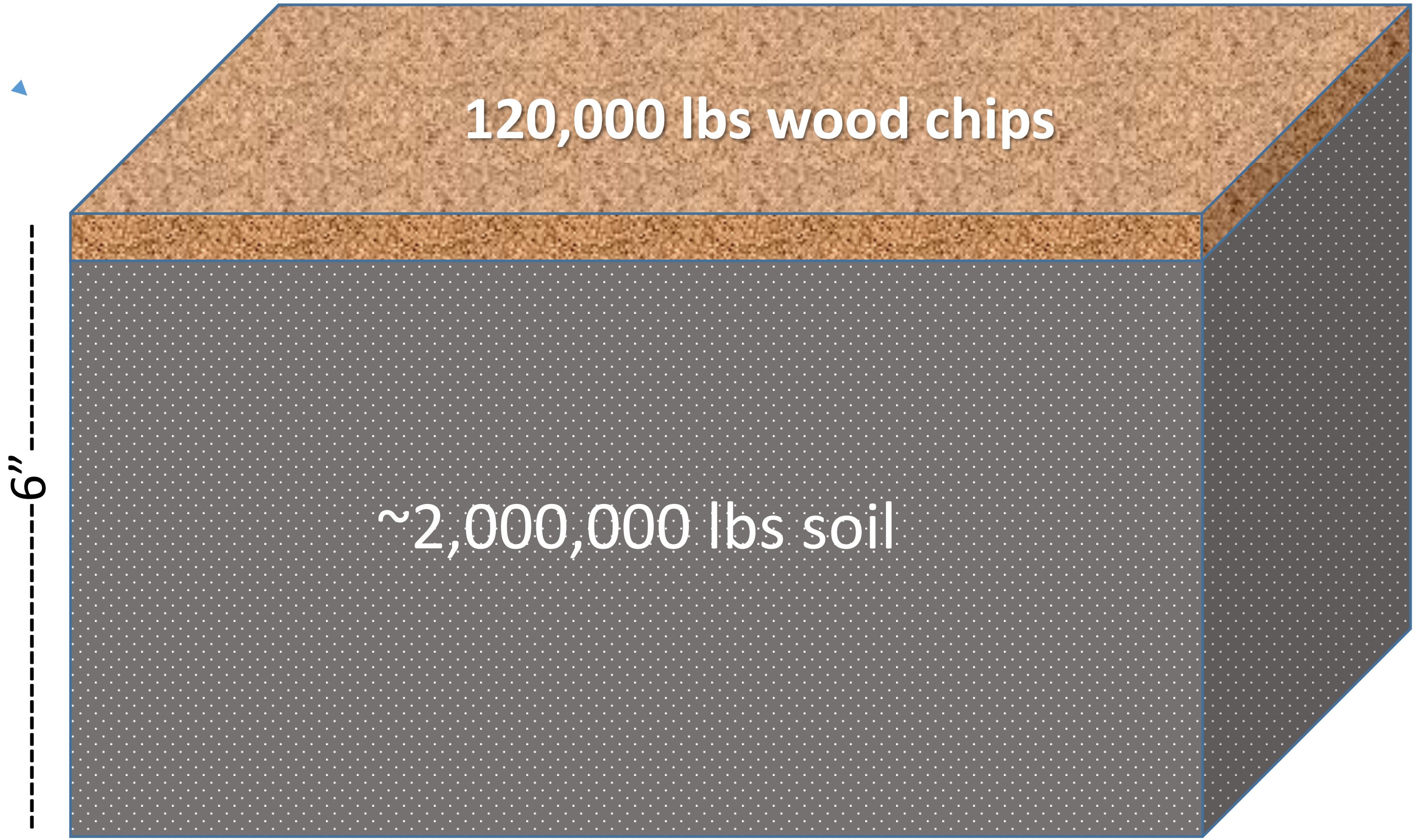
Kuhn & Knight manure spreaders were modified to spread wood chips.

Keeping the chips and having them spread back onto your orchard floor will cost and additional $400 acre.

Wood chips are spread uniformly over entire field surface


FLAGLER'S
LAND LEVELING
New Holland
T9050
EINLM6V69

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



After spreading the woodchips growers can proceed with typical land preparation practices for the next orchard: ripping, disking, fumigation….


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

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

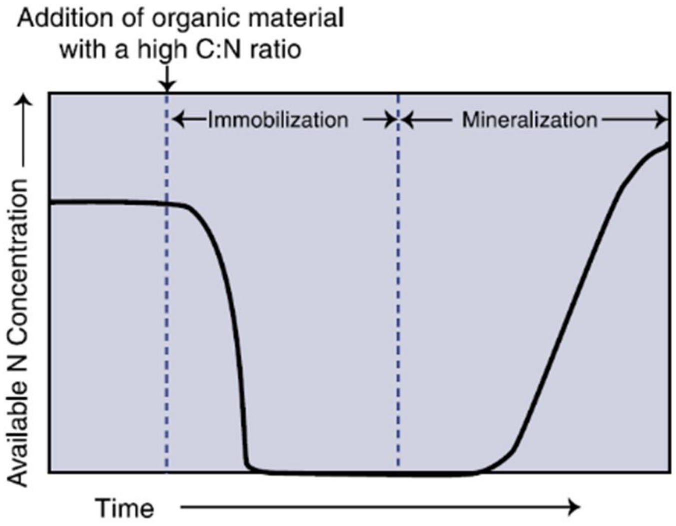
We doubled our nitrogen applications through fertigation in order to get the desired growth.

Problems with double-line drip in the first year

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

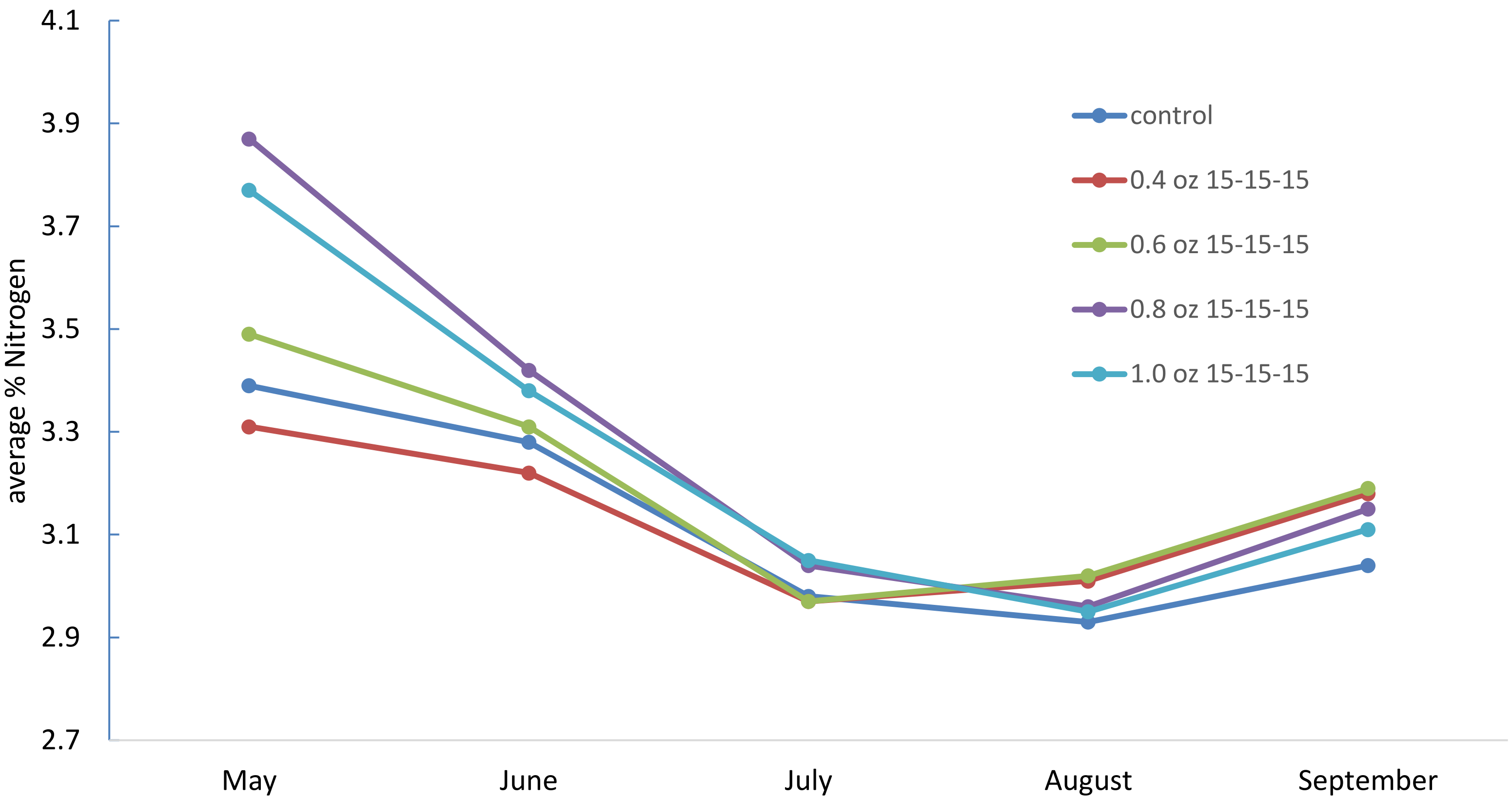
- High C content stimulates microbial N immobilization, as organic material decomposes and microbial communities shift, N is mineralized and available for plant uptake over time
- How long does this process take?

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



Control

0.8 oz of N applied in March



average % Nitrogen
4.1
3.9
3.7
3.5
3.3
3.1
2.9
2.7
May
June
July
August
September
control
0.4 oz 15-15-15
0.6 oz 15-15-15
0.8 oz 15-15-15
1.0 oz 15-15-15

Control

70 tons per acre rate

Control

70 tons per acre rate

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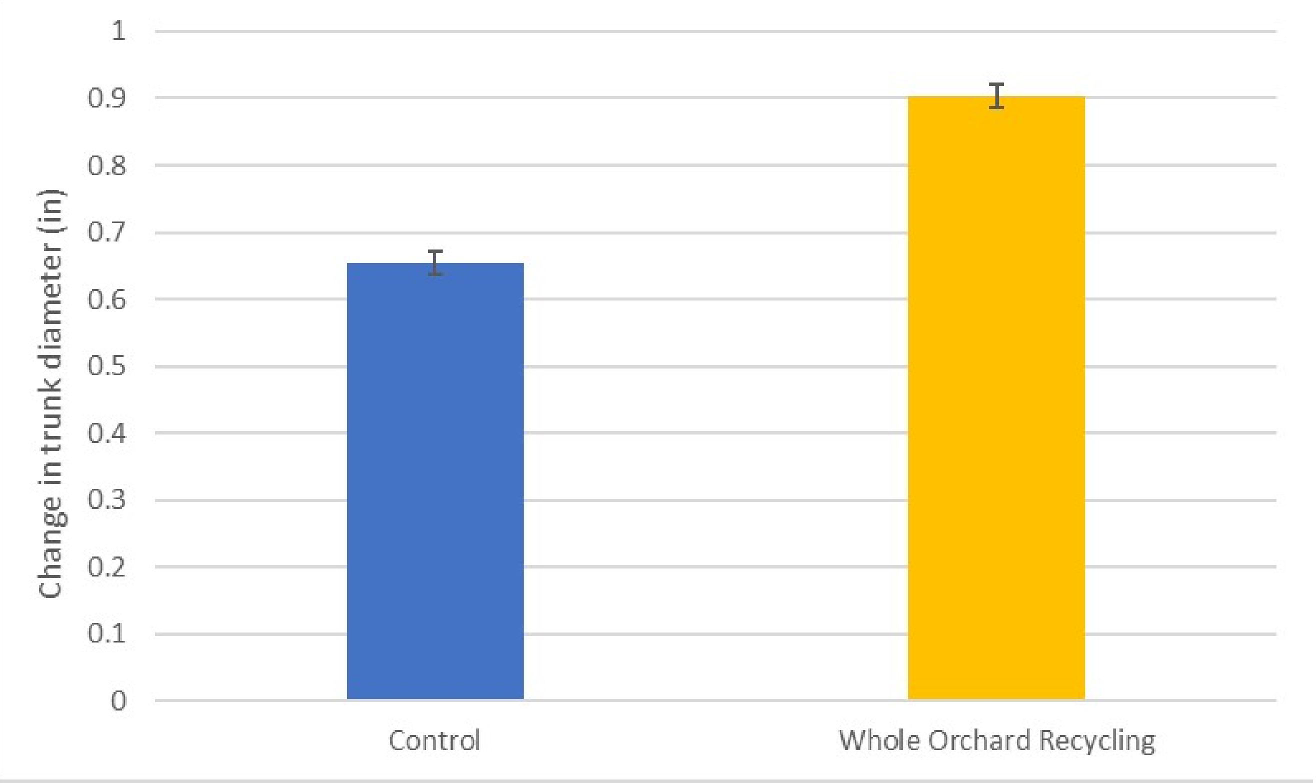
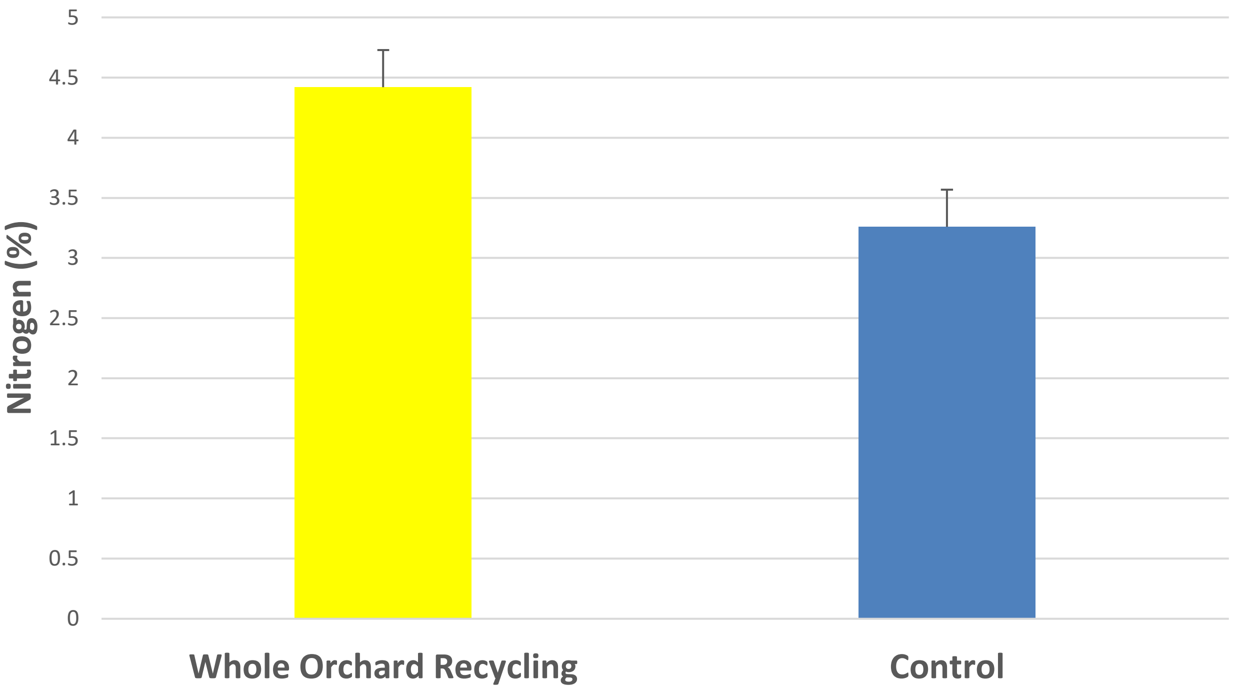
Both treatments received 45 lbs N/acre



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

Leaf Petiole Analysis



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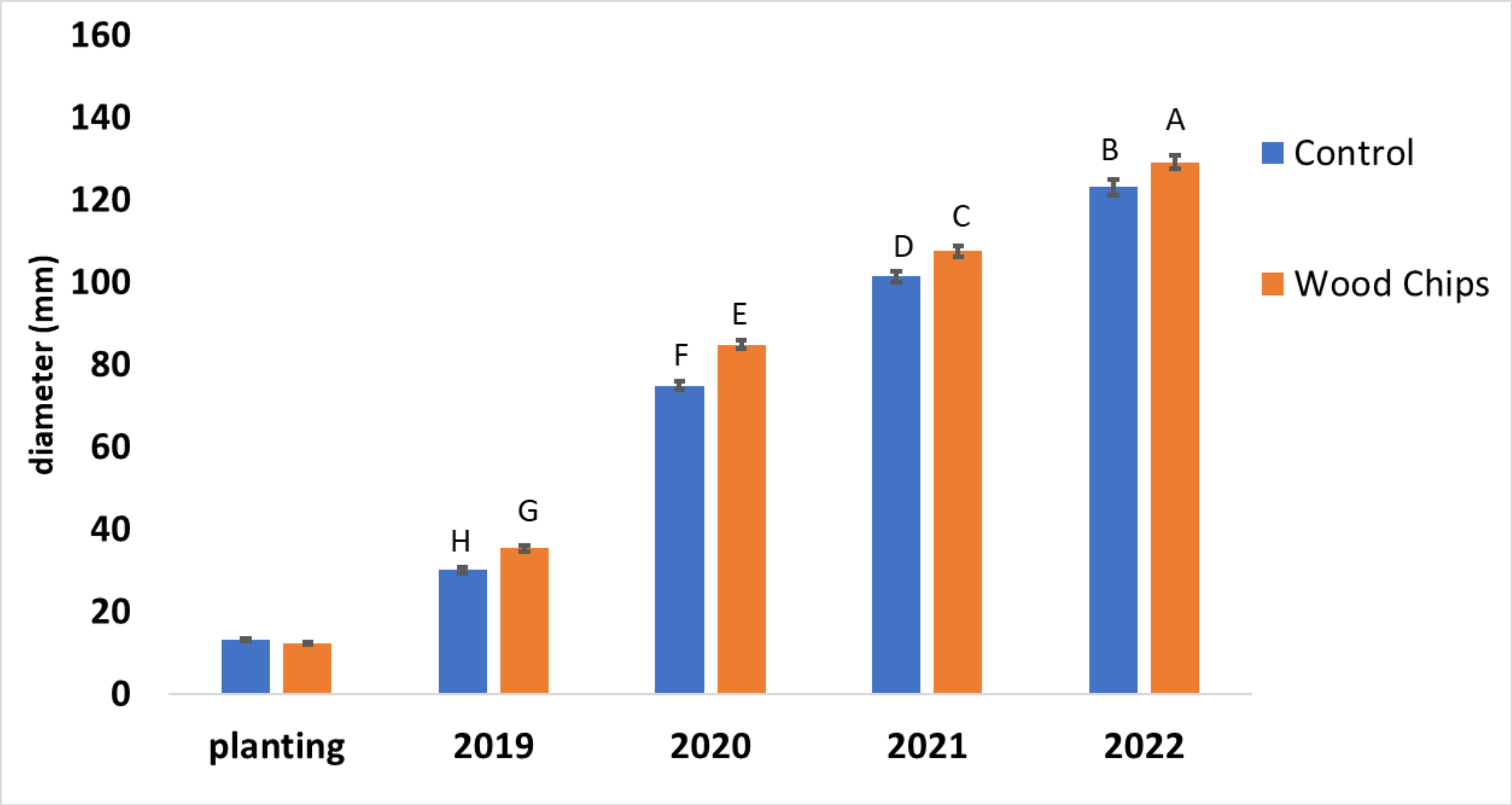
Both received 45 lbs N/acre (5 oz N per tree)



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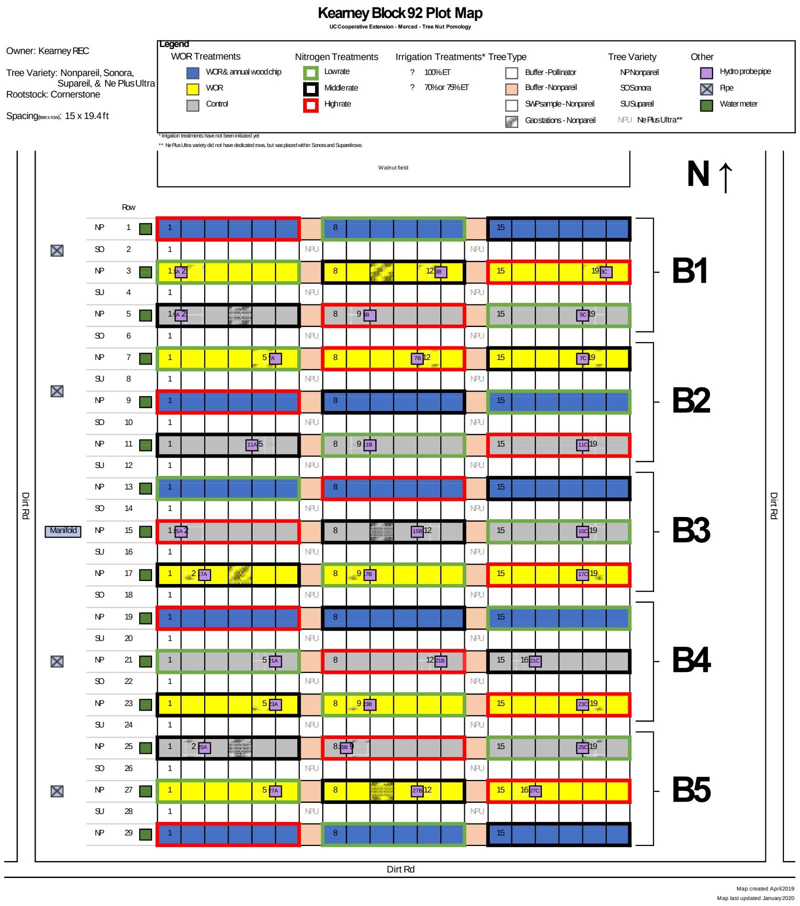


Three WOR treatments:

WOR + annual wood chips (15 tons)

WOR

Control

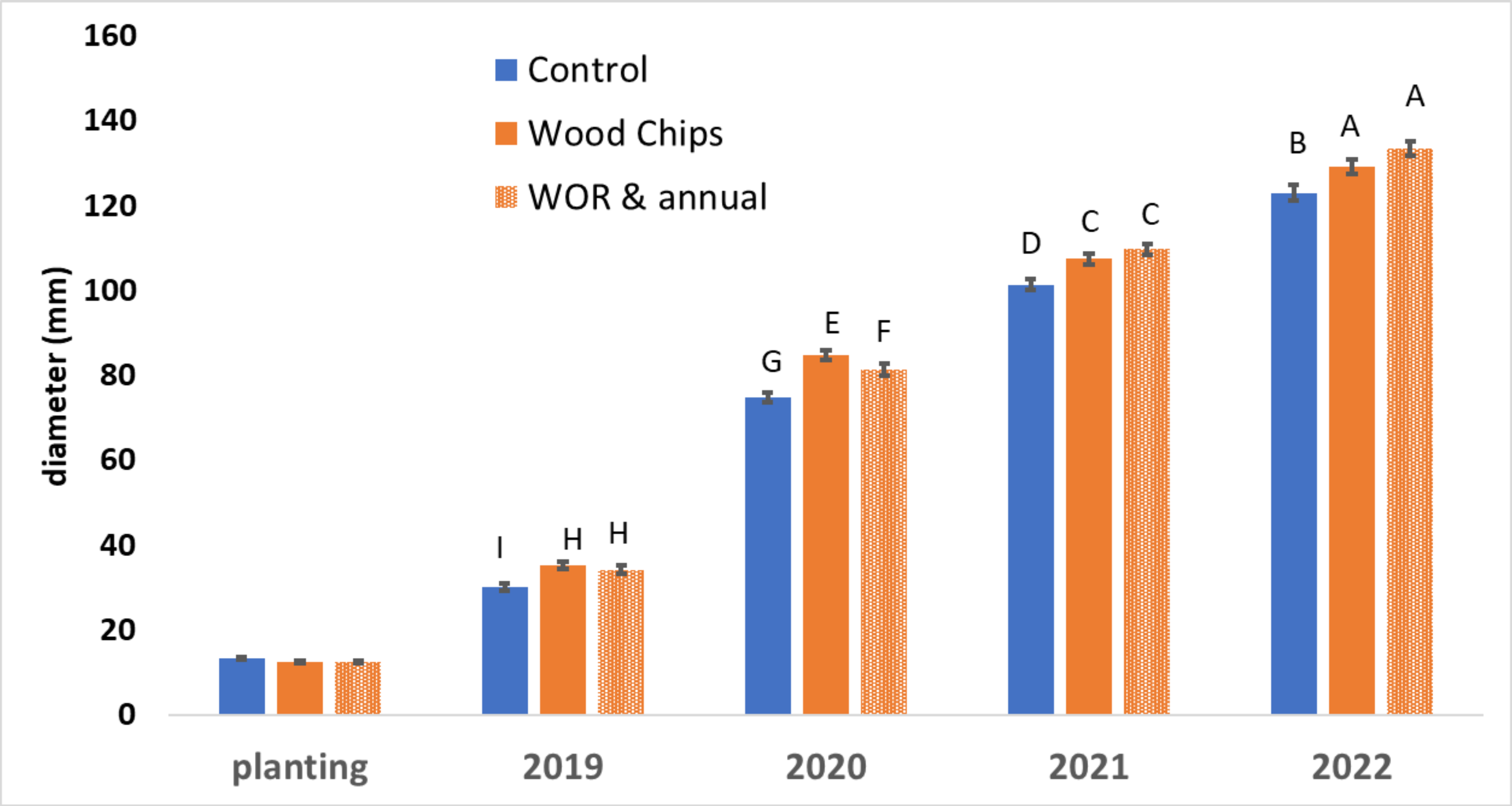
Three sub-treatments:

Low N rate

Middle N

High N (Patrick Brown's)

Annual applications:
15 tons per acre/annually
Hope to see similar benefits to cover cropping



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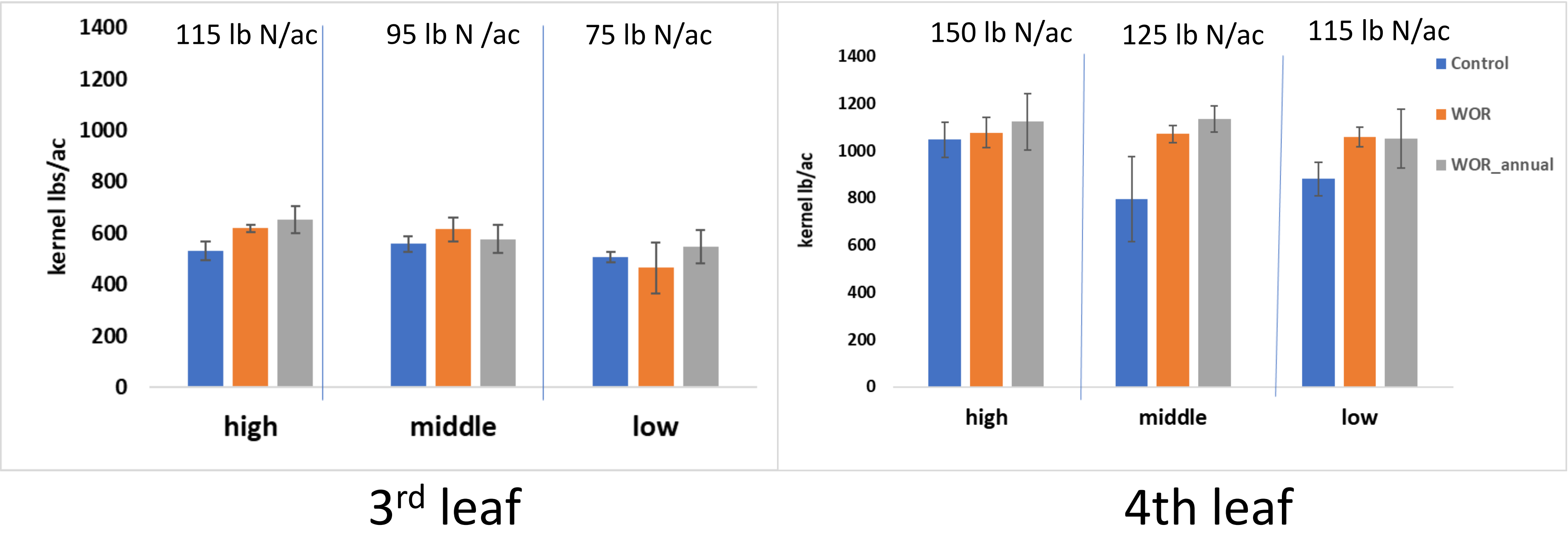
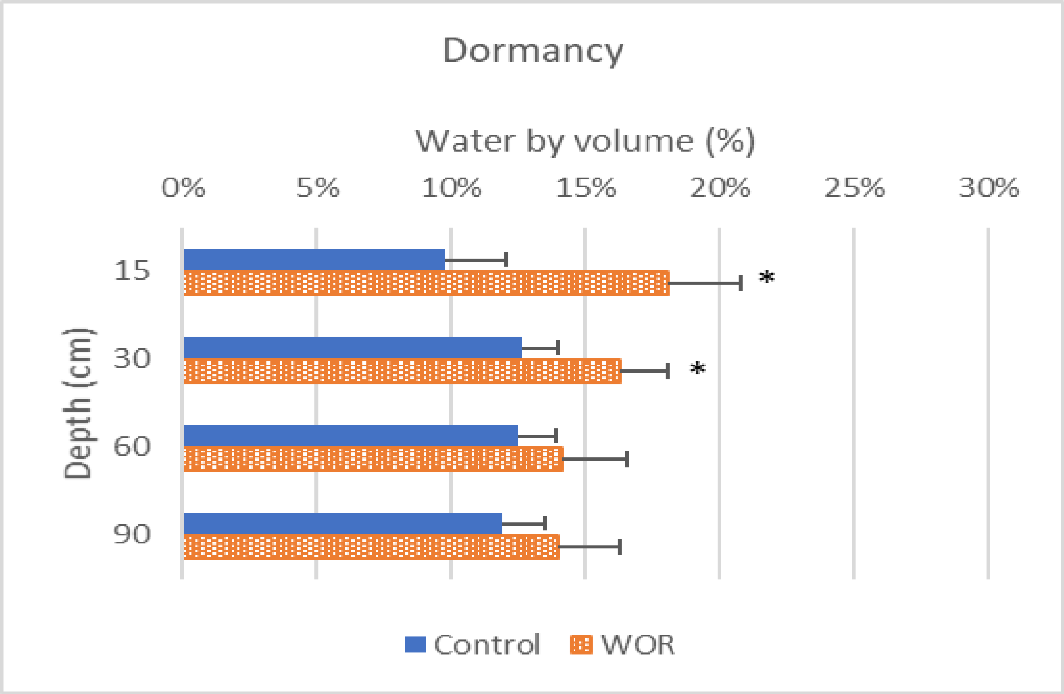
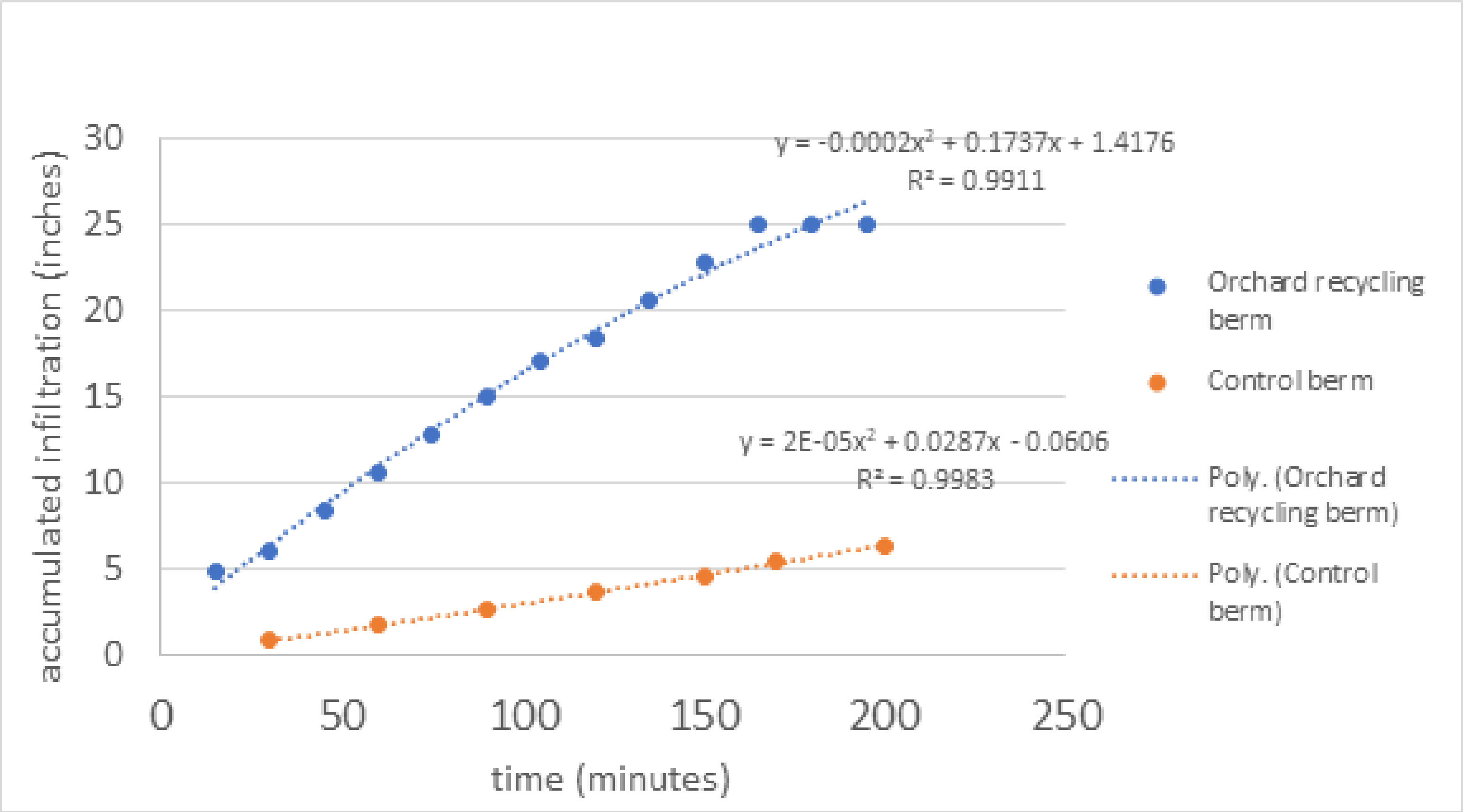
Almond yield after WOR same or better than control with no N rate effect





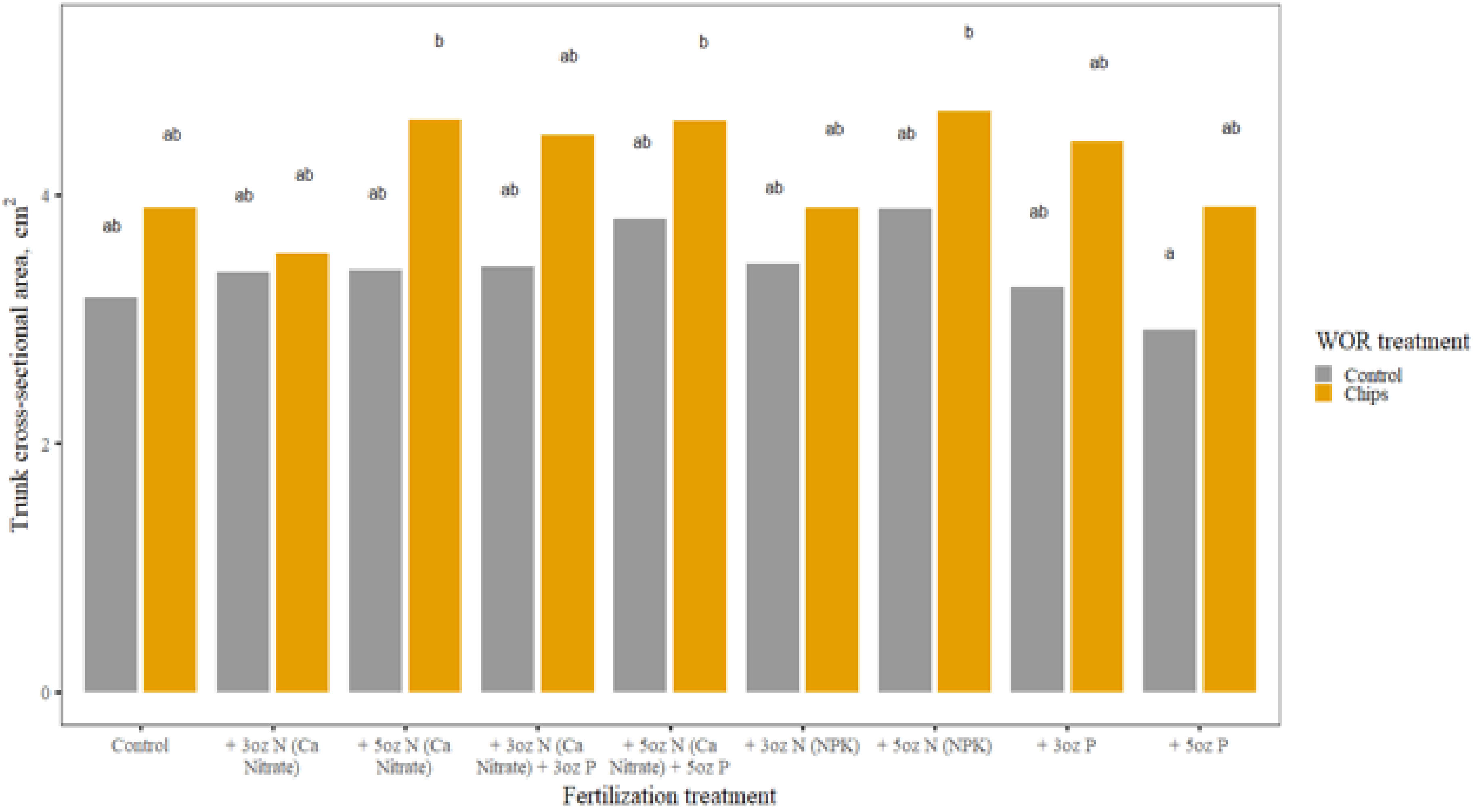
A 42% increase in soil moisture by volume was observed in WOR treatments (17% VWC) compared to the control (11% VWC) during the 2019-2020 dormant period in the top 30 cm


y = -0.0002x² + 0.1737x + 1.4176
R² = 0.9911
y = 2E-05x² + 0.0287x - 0.0606
R² = 0.9983
accumulated infiltration (inches)
30
25
20
15
10
5
0
0
50
100
150
200
250
time (minutes)
Orchard recycling berm
Control berm
Poly. (Orchard recycling berm)
Poly. (Control berm)

Walnut Orchard Recycling can produce up to 100 tons of recycled wood chips per acre

You may have to use a plow or roto-tiller….

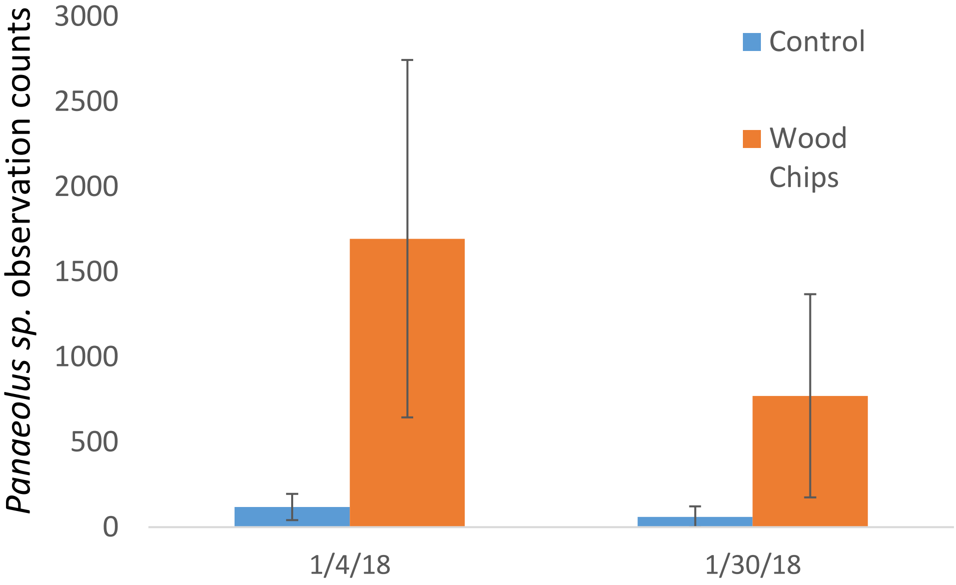
Walnut fertilization trial after WOR in 2024



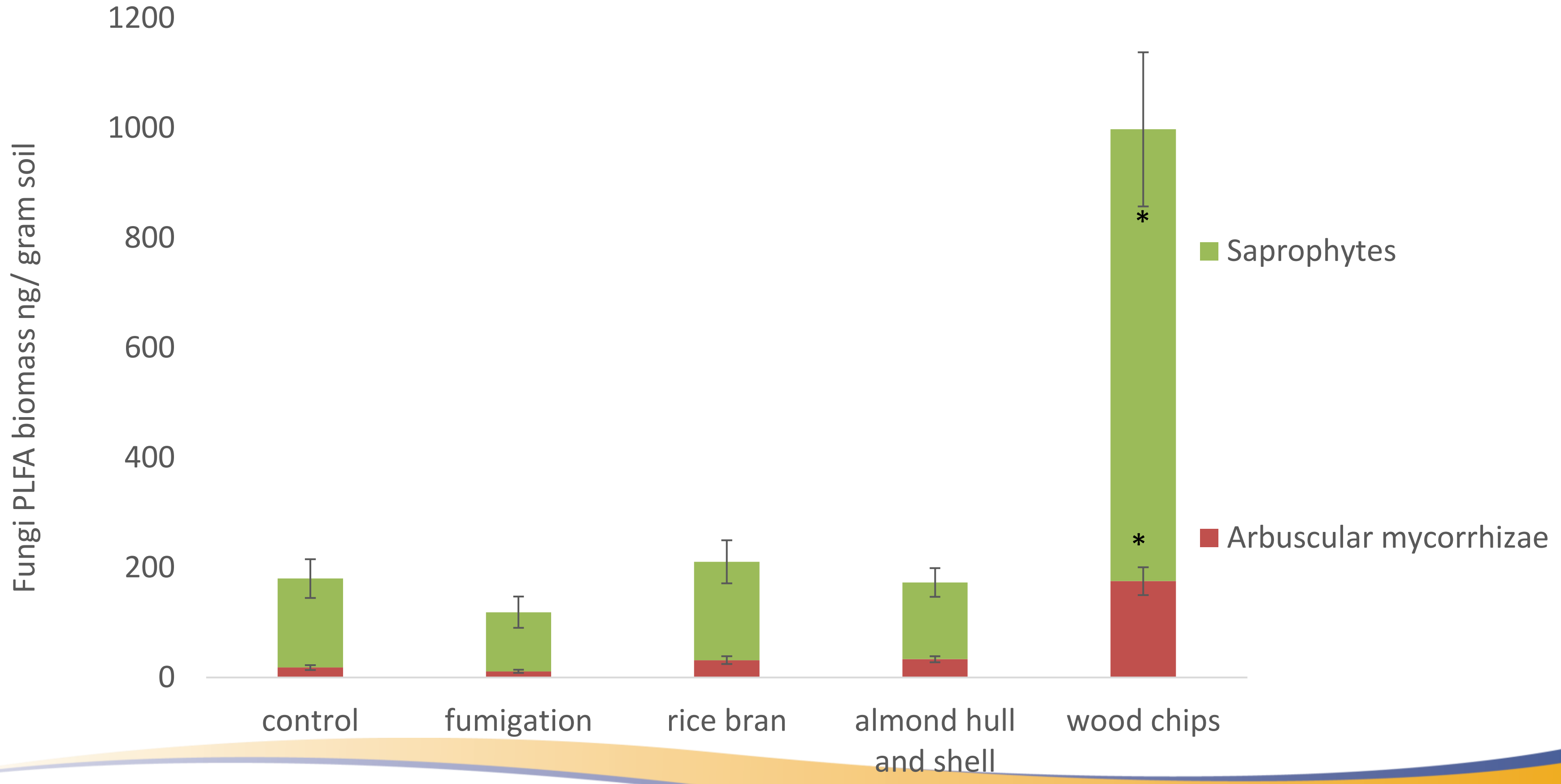
Trunk cross-sectional area, cm²
0
2
4
ab
ab
ab
ab
ab
b
ab
ab
ab
b
ab
ab
ab
b
ab
ab
a
ab
Control
+ 3oz N (Ca Nitrate)
+ 5oz N (Ca Nitrate)
+ 3oz N (Ca Nitrate) + 3oz P
+ 5oz N (Ca Nitrate) + 5oz P
+ 3oz N (NPK)
+ 5oz N (NPK)
+ 3oz P
+ 5oz P
Fertilization treatment
WOR treatment
Control
Chips

Trunk cross sectional area (cm2)

TreatmentWOR	TreatmentFert	emmean	.group	SE	df	lower.CL	upper.CL
Control	+ 5oz P	2.92	a	0.48	1.99	-6.18543218	12.01666063
Control	Control	3.18	ab	0.44	1.45	-17.33162356	23.6849569
Control	+ 3oz P	3.25	ab	0.48	1.94	-6.311414941	12.81558161
Control	+ 3oz N (Ca Nitrate)	3.38	ab	0.48	1.94	-6.186414941	12.94058161
Control	+ 5oz N (Ca Nitrate)	3.40	ab	0.48	1.94	-6.165164941	12.96183161
Control	+ 3oz N (Ca Nitrate) + 3oz P	3.42	ab	0.48	1.94	-6.143081608	12.98391494
Control	+ 3oz N (NPK)	3.45	ab	0.48	1.94	-6.117664941	13.00933161
WOR	+ 3oz N (Ca Nitrate)	3.51	ab	0.50	2.09	-4.991930691	12.00372336
Control	+ 5oz N (Ca Nitrate) + 5oz P	3.81	ab	0.48	1.94	-5.755581608	13.37141494
WOR	Control	3.87	ab	0.47	1.58	-12.63618802	20.36939869
WOR	+ 3oz N (NPK)	3.87	ab	0.50	2.09	-4.624515628	12.37113842
WOR	+ 5oz P	3.88	ab	0.50	2.09	-4.619291154	12.37379413
Control	+ 5oz N (NPK)	3.88	ab	0.48	1.94	-5.683081608	13.44391494
WOR	+ 3oz P	4.40	ab	0.50	2.09	-4.0960473	12.89960675
WOR	+ 3oz N (Ca Nitrate) + 3oz P	4.45	ab	0.50	2.13	-3.695863268	12.60171043
WOR	+ 5oz N (Ca Nitrate) + 5oz P	4.57	ab	0.50	2.13	-3.576859585	12.72071411
WOR	+ 5oz N (Ca Nitrate)	4.58	ab	0.50	2.09	-3.917271447	13.0783826
WOR	+ 5oz N (NPK)	4.65	b	0.50	2.09	-3.850794447	13.1448596



Panaeolus sp. observation counts
3000
2500
2000
1500
1000
500
0
Control
Wood Chips
1/4/18
1/30/18



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- If wood debris is in contact with soil it stays moist and is rapidly colonized by fungal mycelium that binds organic matter (woody aggregates) with inorganic matter, forming soil aggregates.

Root Health

Mulching
to
Control Root Disease
in
Avocado and Citrus

by

Jerrold Turney
John Menge

Department of Plant Pathology
University of California, Riverside

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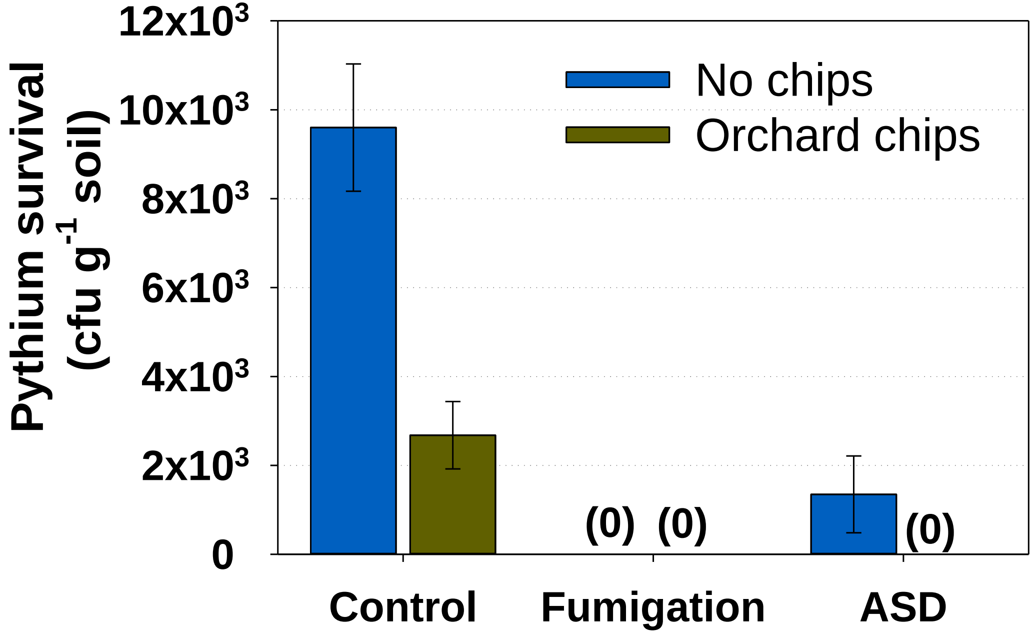
December 1994

Kern County WOR trial 2016-17

Effects of WOR x fumigation vs. ASD treatments on *Pythium ultimum* in preplant bioassay, 3371 trial, Shafter



H. L. Ypema and R. E. Gold
BASF Corporation, Research Triangle Park, NC

KRESOXIM-METHYL

MODIFICATION OF A NATURALLY OCCURRING COMPOUND TO PRODUCE A NEW FUNGICIDE

Historic Perspective

Fungi have been competing with man for crop yields since early crop cultivation. Discovery of the fungicidal effects of lime-sulfur and Bordeaux mixture more than 100 years ago was the precursor of modern fungicide development. Modern methods of fungicide screening rely on random testing of numerous chemical analogs against representative pathogens on their respective host plants to identify lead molecules for fungicide synthesis (18,70). Far less than 0.01% of the chemicals synthesized and randomly screened in this manner reach the market (18). An emerging alternative to random chemical synthesis is the study and exploitation of naturally occurring products with fungicidal properties to identify such lead molecules.

In nature, organisms may possess specialized survival mechanisms, which may be physical, such as spines and thick walls, or chemical, such as toxins or substances with attractive or repellent qualities. Years ago, researchers began to investigate naturally occurring compounds with fungicidal properties. Griseofulvin, isolated from *Penicillium griseofulvum*, showed early promise against several plant pathogens, but its use was discontinued in 1975 due to its high cost for agricultural use (112). During the 1960s and 1970s, Japanese researchers isolated and developed antibiotics (blasticidin-S, kasugamycin, polyoxin, and validamycin) from *Streptomyces* spp. for disease control in rice (18,112). Cycloheximide, isolated from *S. griseus*, has fungicidal activity against a wide range of fungi, but it often demonstrated phytotoxicity. Its use was discontinued in 1981 (112).

Phenylpyrroles, used as seed treatments, are a new class of fungicides based on the lead structure pyrrolnitrin, a secondary metabolite of *Pseudomonas pyrocina* and other pseudomonads (70). Several compounds have been isolated from inconspicuous woodland basidiomycetes. The best known examples are oudemansin and strobilurin A, produced by *Oudemansiella mucida* and *Strobilurus tenacellus* (Fig. 1). These compounds, hereafter referred to as strobilurins, presumably inhibit the establishment of competing fungi on substrates utilized by *O. mucida* and *S. tenacellus*. Several agrochemical companies have developed synthetic strobilurins using these natural strobilurins as lead molecules. Some of these synthetic compounds are now marketed as members of a new class of agricultural fungicides. This article focuses on this interesting class of compounds, with primary emphasis on the evolution, characteristics, and potential benefits of kresoxim-methyl, a representative member of the strobilurin fungicides.

Nomenclature

Sauter et al. (77,78) proposed using the name "strobilurins" for all natural and synthetic members of this new class of fungicides based on the most simple, natural lead molecule, strobilurin A, from which the structural variations are derived. The original name for the group was β-methoxyacrylates, or β-MOAs, based on the structure of the toxophore, the active part of the molecule. Other molecules have since been synthesized with the same mode of action and a toxophore structure similar to strobilurin A, but not containing the β-MOA moiety. Therefore, compounds that will be discussed in later sections, such as those with enol ether ester toxophores (which are β-methoxyacrylates) and those with oxime ether ester toxophores, will all be referred to by the umbrella term "strobilurins."

Fungicide Resistance

The strobilurins and other novel active ingredients play increasingly important roles in managing the development of fungicide resistance. Many fungi have developed resistance to fungicides that once controlled them due to the fact that many fungicides are single-site inhibitors of fungal metabolism (25,31). For instance, this has been confirmed recently for members of the class of demethylation inhibitors (DMI fungicides) in the economically important pathogens *Venturia inaequalis*, which causes apple scab (45,47), and *Uncinula necator*, which causes grape powdery mildew (29,116). Thus, the possibility of fungicide resistance should be considered when a disease management program is set in place. Individuals that

Fig. 1. ***Strobilurus tenacellus*, an important basidiomycete from which natural strobilurins were isolated.**

Dr. Ypema's address is: BASF Corporation, 26 Davis Drive, P.O. Box 13528, Research Triangle Park, NC 27709.

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Publication no. D-1999-1106-01F

Strobilurin fungicides were compounds that *Strobilurus tenacellus* produced QoI (quinone outside inhibitors:

Pristine
Abound
Gem
Quadris Top
Luna Sensation
Quilt Xcel

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Research Article

Non-chemical control of *Armillaria mellea* infection of *Prunus persica*

Jim Downer* and Ben Faber

University of California, Cooperative Extension, 669 County Square Drive Suite 100 Ventura CA, 93003, USA

***Address for Correspondence:** Jim Downer, University of California, Cooperative Extension, 669 County Square Drive Suite 100 Ventura CA, 93003, USA, Tel: 805 825 9081; Email: ajdowner@ucanr.edu

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Keywords: *Armillaria mellea*; Yardwaste; Trichoderma; Planting hole; Peach; *Prunus persica*

Abstract

Peaches, *Prunus persica* were planted as grafted saplings in an avocado orchard previously infested with *Armillaria mellea* (Vahl) P.Kumm. Trees were planted in large or small holes with or without fresh yardwaste chips added as an amendment and with or without a Trichoderma biocontrol product sprayed into the hole. Trees were monitored for six years -- growth and mortality was tabulated. Six years later 40% of the trees had died from the disease. Trees planted in a large hole were more likely to survive than in a smaller hole (P=0.07) and trees in large holes with fresh organic matter added were the most likely to survive (P=0.04). *Trichoderma* sprays in the planting hole did not increase survival rates. While growth was initially retarded by adding fresh yardwaste to the hole, in later years none of the treatments affected growth rates.

Introduction

Armillaria mellea is the pathogen that causes root rot of many forest and ornamental and agronomic trees. [1,2]. The pathogen occurs in landscapes and urban soils as well as a natural pathogen in forests and on lands converted to farming. While symptoms can appear suddenly, it is generally considered a slowly developing pathogen that takes years to kill a tree. When infected trees begin to die and are removed from orchards the fungus rapidly colonizes the remaining roots and resides in soil as potential inoculum for trees planted later (Raabe, 1965).

Armillaria is difficult to control. Fungicides are not effective and even the most

Armillaria mellea-Oak Root Rot

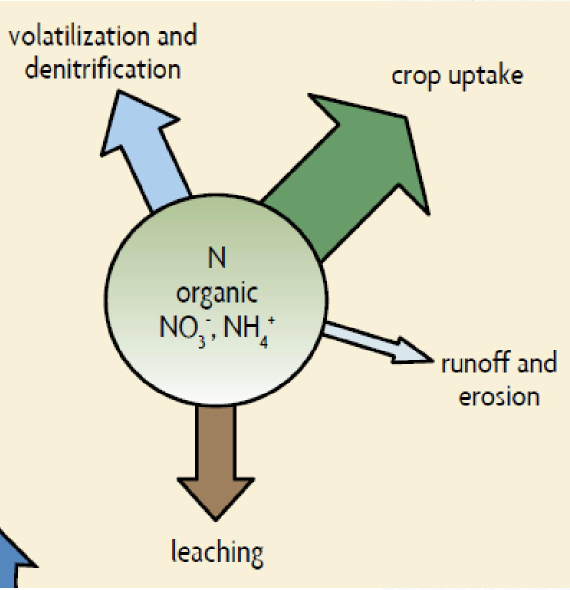
Image 1: Dead peach tree in conventional hole, fully girdled by *Armillaria mellea*. Healthy peaches in the background. Note old stump (left of dyeing peach) of Avocado that had previously died of *Armillaria* serving as inoculum source.

Table 1: Percent Survival from *Armillaria* infection.

	Treatment factor					
	Hole Size		Yardwaste		*Trichoderma*	
	Large hole	Small hole	+	-	+	-
Live[1]	24	3	14	13	13	14
Dead	12	6	4	14	5	13
% survival[2]	66a	33b	78a	48b	72	50
Chi-Square[3]; and P value	3.28; P=0.070		4.11; P=0.043		1.91; P=0.167	

[1] Numbers in rows are live and dead tree counts for each category from 2010.
[2] Percent survival is the percent surviving infection in each column. Letters signify significant differences (P< 10% for Hole size and P<5% for Yardwaste) according to binary logistic regression
[3] Chi-square and P values for the regression model respectively for each treatment variable (column)

may not be evenly distributed in a field, condition may vary in the area under study and edaphic factors can vary or change during the course of study. We were fortunate in this study to have a field with an even distribution of dead trees, their stumps left in the ground to serve as inoculum for our newly planted peach trees. We planted as many



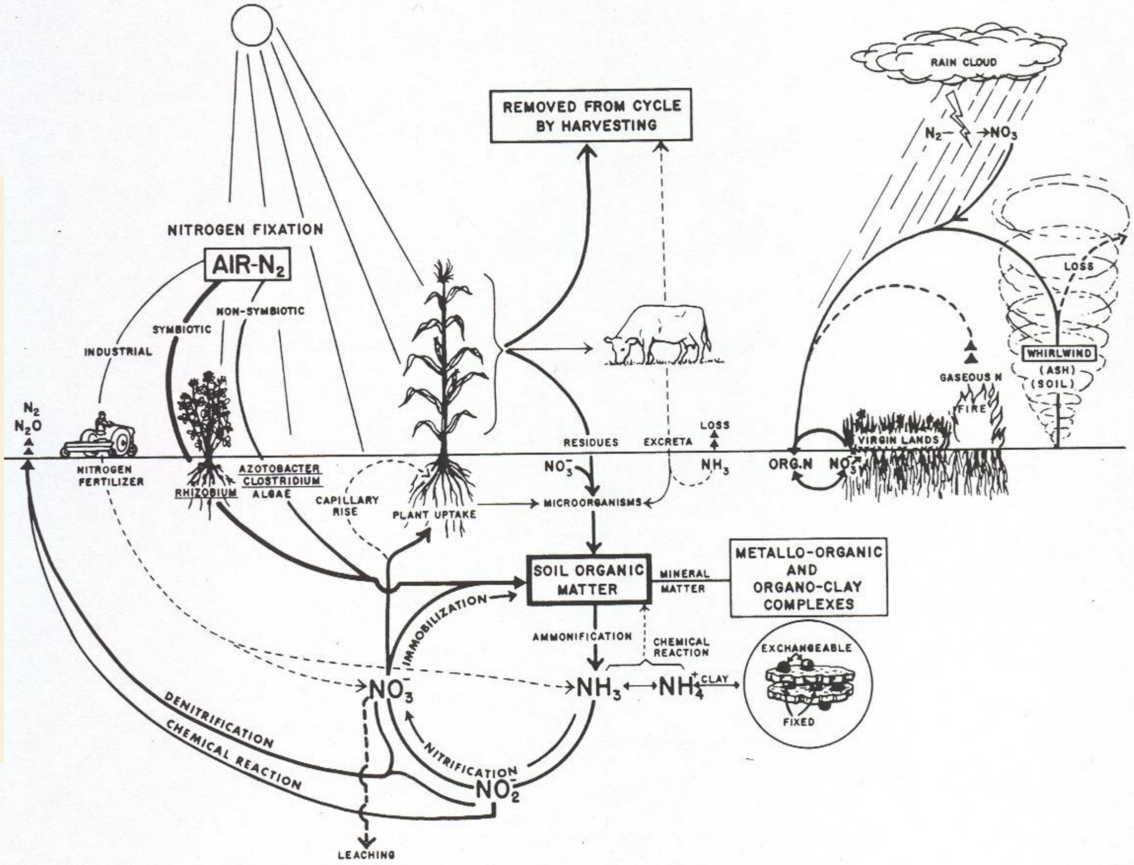


Figure 8.1. Nitrogen cycle in soil. (From Stevenson, 1982.)

San Joaquin Valley Air Pollution Control District

$185 million since 2018

University of C
Agriculture and Nat

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%**

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.

Blue Diamond Almond Growers received a $40 M Climate Smart Grant to help growers with WOR and cover cropping.

WOR Co-Investigators:

Catherine Culumber, Ph.D., Farm Advisor, UCCE in Fresno County, cmculumber@ucanr.edu

Suduan Gao, Ph.D., Soil Scientist, USDA-ARS in Fresno, Suduan.Gao@ars.usda.gov

Amisha Poret-Peterson, Ph.D., Microbiologist, USDA-ARS, UCD, aporetpeterson@ucdavis.edu

Greg Browne, Ph.D., Research Plant Pathologist, USDA-ARS, UCD, gtbrowne@ucdavis.edu

Amélie CM Gaudin, Ph.D., Assistant Professor, Agroecology, UCD, Plant Science, agaudin@ucdavis.edu

Emad Jahanzad, Ph.D., Senior Environmental Scientist, CDFA, Emad.Jahanzad@cdfa.ca.gov

Amanda Hodson, Ph.D., Assistant Professor, Entomology and Nematology, UC Davis,

Cameron Zuber, Farm Advisor, UCCE Merced County, cazuber@ucanr.edu

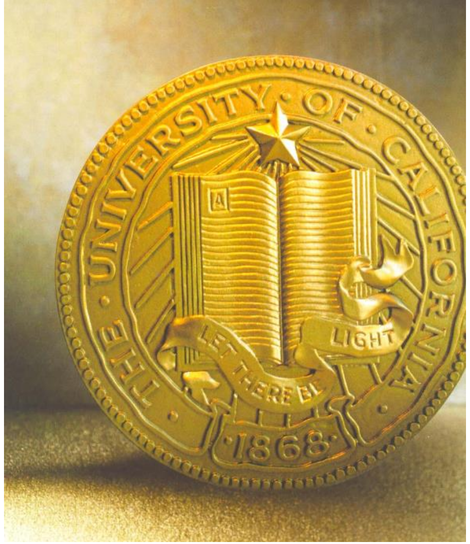
Astrid Volder, Ph.D., Professor, Plant Sciences, UCD, avolder@ucdavis.edu

David Doll, ex-Farm Advisor, Rua Dordio Gomes, daviddoll01@gmail.com

Franz Niederholzer, Ph.D., Farm Advisor, UCCE in Colusa/Sutter/Yuba Counties, fjniederholzer@ucanr.edu

Mohammad Yaghmour, Ph.D., Farm Advisor, UCCE in Kern County, mayaghmour@ucanr.edu

Phoebe Gordon, Ph.D., Farm Advisor, UCCE in Madera County, pegordon@ucanr.edu



Thank You!

cdfa
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