Orchard Renewal: Lesson Learned from California

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18th Australian Almond Conference
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Thank you for the invitation to speak at the:

18th Australian Almond Conference

October 30th - November 1st, 2018

WHOLE ALMOND ORCHARD RECYCLING AND THE EFFECT ON SECOND GENERATION TREE GROWTH, YIELD, AND FERTILITY

***Holtz, B.*[1], Browne, G.[2], Doll, D.[3], Lampinen, B.[4], Gaudin, A.[4], Culumber, M.[5], Yaghmour, M.[6], Gordon, P.[7], and Jahanzad, E.[4]**

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Sponsored by the Almond Board of California and the California Department of Food and Agriculture

University *of* California
Agriculture and Natural Resources

This project evolved from farming on the urban edge

Are these wood chips effecting soil nutrients and the microbial community of almond soils?

Wood chipped vs Non-chipped

Wood chipped almond orchard soils were sampled and compared to non-wood chipped orchards

Wood chipped vs Non-chipped Orchard

Wood chipped almond orchards:

- more wood rotting basidiomycetes
- more bacterial and fungal feeding nematodes
- Increased soil nutrient levels
- lower pH
- more organic matter, higher soil carbon

Burning before the clean air act

Grinding orchards for co-generation plants

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?

- When we remove an orchard we grind up 25-30 years worth of photosynthesis and carbon and nutrient accumulation and haul it away. 25-30 years of organic matter is lost from our system, estimated at 60 tons per acre for almond.


The Iron Wolf

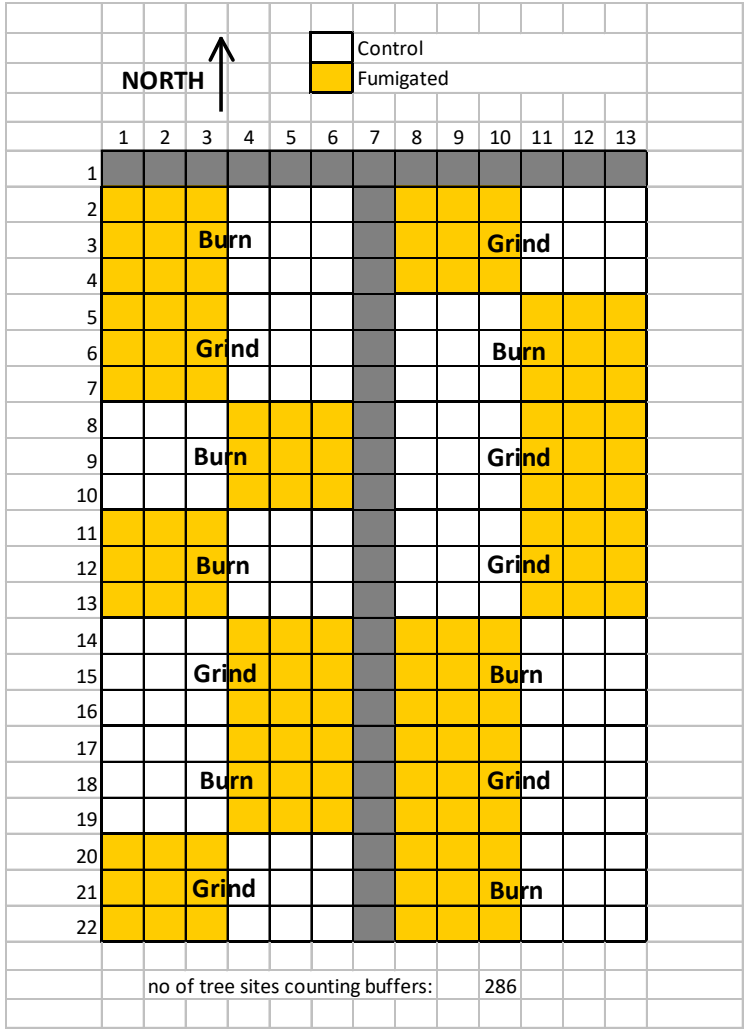
http://ucanr.edu/?blogpost=16603&blogasset=74534

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


The Iron Wolf

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.


NORTH
Control
Fumigated
1 2 3 4 5 6 7 8 9 10 11 12 13
1
2
3 Burn Grind
4
5
6 Grind Burn
7
8
9 Burn Grind
10
11
12 Burn Grind
13
14
15 Grind Burn
16
17
18 Burn Grind
19
20
21 Grind Burn
22
no of tree sites counting buffers: 286

2009 First leaf trees growing in grinding plot

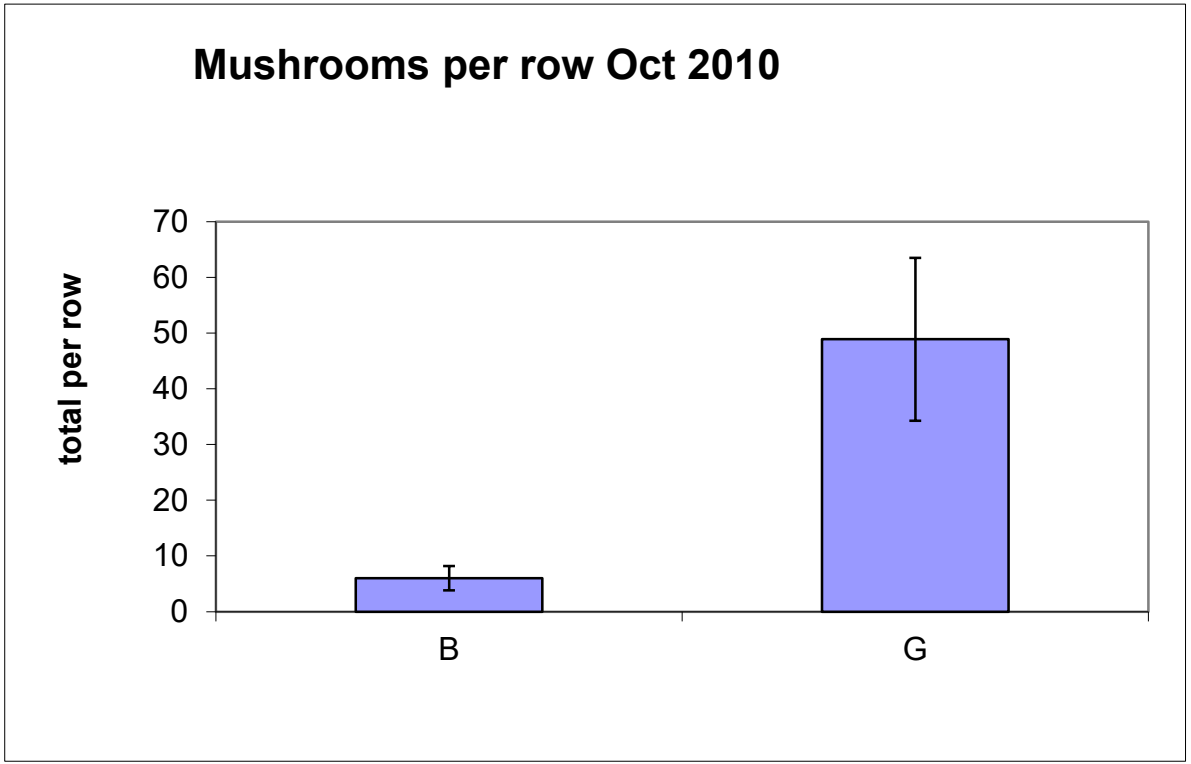
2010 Second leaf trees

No difference in tree circumference

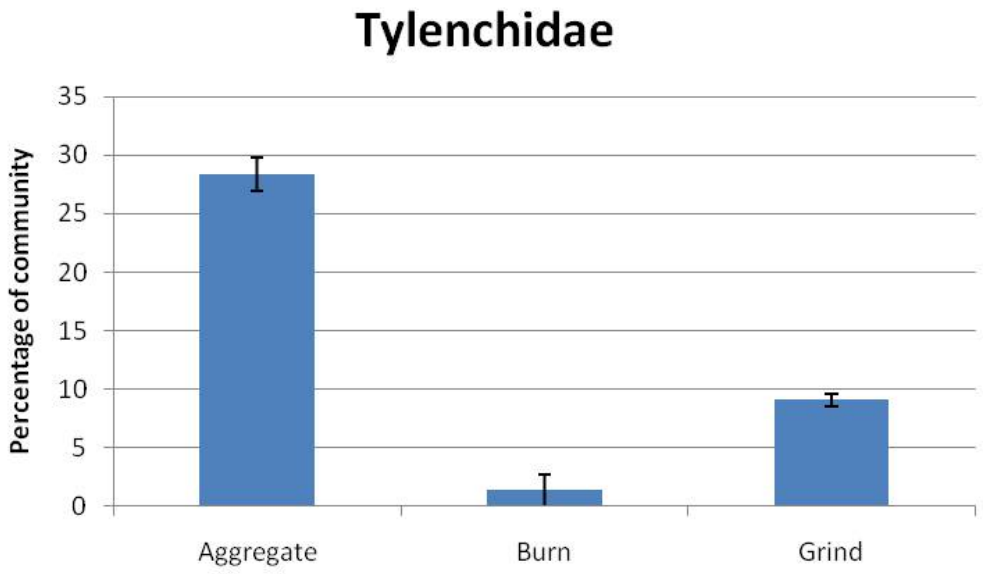
The Grinding did not stunt the second generation orchard

2011 Third leaf trees growing in grinding plot

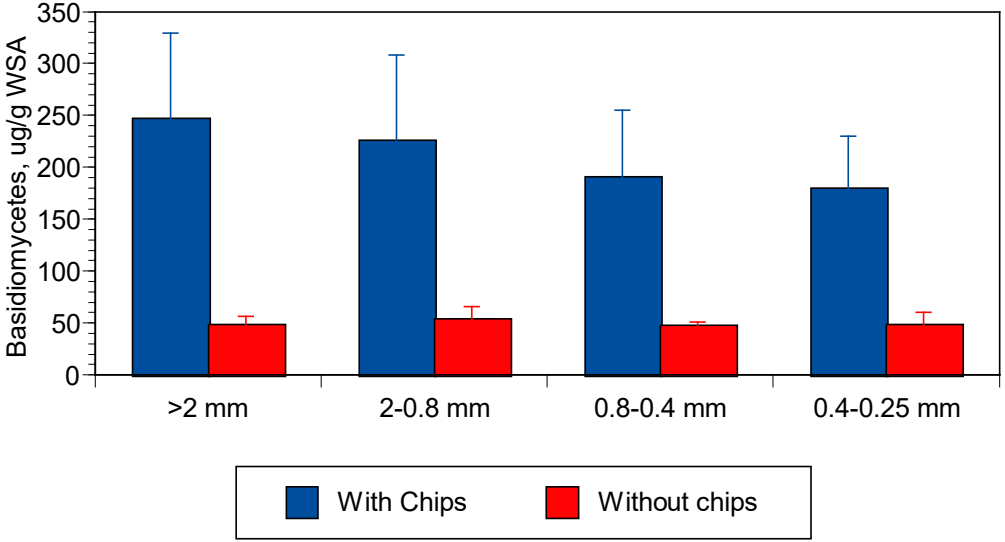
2012 Fourth leaf trees growing in grinding plot


Mushrooms per row Oct 2010
total per row
70
60
50
40
30
20
10
0
B
G

Significantly greater Tylenchidae were observed in the grind plots, especially next to woody aggregates. Nematode species of the family Tylenchidae feed on algae and fungi and are not parasitic to trees.

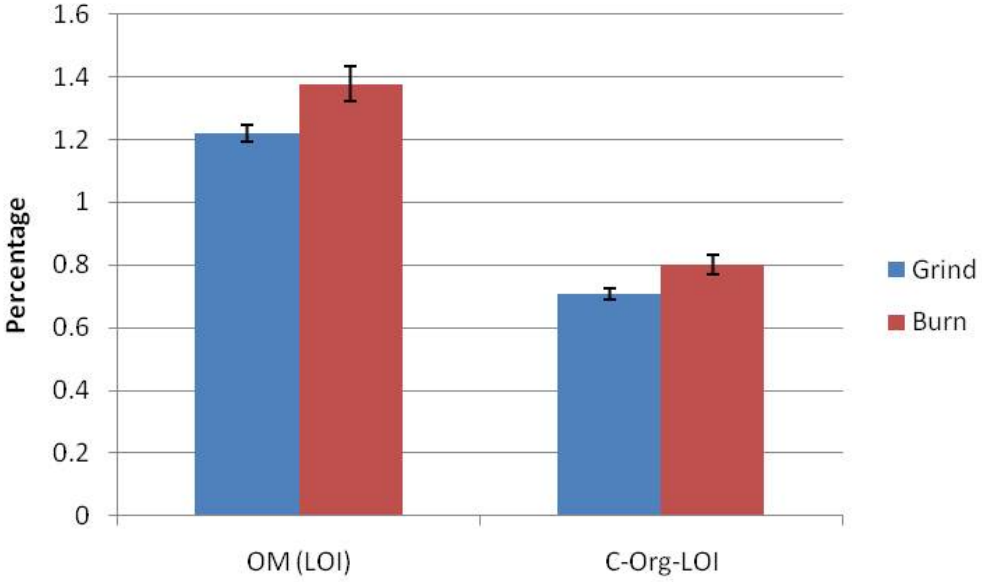


Experiment on field plots amended or not with wood chips.
Soil aggregating basidiomycete amount in water stable aggregates (WSA) retrieved from the top surface layer



The wood debris is rapidly colonized by fungal mycelium after making contact with moist soil.

In 2010, Burn treatments had significantly more organic matter (OM), carbon (C), and Cation Exchange Capacity (CEC) in the top 10-15 cm of soil.



Burning appears to release nutrients back into the orchard soil more rapidly than decomposition.

Soil Analysis

	2010		2011		2012	
	Grind	Burn	Grind	Burn	Grind	Burn
Ca (meq/L)	4.06 a	4.40 b	2.93 a	3.82 b	4.27 a	3.17 b
Na (ppm)	19.43 a	28.14 b	13.00 a	11.33 b	11.67 a	12.67 a
Mn (ppm)	11.83 a	8.86 b	12.78 a	9.19 b	29.82 a	15.82 b
Fe (ppm)	32.47 a	26.59 b	27.78 a	22.82 b	62.48 a	36.17 b
Mg (ppm)	0.76 a	1.52 b	1.34 a	1.66 a	2.05 a	1.46 b
B (mg/L)	0.08 a	0.07 a	0.08 a	0.08 a	0.08 a	0.05 b
NO_3-N (ppm)	3.90 a	14.34 b	8.99 a	11.60 a	19.97 a	10.80 b
NH_4-N (ppm)	1.03 a	1.06 a	2.68 a	2.28 a	1.09 a	1.06 a
pH	7.41	7.36	6.96 a	7.15 b	6.78 a	7.12 b
EC (dS/m)	0.33 a	0.64 b	0.53	0.64	0.82 a	0.59 b
CEC(meq/100g)	7.40 a	8.47 b	8.04	7.88	5.34	5.32
OM %	1.22 a	1.38 b	1.24	1.20	1.50 a	1.18 b
C (total) %	0.73 a	0.81 a	0.79 a	0.73 a	0.81 a	0.63 b
C-Org-LOI	0.71 a	0.80 b	0.72	0.70	0.87 a	0.68 b
Cu (ppm)	6.94 a	6.99 a	7.94 a	7.54 a	8.87 a	7.92 b

Blue Pair = grinding significantly less than burning

Yellow pair = grinding significantly greater than burning

Soil Analysis

	2013		2014		2015	
	Grind	Burn	Grind	Burn	Grind	Burn
Ca (meq/L)	3.78 a	3.25 b	7.55 a	5.45 b	4.02 a	1.36 b
Na (ppm)	2.74 a	1.90 b	3.41 a	2.34 b	2.32 a	1.21 b
Mn (ppm)	26.35 a	5.71 b	14.46 a	10.65 b	7.31 a	4.67 b
Fe (ppm)	32.56 a	20.38 b	38.58 a	29.30 b	24.29 a	17.21 b
Mg (ppm)	2.15 a	1.20 b	3.61 a	2.57 b	2.01 a	0.68 b
B (mg/L)	0.06	0.07	0.07 a	0.10 b	0.05 a	0.07 b
NO_3-N (ppm)	20.11	12.27	26.53 a	18.89 b	20.64 a	5.23 b
NH_4-N (ppm)	0.37	0.33	1.59 a	1.36 b	0.89 a	0.65 b
K (mg/L)	94.50	84.88	28.50 a	13.60 b	19.76 a	16.97 b
pH	7.39 a	7.53 b	6.95	7.06	7.27 a	7.60 b
EC (dS/m)	0.91 a	0.68 b	1.54 a	1.08 b	0.90 a	0.38 b
CEC(meq/100g)	9.54	10.16	7.78	8.30	5.16	5.14
OM %	1.55 a	1.06 b	1.21 a	0.93 b	1.37 a	1.08 b
C (total) %	0.87 a	0.51 b	0.71 a	0.54 b	0.66 a	0.50 b
C-Org-LOI	0.87 a	0.61 b	0.70 a	0.54 b	0.79 a	0.62 b
Cu (ppm)	8.26 a	7.11 b	8.03	7.73	7.51 a	7.03 b

Blue Pair = grinding significantly less than burning

Yellow pair = grinding significantly greater than burning

Soil Analysis

	2016		2017		2018	
	Grind	Burn	Grind	Burn	Grind	Burn
Ca (meq/L)	5.53 a	2.66 b	3.02	3.05		
Na (ppm)	1.50 a	1.20 b	0.89 a	0.72 b		
Mn (ppm)	10.86 a	7.66 b	9.03 a	6.79 b		
Fe (ppm)	30.25 a	23.15 b	33.23 a	28.01 b		
Mg (ppm)	2.60 a	1.29 b	1.46	1.43		
B (mg/L)	<0.05	<0.05	0.30	0.31		
NO_3-N (ppm)	13.87 a	10.50 b	11.93	12.66		
NH_4-N (ppm)	1.15 a	0.98 b	1.39	1.31		
K (mg/L)	54.78 a	11.33 b	11.06	11.68		
pH	7.20 a	7.37 b	6.94	7.02		
EC (dS/m)	1.21 a	0.56 b	0.57	0.58		
CEC(meq/100g)	8.35	9.25	8.23	7.78		
OM %	1.41 a	1.10 b	1.52 a	1.07 b		
C (total) %	0.82 a	0.55 b	0.79 a	0.55 b		
C-Org-LOI	0.82 a	0.64 b	0.88 a	0.62 b		
Cu (ppm)	8.43	8.20	9.25	9.25		

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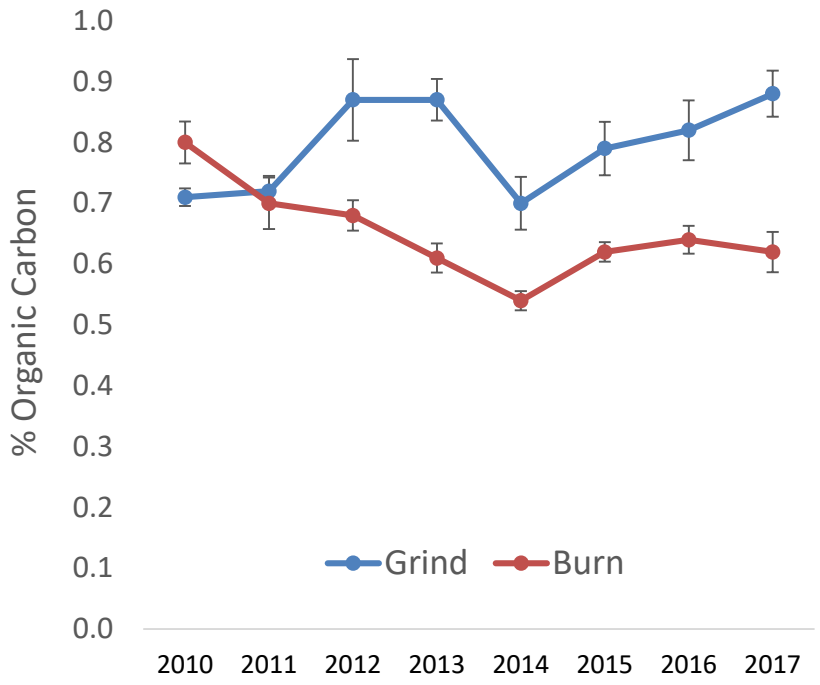
Yellow pair = grinding significantly greater than burning

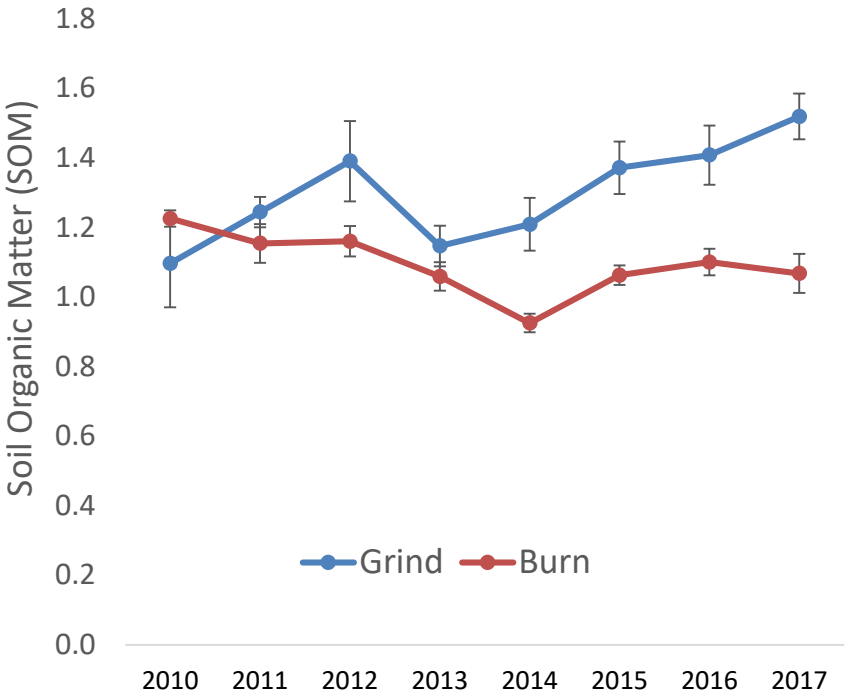
Leaf Analysis

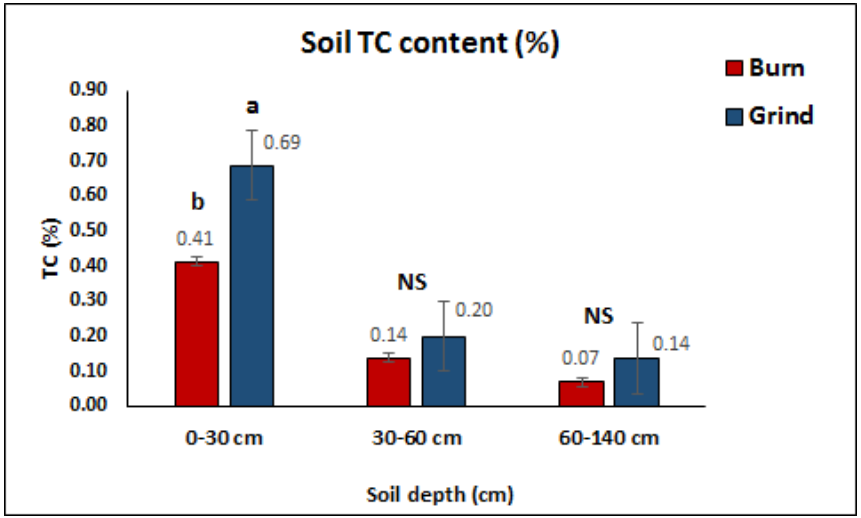
	Nitrogen %		Phosphorus %		Potassium %		Magnesium %		Manganese ppm		Iron ppm		Sodium ppm	
	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn
2010	2.40 a	2.33 b	0.11 a	0.10 b	1.76 a	1.44 b	0.98 a	1.03 b	23.63 a	17.44 b	102.5	104.3	340.5 a	455.5 b
2011	2.58	2.58	0.14	0.14	1.92 a	1.67 b	0.66 a	0.71 b	25.70	24.91	91.34	93.75	19.38 a	54.00 b
2012	2.46	2.44	0.13	0.13	1.14 a	1.02 b	0.87	0.90	20.13	19.13	84.84	83.95	24.88 a	49.50 b
2013	2.57 a	2.49 b	0.112 a	0.106 b	0.94 a	0.73 b	1.04 a	1.12 b	27.83 a	23.25 b	113.59 a	102.79 b	634.6 a	957.5 b
2014	2.40 a	2.33 b	0.11 a	0.10 b	1.76 a	1.44 b	0.98 a	1.03 b	23.63 a	17.44 b	102.5	104.0	340.5 a	455.5 b
2015	2.42	2.39	0.12	0.11	1.66 a	1.43 b	0.97	1.01	23.96 a	17.88 b	142.5	148.22	243.8 a	358.22 b
2016	2.77	2.75	0.14	0.14	1.35 a	1.16b	0.93	0.97	24.46 a	21.58 b	97.09 a	88.20 b	207.1 a	335.38 b
2017	2.57 a	2.50 b	0.12	0.12	1.28	1.20	1.09	1.09	29.23 a	27.11 b	199.50 a	225.63 b	353.50	392.88

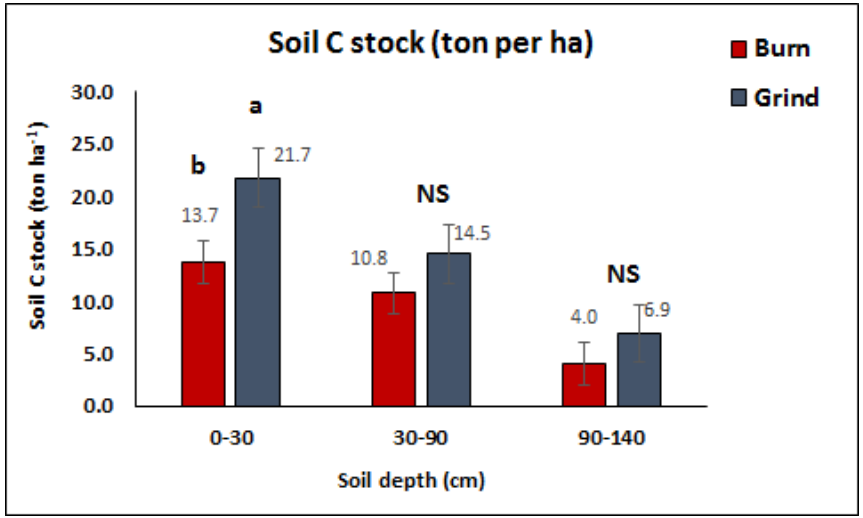
Blue Pair = grinding significantly less than burning

Yellow pair = grinding significantly greater than burning


% Organic Carbon
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2010
2011
2012
2013
2014
2015
2016
2017
Grind
Burn


Soil Organic Matter (SOM)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010
2011
2012
2013
2014
2015
2016
2017
Grind
Burn





WOR increased soil C content by 68% (0-30 cm) compared to the Burn treatment

WOR lead to + 8 tons per ha of C sequestered compared to the burn treatment, 9 years after recycling

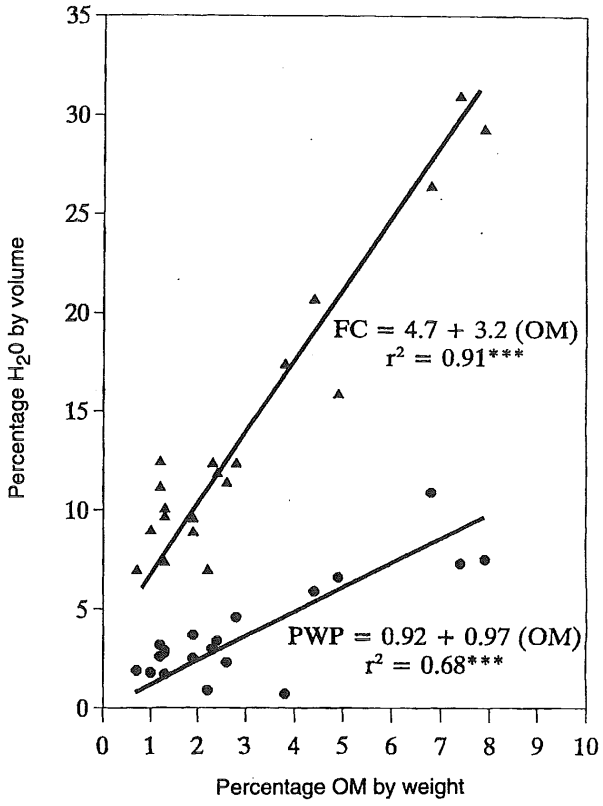
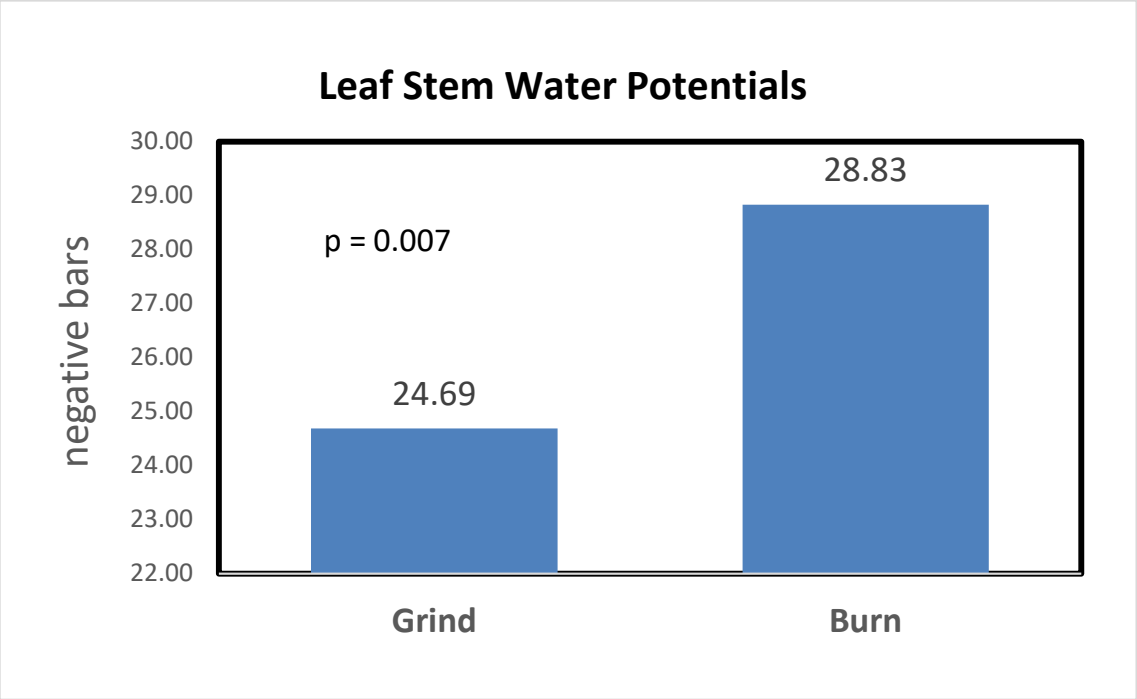


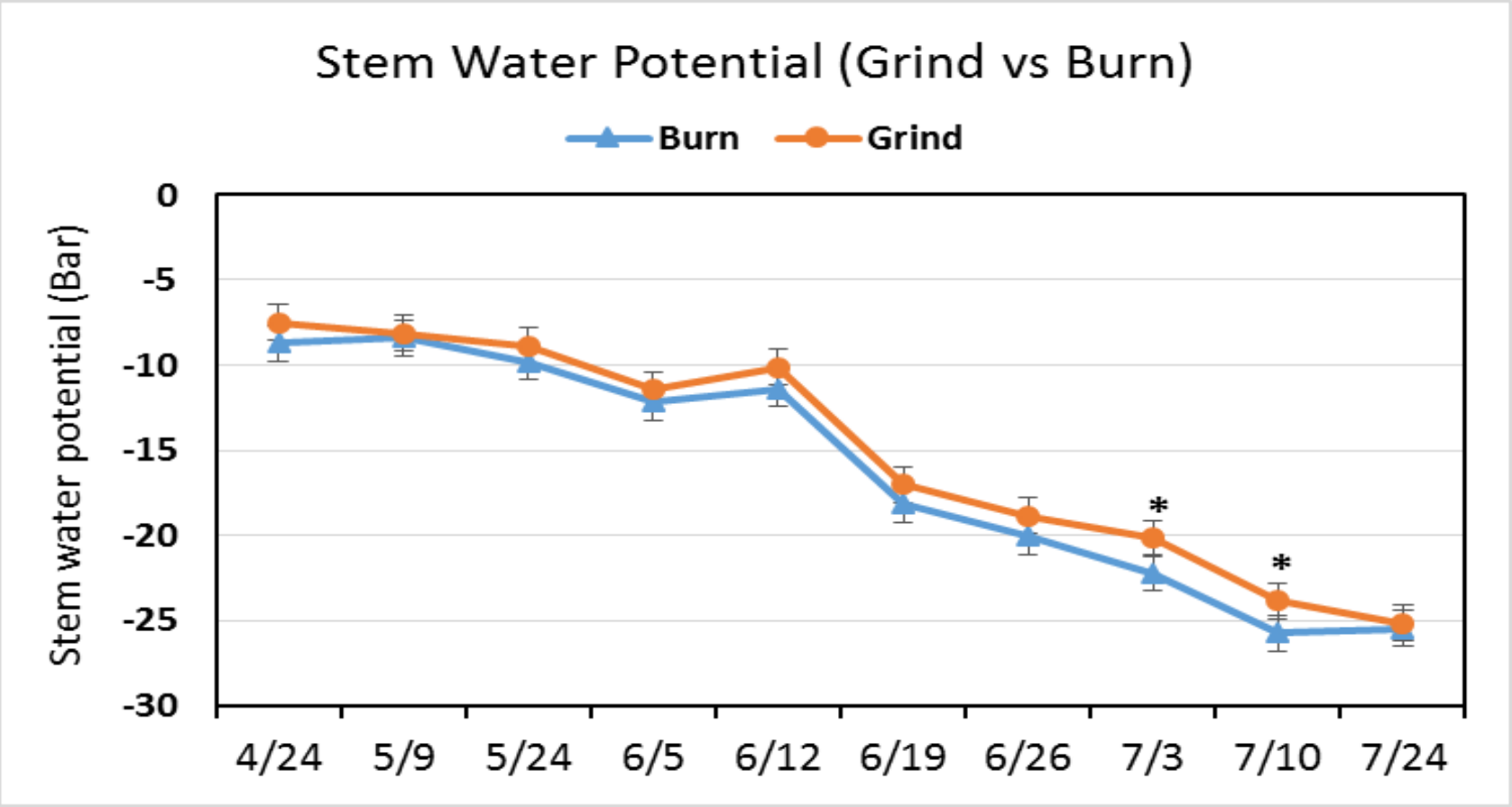
Figure 1. Water content at FC and PWP versus OM content of sand surface horizons.

Soil Organic Matter and Available Water Capacity
by
Berman D. Hudson
J. Soil and Water Cons. 49(2):189-194.

We estimate that Whole Orchard recycling has increased the water holding capacity of our soil by 15% based on this curve and that SOM has increased from in 1.07 (burn) to 1.52 (grind) (2017 results).

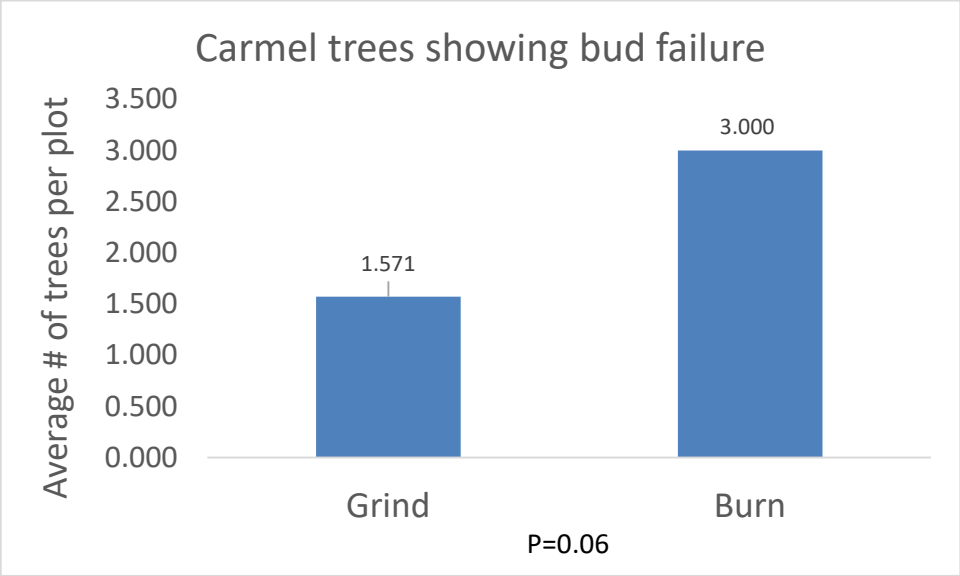


The trial went 57 days without an irrigation during harvest
Trees growing in the grind plots had less water stress

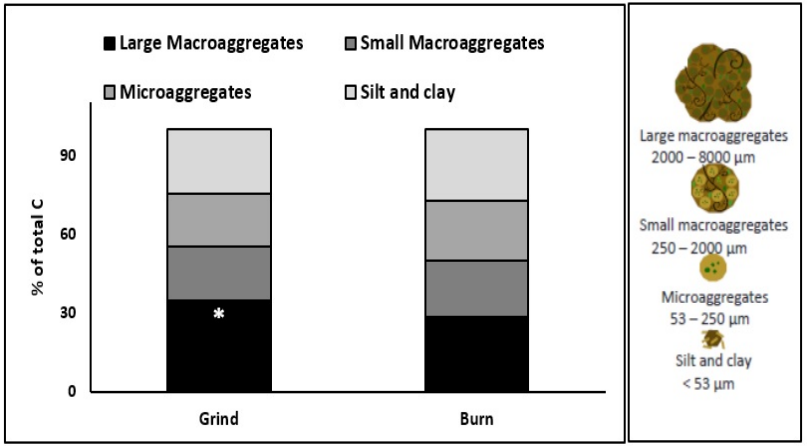

Stem Water Potential (Grind vs Burn)
Burn
Grind
Stem water potential (Bar)
0
-5
-10
-15
-20
-25
-30
*
*
4/24
5/9
5/24
6/5
6/12
6/19
6/26
7/3
7/10
7/24

Carmel trees were rated for bud failure symptoms

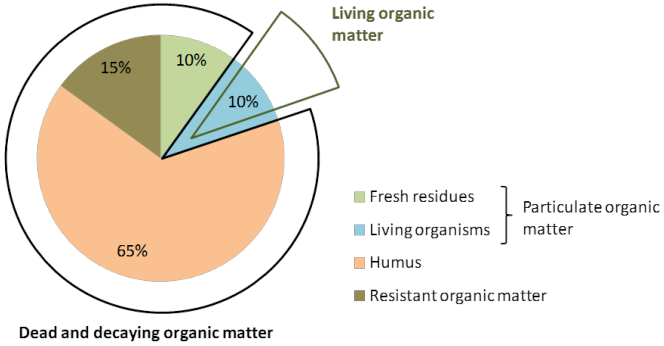
Trees growing in the grind plots had less bud failure



Soil TC storage in soil aggregates



- 14% increase in large macroaggreagate TC storage in the Grind treatment compared to the Burn

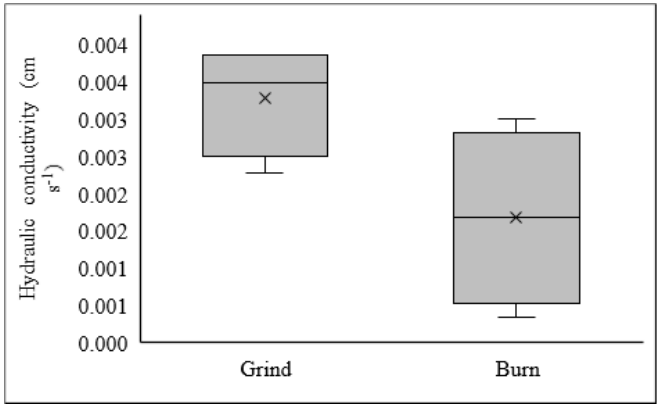


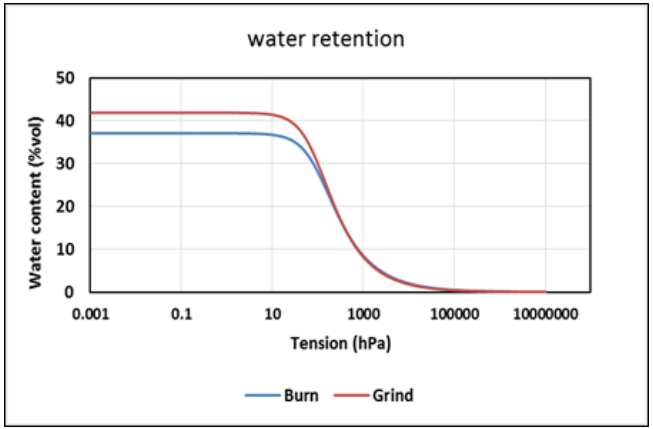
Soil organisms are more abundant and more active

- Soil microbial biomass carbon (MBC) increased (+ 47%)
- Soil microbial biomass nitrogen (MBN) was slightly higher
- Overall, higher N and C cycling enzyme activity rates in the Grind treatment compared to the Burn

Impacts on soil hydraulic properties?

- Improved soil aggregation (significant higher Mean Weight Diameter in the Grind treatment (610 vs 534)
- Compaction was reduced in the Grind plots (- 27%)
- Higher infiltration rate in the Grind treatment (0.003 vs 0.001 cm/s)
- Increased water retention (+ 13% at FC) in the Grind plots





% photosynthetically Active radiation (PAR) light interception

Date	Variety	Treatment	PAR(%)	Yield (kernel lbs/ac)	Yield per unit PAR intercepted
10/16/17	Butte	Grind	56.8 a	2025 a	35.1 a
		Burn	54.3 a	1590 a	29.1 a
10/16/16	Nonpareil	Grind	66.0 a	2268 a	34.3 a
		Burn	61.4 a	1868 a	30.7 a

Trunk Diameter

Butte Variety (cm)

Year	Grind	Burn	P value
2009	4.87	4.96	P= 0.19
2010	14.56	15.22	P=0.07
2011	22.39	22.72	P=0.38
2012	30.53	30.23	P=0.18
2013	38.52	37.73	P=0.09
2014	46.50 a	45.24 b	P=0.01
2015	55.71 a	53.79 b	P=0.01
2016	63.15 a	60.58 b	P=0.007
2017			

Butte Variety, Kernel kilograms/hectare(kg/ha)				
Year	Grind kg/ha	Burn kg/ha	Difference kg/ha	
2011	770.47	770.43	0.04	(P= 0.49)
2012	1,650.26	1,546.05	104.21	(P=0.19)
2013	2,140.32	1869.39	270.93	(P=0.05)
2014	2,546.58	1980.73	565.84	(P=0.12)
2015	1,202.51	983.55	218.96	(P=0.11)
2016	1,504.07	1,352.76	151.31	(P=0.14)
2017	2,192.29	1,725.10	467.18	(P=0.07)
Total	**12,006.49**	**10,227.99**	**1,778.49**	

Nonpareil, kernel kilograms/hectare (kg/ha)

Year	Grind kg/ha	Burn kg/ha	Difference kg/ha
2014	2,406.48	2,194.57	211.89 (P=0.02)
2016	3,162.86	2,674.35	488.50 (P=0.03)
2017	2,518.15	2,098.06	420.08 (P=0.01)
Total	**8,087.49**	**6,966.98**	**1,120.47 kg/ha**

Whole Orchard Recycling has:

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

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,

AgAlert®

THE WEEKLY NEWSPAPER FOR CALIFORNIA AGRICULTURE

A few growers have used manure spreaders to spread wood chips back on the soil surface

Will Whole Orchard Recycling:

- Increase water holding capacity?
- Bind pesticides and fertilizers?
- Increase Nitrogen efficiency?
- Increase/decrease Green House Gas production?
- Provide carbon credits to farmers?

Whole Orchard Recycling

1 UC Kearney Research and Extension Center (KREC) 2008, Fresno County
2 UC Kearney (KREC) Micro-plot study 2016, Fresno County
3 Agriland Farming, Chowchilla, Madera County 2016
4 Wonderful Orchards, Ranch 3371, Kern County 2016
5 Wonderful Orchards, Ranch 3381, Kern County 2016
6 Tallerico Orchards, Manteca, San Joaquin County 2016
7 Warkentin Ranches, Parlier, Fresno County 2017
8 Fresno State, CSUF, Fresno County 2017
9 Nickels Estate, Arbuckle, Colusa County 2017
10 UC Kearney 2018 Experiment

Chowchilla Trial: The Iron Wolf pushes the trees over going forward and grinds up the branches and trunk

Then Iron Wolf goes in reverse and incorporates the wood into the ground. Just one 50 ton machine that costs $1,500 acre to operate. Can do ~2 acres per day.

Whole almond rows after being ground up and incorporated with the Iron Wolf 700 B. Wood distribution is uneven and large chunks are left behind ‘bowling ball pins’

G & F Ag Services orchard removal typically involves 5 machines and costs ~$600 acre

The Morbark horizontal chipper can chip up 15-20 acres per day.

Screens can be used to limit chip size to 2 inches or less.

The Iron Wolf is being compared to this Morbark Chipper at Agriland Farming in Chowchilla.

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

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

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

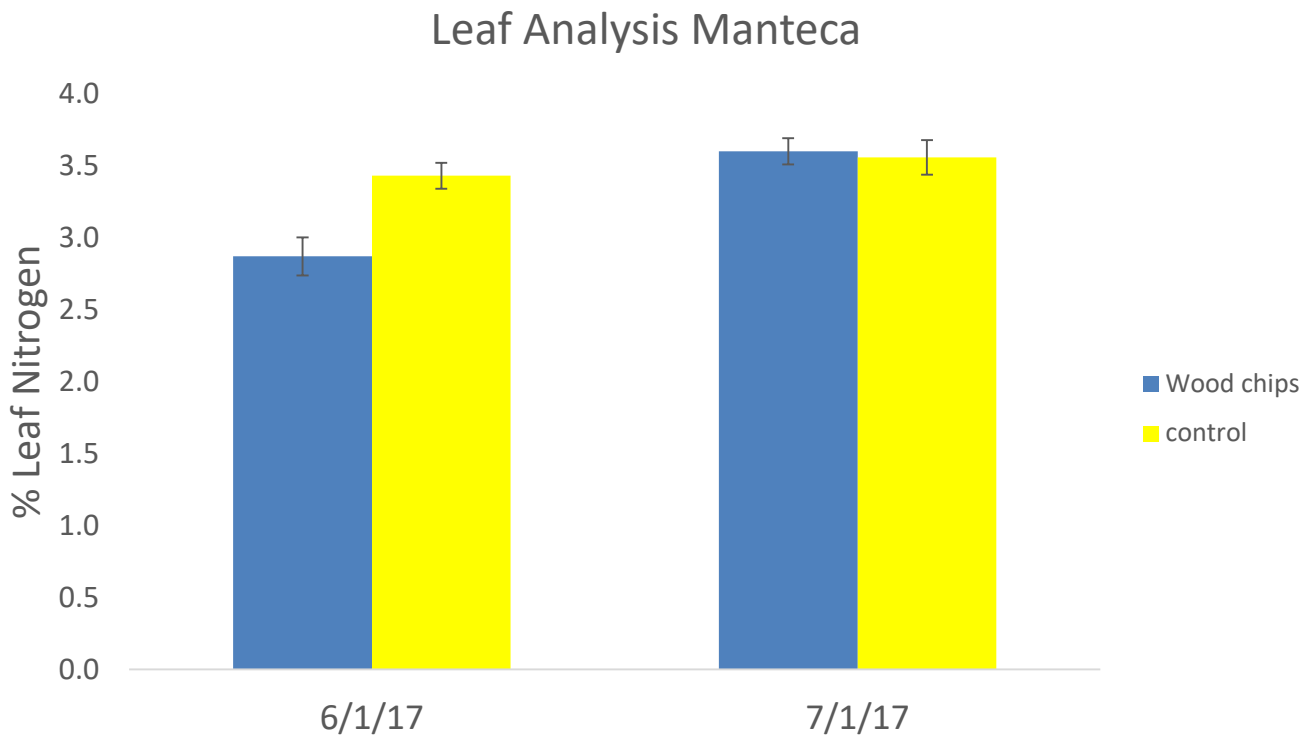

JOHN DEERE

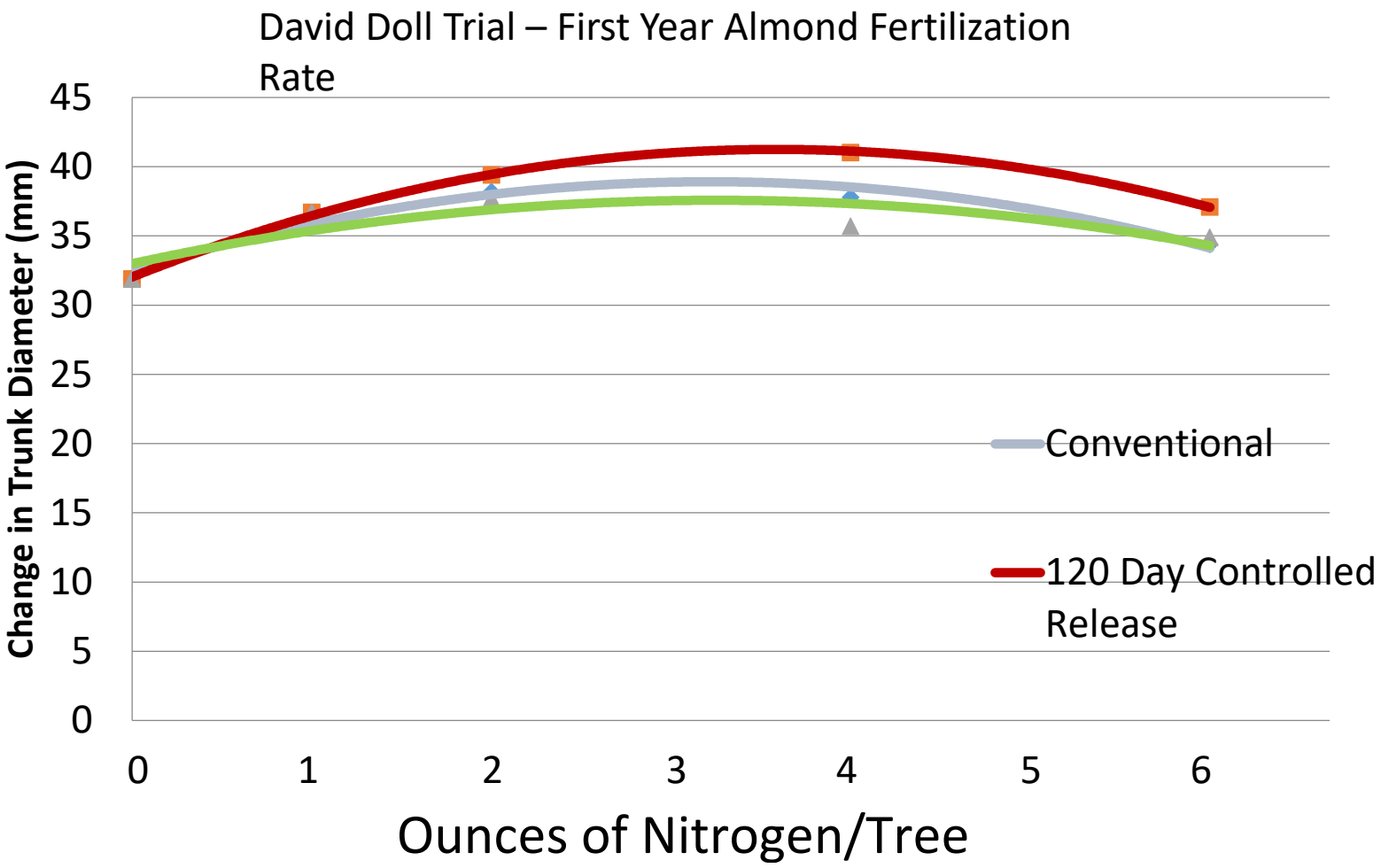
Tallerico Orchard in Manteca:

64 tons per acre

In the portion of the orchard where the wood chip piles were—there was total weed suppression.

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


Leaf Analysis Manteca
% Leaf Nitrogen
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
6/1/17
7/1/17
Wood chips
control


David Doll Trial – First Year Almond Fertilization Rate
Change in Trunk Diameter (mm)
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
Ounces of Nitrogen/Tree
Conventional
120 Day Controlled Release

Control

0.8 oz of N applied in March

	100% efficiency total N oz/tree/year	22% efficiency of UAN 32 total N oz/tree/year
White	8.65	1.91
Blue	12.78	4.31
Yellow	13.98	5.51
Orange	15.18	6.71
Red	16.38	7.91

	100% efficiency total lbs N /acre	22% efficiency total lbs N /acre
White	62.70	13.84
Blue	92.60	31.24
Yellow	101.35	39.94
Orange	110.05	48.64
Red	118.75	57.34

Northwest Tiller
till, level, and roll in one pass

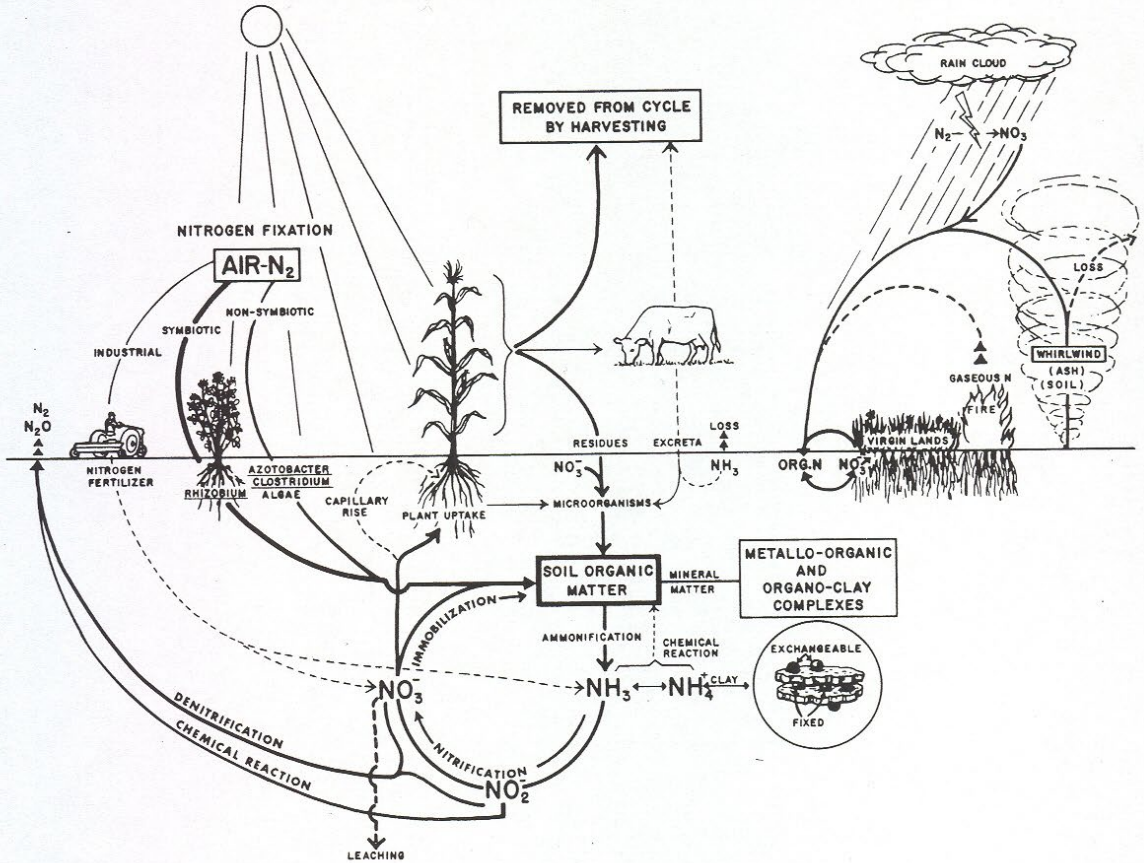


Figure 8.1. Nitrogen cycle in soil. (From Stevenson, 1982.)

This Duratech grinder is mobile and spreads the wood chips evenly as it grinds.

Efficiencies are improved every year that whole orchard recycling is performed.

We estimate that 10,000 hectares have been recycled in CA.


MORBARK
50/48
DRUM CHIPPER
MORBARK
MORBARK

Thank You!

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