

Soil Health Improvements in a Walnut Orchard using Cover Crops

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Objective: To improve infiltration, build organic matter, and reduce runoff in a walnut orchard using four cover crop treatments.

County: San Joaquin Co.

Average Annual Precipitation: 17 in

MLRA: 2

Practice: 340-Cover Crop

Dominant Soil Type: Cogna fine sandy loam

Slope: <1%

Aspect: N/A

Elevation: 98 ft

Site Preparation: None. Drilled into walnut leaf residue.

Seeding Dates: 12/6/2017; 11/19/18; 11/14/19.

Seeding Rates: See Table 1.

Seeding Costs: See Table 1 (Costs are based on 2019 CA pricing).

Seeding Method: Drilled with modified 10 ft grain planter.

Acres Seeded or Plot Design: 2 acres (12 orchard middles).

Previous Site History: Mowing resident vegetation in middles.

Fertilizer: According to walnut orchard nutrient requirements and applied only in tree rows.

Irrigation: Sprinklers in tree rows.



Fig. 1. Field office staff evaluating cover crops in Spring 2018.

Table 1. Species, Rates and Costs of Cover Crop Treatments.

Mix Name	Target Mix Seeding Rate (lb/ac)	Species or cultivar	% Mix	Desired Seeding Rate (lb/acre)	% PLS	Actual Seeding Rate (PLS lb/acre)	Cost (\$/lb)
Annual Plow Down Mix (Grower Provided 1st year)	80-100	Common vetch	10.0%	10	92	9.2	
		Cayuse oats	10.0%	10	95	9.5	
		Field peas	35.0%	35	88	30.8	
		Fava bean	45.0%	45	81	36.5	
		Total	100%	100		86.0	\$0.47
Triticale	80-100	Triticale 2700	100%	100	97	97.0	\$0.37
Experimental Mix	100 - 120	Common vetch	8.3%	10	92	9.2	
		Cayuse oats	8.3%	10	98	9.8	
		Field peas	29.0%	35	90	31.5	
		Fava bean	37.5%	45	81	36.5	
		Daikon radish	4.3%	5	97	4.9	
		Yellow mustard	4.3%	5	96	4.9	
		Triticale 2700	8.3%	10	97	9.7	
		Total	100%	120		106.4	\$0.54
Brassica Mix (Grower Provided 2nd & 3rd years)	8-12	Nemfix Mustard	30.0%	4	95	3.4	
		Braco Mustard	30.0%	4	90	3.2	
		Oriental Mustard	20.0%	2	87	2.1	
		Canola	10.0%	1	94	1.1	
		Daikon radish	10.0%	1	85	1.0	
		Total	100%	12		10.9	\$1.95

Introduction:

The purpose of this field planting was to evaluate differences in cover crop establishment and soil health properties after three years of cover cropping in a walnut orchard near Linden, CA. Grower resource concerns included reduced infiltration, organic matter depletion and runoff into the Calaveras River. The field planting is located in San Joaquin County on a 24-acre Chandler walnut orchard with trees ranging from 10-30 years old. Historically the orchard floor management in the middles consisted of disking and mowing resident vegetation, with herbicide use in tree rows.

Methods:

This demonstration was a side-by-side, non-replicated comparison in orchard middles planted with four different cover crop mixes and species. Three consecutive middles of each mix/species were planted and evaluated every year for three years (2017, 2018, and 2019), totaling 0.5 planted acres for each treatment (Table 1). Cover crop species and mixes included a Brassica Mix (added in 2018), a single species of triticale (2700 variety), a standard Annual Plow Down Mix (APDM), and an Experimental mix (developed by the CAPMC). Legume inoculant was provided by the CAPMC for the APDM and the Experimental Mix. The cover crop mixes were planted by the grower in the late fall, using a modified grain planter and were in accordance with NRCS standards and specifications. Walnut leaf residue was moderate to heavy in places, making proper seed placement challenging. Cover crop treatments were terminated by mowing in early to late April, every spring.

Baseline soil health data was collected in Spring of 2017. In May 2017, the Stockton field office staff and PMC staff conducted an initial soil health assessment in the orchard middles and tree rows at the selected field planting location. Evaluations were based on the NRCS Soil Health Assessment Worksheet and the USDA Soil Quality Test Kit Guide (Tables 2 and 4). Evaluations included compaction, structure, surface crusts and residue cover, roots and pores, earthworms and other biological activity. Data on soil stability, infiltration and bulk density was also collected. In November 2017, an initial water holding capacity and permeability evaluation was also conducted at the site by the Area 2 Resource Soil Scientist and composite soil samples were collected and submitted to a local lab for basic soil property and fertility analysis (Table 3). The final soil health evaluations were conducted in June 2020, at the end of the 3-year demonstration and composite soil samples were collected and sent to a local lab for analysis. Prior to spring termination, cover crop observations were made yearly on height, percent bloom, percent cover, and disease and insect damage (Table 5). Aboveground biomass samples (four replications) were also collected from the different treatments and analyzed for total nitrogen content.

Results:

Changes in soil health were observed over the course of the trial. Residue cover was >75% in all treatments and no surface crusts were present (Table 2). There was an increase in the number of roots and pores, as well as earthworms and biological activity (such as the presence of macroinvertebrates) in some treatment rows. Stability class increased from class 4 (some stability, but very little strength) to class 5 (relatively stable soil fragments/aggregates) and infiltration class increased from moderately slow (0.2 to 0.6 in/hr) to moderate (0.6 to 2 in/hr) in the Brassica Mix and triticale treatments, and moderately rapid (2 to 6 in/hr) in the APDM and Experimental Mixes (Table 4). Bulk density was also reduced to <1.4 g/cm³ in almost all treatments. As bulk density values start to drop, pore space and water holding capacity increase, leading to higher infiltration rates and the potential for more water storage. The Brassica Mix and triticale treatments resulted in >50% soil porosity. There were also increases in organic matter content in every mix treatment, compared to the baseline data (Table 3).

The first cover crop treatments to bloom were the Brassica and Experimental Mixes, due to mustard and radish components in the mixtures, while the triticale was terminated by mowing at or prior to the boot stage and never reached bloom (Table 5). The three cover crop mixes were greater than 2 feet in height on average, while the triticale was shorter than 2 feet. All four cover crop treatments provided over 50% ground cover and only slight damage was observed by insects and disease in the form of some holes or spots on leaves.

The APDM and the Experimental mix both produced the largest amounts of aboveground wet biomass and dry matter across all treatments (Table 5 and Figure 2). The APDM could contribute a fair amount of nitrogen back to the orchard system due its high total nitrogen content (3.1%) and low carbon to nitrogen (C:N) ratio (16:1) (Figure 3). The C:N ratio of <20:1 indicates that the cover crop would break down and release nitrogen relatively quickly (depending on soil conditions such as tillage, moisture content, and the microbial community). Assuming that up to 50% of the total nitrogen would be available the first year as plant available nitrogen, the APDM cover crop could contribute up to 51 - 67 lb N/acre. The Experimental Mix and the Brassica Mix contained high amounts of total nitrogen (2.7% and 2.6%) but also had higher C:N ratios (19:1 and 20:1). These results indicate that these mixes may tie up nitrogen, depending on the levels of mineral nitrogen in the soil. The triticale had a lower total nitrogen content than the mixes and had a higher C:N ratio (22:1).

Table 2. Soil Health Field Assessment Worksheet.

Year	Treatment	Compaction	Structure	Surface Crusts	Residue Cover	Roots & Pores	Earthworms [‡]	Biological Activity [§]
Spring 2020	Annual Plow Down Mix	clear compacted layer	weak/structureless	none	>75%	few to common	none	none
	Triticale	clear compacted layer	weak/structureless to moderate	none	>75%	few to common	few	few
	Experimental Mix	clear compacted layer	weak/structureless	none	>75%	few to common	none	few
	Brassica Mix	clear compacted layer	weak/structureless	none	>75%	common	few	none
Spring 2017	Resident Vegetation	clear compacted layer	weak/structureless	some in places	<25%	few to none	none	none to few

Results are an average of 3 samples.

[‡]Earthworms: Number of worms or worm sign/cubic foot of soil: abundant =>10; few = 1 - 9; none = 0.

[§]Biological Activity: Presence of fungal hyphae, macro-invertebrates, etc.: Common = clearly evident; Few = evident upon close examination; None = no visible biological activity.

Table 3. Soil Lab Analysis.

Year	Treatment	Sample depth (inches)	OM %	EC (dS/m)	pH	NO ₃ -N (ppm)
Spring 2020	Annual Plow Down Mix	0 - 6	2.5	0.4	7.3	12
	Triticale	0 - 6	2.1	0.3	7.3	6
	Experimental Mix	0 - 6	2.5	0.3	7.2	9
	Brassica Mix	0 - 6	2.7	0.3	7.2	6
Fall 2017	Resident Vegetation	0 - 6	2.0	0.2	7.2	6

Lab results are from composite soil samples.

Table 4. Soil Quality Test Kit Results.

Year	Treatment	Soil Stability Class*	Infiltration Rate (in/hr)	Infiltration Class [#]	Soil Blk Density (g/cm ³)	Volumetric water content (g/cm ³)	Soil porosity (%)
Spring 2020	Annual Plow Down Mix	4.8	2.7	moderately rapid	1.45	0.23	45.19
	Triticale	4.7	1.6	moderate	1.25	0.17	52.78
	Experimental Mix	5.2	2.3	moderately rapid	1.33	0.50	49.82
	Brassica Mix	4.8	1.0	moderate	1.25	0.53	52.75
Spring 2017	Resident Vegetation	4.0	0.3	moderately slow	1.43	0.17	45.94

Results are an average of 2 samples.

*Soil Stability Class Criteria: 0 = Too unstable to sample; 1 = 50% structural integrity lost in 5 seconds after insertion in water; 2 = 50% structural integrity lost 5-30 seconds after insertion; 3 = 50% structural integrity lost 30-300 seconds after insertion or <10% remains on sieve after 5 dipping cycles; 4 = 10-25% remains on sieve after 5 dipping cycles; 5 = 25-75% remains after 5 dipping cycles; 6 = 75-100% remains after 5 dipping cycles.

[#]Infiltration classes: Very Rapid = >20 in/hr; Rapid = 6-20 in/hr; Moderately Rapid = 2-6 in/hr; Moderate = 0.6-2 in/hr; Moderately Slow = 0.2-0.6 in/hr; Slow = 0.06-0.2 in/hr; Very Slow = 0.0015-0.06 in/hr; Impermeable = <0.0015.

Table 5. Average Cover Crop Treatment Results.

# of Years	Cover Crop Treatment	Height (in)	% Bloom	Species in bloom	% Cover	Aboveground Wet Biomass (lbs/ac)	Dry Matter Yield (lb/ac)	Total % N	Total N (lbs/ac)	C:N Ratio
3	Annual Plow Down Mix	28	51	field pea, fava bean, vetch	64	28,861	3,766	3.1	117	16:1
3	Triticale	19	0	none	57	17,310	2,576	2.3	57	22:1
3	Experimental Mix	32	69	mustard, radish, fava bean, vetch, field pea	56	37,694	5,122	2.7	140	19:1
2	Brassica Mix	30	55	mustard, radish	56	22,573	3,031	2.6	78	20:1

Results are an average of 4 samples.

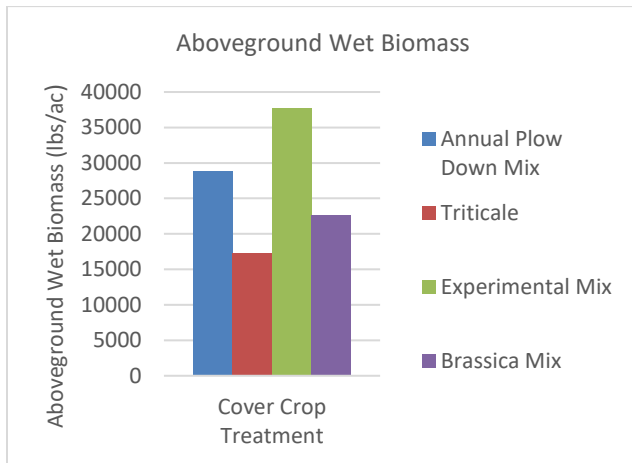


Fig. 2. Cover crop treatment average aboveground wet biomass.

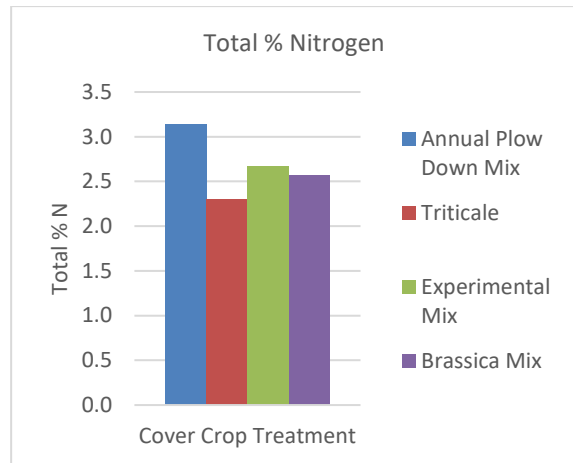


Fig. 3. Cover crop treatment average total nitrogen content.

Summary and Discussion:

Improvements in soil health properties were detected after 3 years of implementing cover crops. The Brassica Mix and triticale cover crop treatments were able to increase infiltration rates, reduce bulk density and increase soil porosity, which would help reduce runoff. The Brassica Mix was also able to increase the soil organic matter content. Brassica and cereal cover crops can have other benefits including scavenging nutrients that would otherwise be leached and lost and help in alleviating soil compaction with their unique root systems. The APDM and Experimental Mixes increased infiltration rates and the organic matter content of the soil. They also produced large amounts of green manure and will likely increase nitrogen availability for the tree crop. All four treatments provided some improvements to soil health after just three years of implementation indicating that cover cropping, even for a short period of time, can lead to soil resilience and contribute to long-term walnut orchard health. At the end of the cover crop demonstration, the producer was pleased with the results and has decided to implement cover crops into all of his walnut orchard operations.



Fig4. PMC staff collecting bulk density samples, Spring 2017.



Fig6. Four walnut orchard cover crop treatments. Top left to right: A) Annual Plow Down Mix, Spring 2018; B) Experimental Mix, Spring 2018; C) Brassica Mix, Spring 2020; D) Triticale, Spring 2018.



Fig5. Drilling cover crop seed into walnut leaf litter, Fall 2017.