Almond Orchard Recycling

Project No.: **15-PREC3-Holtz (AIM/COC)**

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Objectives:

The overall goal of this project is to comprehensively assess management implications of two forms of whole orchard recycling (WOR), orchard chipping (WOR-C) with a tub or rectangular wood chipper vs. orchard grinding (WOR-G) with an “Iron Wolf”, compared to the standard practice of orchard removal for energy co-generation. In addition, we will continue to monitor impacts of WOR-G in the 2008 orchard recycling trial established by Holtz et al. at Kearney REC or soil and orchard health.

Our specific objectives, for WOR-C, WOR-G, and conventional orchard residue removal are:

1. Refine life cycle assessment (LCA) model for evaluation of carbon dynamics and balance.
2. Quantify effects of the treatments on the physical and chemical soil properties and tree nutrients.
3. Quantify effects of the treatments on biological soil properties.
4. Assess impacts of the treatments on replanted orchard growth, health, nutrition, production, and water relations.

Interpretive Summary:

Whole orchard recycling (WOR), as an alternative to co-generation burning, could reduce net orchard greenhouse gas emissions by sequestering for some time carbon stored in tree biomass into soils. The woody residue generated by WOR, estimated to be 30-65 tons per acre depending on tree size, spacing, and varieties, could increase soil organic matter, soil fertility, soil water infiltration rates and soil water retention. Impacts of the orchard debris on incidence and severity of soil-borne diseases of almond are largely unexplored, but increases in soil organic matter content have resulted in favorable soil microbial community shifts, resulting in suppression of some soil-borne diseases and improved plant nutrient dynamics.

The first orchard grinding trial at Kearney, established in 2008, compared WOR of stone fruit trees with the Iron Wolf, estimated, at 30 tons per acre, to burning and incorporating the ash. The orchard was replanted to almond. Ultimately, greater yields, significantly more soil nutrients, organic matter, and total carbon were observed in the grind treatment when compared to the burn. Leaf petiole analysis also revealed higher nutrients levels in trees growing in the grind treatment, thus proving that the organic matter did not stunt replanted trees. Based on positive results from this trial and the closure of co-generation plants, we estimate almond growers ground and incorporated 1,500 acres in 2015/16. Preliminary data from the Kearney deficit irrigation trial has shown less water stress from trees growing where the previous orchard was ground, suggesting increased water holding capacity with the additional organic matter. Three additional orchard grinding trials with almond were established in 2016. A second trial with the Iron Wolf was established with Agriland Farming in Chowchilla comparing Iron Wolf grinding (WOR-G) with tub grinding/chipping (WOR-C), and complete tree removal for co-generation. WOR-C was estimated at 68 tons per acre, and in some plots this rate was doubled. Third and Fourth trials were established with Wonderful Orchards, in Bakersfield and Shafter, where WOR-C was compared to complete tree removal, with and without fumigation. WOR-C was estimated at 39 and 65 tons per acre respectively. The three WOR trials established in 2016 will be fumigated in fall 2016 and planted to second-generation almond trees either in late 2016 or early 2017.

Materials and Methods:

Research sites. We have established and begun monitoring four orchard trials. The first trial, established in 2008 at the **Kearney** REC in Parlier, allows comparisons between WOR-G and burning and incorporating the ash. There are 7 replications of each treatment and each replication or plot consists of 18 trees. The second trial compares two forms of WOR with orchard-removal-for-cogeneration burning. This trial with **Agriland** Farming, in Chowchilla, is composed of 40 ½ mile long rows with three replicated main treatments: WOR-G, with the Iron Wolf, tub grinding or chipping (WOR-C), and complete tree removal for co-generation. The orchard will be planted to second-generation almonds in January/February 2017. There are 2 replications of each treatment and each replication or plot consists of approximately 400 trees when planted. WOR-G, with the Iron Wolf (**Figure 2**), took place in February/March while WOR-C, with the Morbark Horizontal Chipper (**Figure 3**), took place in April/May. Chips from WOR-C were later spread at the same rate they were removed (68 tons per acre). Afterwards the orchard was deep ripped and cultivated with a stubble disk followed by a ring roller.

Third and Fourth trials were established with **Wonderful** Orchards, in Bakersfield and Shafter, both are composed of 50 rows each of either WOR-C or complete tree removal with fumigated (spot fumigation, strip fumigation) or non-fumigated plots arranged in a factorial design with six replications of 18 trees per treatment. The orchards will be planted to second-generation almond trees in fall 2016.The two trials with Wonderful Orchards will be referred to as Kern R1 and Kern R2. Soils at each trial site had previously been characterized for potential to induce Prunus replant disease (PRD), populations of plant parasitic nematodes, and soil physical and chemical parameters (the results for Kern R1 and R2 are listed under soil numbers 22 and 23, respectively, in Browne et al. Annual Report to the Almond Board of California, 2015). Soils from both Kern R1 and R2 induced PRD in the bioassays, but only in soil from Kern R1 were significant populations of plant parasitic nematodes detected (ring and lesion nematodes were found).

At each trial site, the old trees were removed and “chipped” using a conventional tub grinder (WOR-C) during fall 2015 and winter 2016. A smaller 2 inch screen size was used to manage size of the wood chips for each trial. Our goal was to spread the orchard residue chips back on the cleared land at the same rate (in tons per acre) the trees or biomass were removed. Wood chips that had been left in large piles at each station of tub grinding (**Figure 3**) had to be spread evenly over replicate plots (**Figure 4**), and it was therefore necessary to estimate, based on previous cogeneration plant weight receipts for wood residues yielded from known almond acreages, how much wood residue to spread per unit of orchard area. Both in Kern R1 and Kern R2, WOR-C residue treatments were spread on six replicate mainplots arranged in randomized complete blocks with six control treatment mainplots. In both trials, each replicate mainplot measured 66 ft x 648 ft (three tree rows wide, 36 tree planting sites long). Chip spreading for Kern R1 occurred May 2016 at 65 tons (oven dry weight) per acre, while that for Kern R2 occurred February 2016 at 39 tons per acre. All plots were cultivated with a stubble disk followed by a ring roller, which was sufficient to incorporate the wood chips (**Figure 4**). In fall 2016, each mainplot will be subdivided into subplots that receive fumigation (Telone C35) and control treatments.

Soil carbon and physio-chemical properties. Total carbon and nitrogen in soil and tree residues are being analyzed using combustion method (Costech elemental Analyzer, Gaudin Lab) in soil micro aggregates after fractionation. Labile carbon pools (PoxC) and soil indicators of microbial functions such as total activity (FDA) and C and N cycling (microbial enzymatic activities) are measured using established colorimetric assays. Total C and N in microbial biomass will be measured using the fumigation method. Wet aggregate stability, water infiltration (double ring infiltrometer) and water holding and release dynamics (Hyprop system) will be tested in the fall using standard methods. Additional soil properties (texture, CEC and other macro/micronutrients) are being determined at UCD ANL laboratory.

N retention: Soil samples have been collected from paired plots at the **Kearney** REC site to test for NO_3^- leaching in lab setting using soil columns with fine mesh supporting a glass filter at the base. For the nitrate leaching study, the soil samples from the different field treatments will be amended with mineral fertilizer and incubated. After 2 weeks, excess water will be applied, and water flowing out from the column will be collected. The NO_3^-- content of the outflow water and soil will be determined by standard methods.

Tree-soil water relationships. A fully watered (100% ET) and deficit irrigation treatments (64% of ET at hull split for three weeks) were established this season on Nonpareil rows in the whole tree incorporation and burned control plots (**Kearney** REC site). Tree water status was monitored weekly using a pressure bomb while neutron probe tubes were installed to monitor soil moisture at multiple depths.

Results and Discussion:

Objective 1. Refine life cycle assessment (LCA) model for evaluation of carbon dynamics and balance. Tree residues have been weighed and collected at the newly incorporated sites and are being analyzed for total carbon, labile C pools, and total nitrogen in the Gaudin lab. This will provide temporary carbon storage input data for use in the revised almond LCA model under development. In addition, management data is being collected to estimate energy and input costs.

Objective 2. Quantify effects of the treatments on physical and chemical soil properties and tree essential nutrients. Baseline samples of bulk soil at depth of incorporation from treatment plots were dried for physical analysis and sent to UCD ANL laboratory. Samples will be characterized for plant essential nutrients, texture, pH, electrical conductivity of soil extract, cation exchange capacity, and total organic and inorganic carbon. Analysis of long-term C sequestration and N retention potential is under way with soils collected from the **Kearney** REC site.

Objective 3. Quantify effects of the treatments on biological soil properties. Soil sampling was initiated at the trial locations. Resident nematode populations were determined. At **Agriland** root-knot nematode was detected. Although the sampling pattern at this site was not exhaustive, a higher incidence of root-knot nematode was detected in the “Iron wolf” treatment than in the traditional “tree removal” sites. Soil is currently further prepared for greenhouse experimentation to determine the intrinsic soil suppressiveness potential of the soils from the different treatments. Greenhouse plants have been raised for this purpose, and other preparations will allow for a speedy installation of these trials.

Objective 4. Assess impacts of the treatments on replanted orchard growth, health, nutrition, and water relations. New orchards will be planted in the fall and growth, tree health, and nutrition will be monitored over the next seasons. We therefore focused our efforts on characterizing shifts in tree water relationships and water use efficiency at **Kearney** REC sites. Nonpareil trees were grown under fully watered (100% ET) and deficit irrigation treatments (64% of ET at hull split for three weeks) following whole tree incorporation or burned biomass since 2008. We found that Nonpareil trees planted in ground tree plots were significantly less affected by deficit irrigation in July while no differences were observed between treatments in the well-watered control (**Figure 1**).

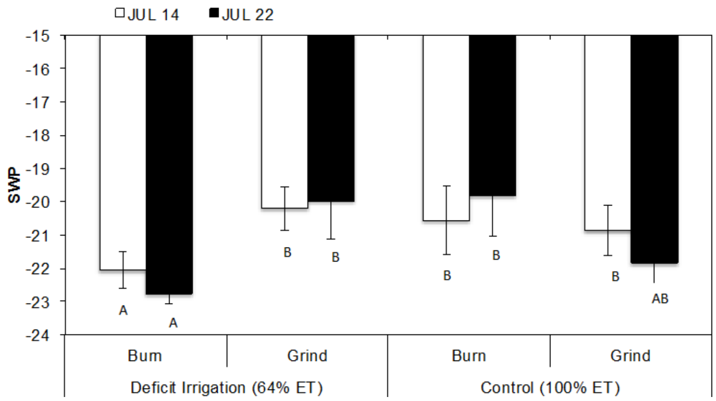

Figure 1: Stem water potential was measured with pressure bomb on July 14 and 22 after onset of the deficit irrigation treatment in the WOR-G plots (grind) and burned control. Treatments with the same letter were not significantly different (p=0.05).

Although analysis of resilience of soil biological functions to deficit irrigation is under way, and yields and soil health remain to be quantified, these preliminary results highlight the potential benefits of healthier soils and WOR to mitigate water shortages and reduce irrigation water demand in California orchard.

Research Effort Recent Publications:

Holtz, B.A., Doll, D.A, and Browne, G. 2016. Whole orchard recycling and the effect on second generation tree growth, soil carbon, and fertility. Acta Horticulturae 1112: 315-319.

References Cited:

Holtz, B.A., Doll, D., Browne, G. 2014. Orchard carbon and nutrient recycling. Proceedings of the sixth international symposium on Almonds and Pistachios. Acta Horticulturae 1028: 347-350.

Holtz, B.A., McKenry, M.V., and Caesar-TonThat, T.C. 2004. Wood chipping almond brush and its effect on the almond rhizosphere, soil aggregation, and soil nutrients. Acta Horticulturae 638:127-134, ISSN:0567-7572, ISBN: 90 6605 707 6.

Holtz, B.A. 2015. Pacific Nut Producer's October Orchard Tasks: Almonds. Pacific Nut Producer (ISSN 1087-4674) Volume 21, number 9, pages 12-17, Whole almond orchard recycling and the effects on second generation orchard growth and soil nutrients, www.pacific nutproducer.com.

Figure 2. The 'Iron Wolf' 700 B, a 50-ton rototiller, built to remove forests and crush rock, was used to grind up almond trees at **Agriland** Farming in Chowchilla. In the photo the Iron Wolf is going in reverse and incorporating the ground up trees.

Figure 3. The Morbark horizontal chipper was used to chip up almond trees at Agriland for comparison with the Iron Wolf. These chips were spread out on the soil surface in the whole orchard recycling with wood chips treatment (WOR-C), then cultivated back into the soil with a stubble disk.

Figure 4. Appearance of wood chips, from a tub grinder, after being spread back onto the soil surface, and before incorporation with a stubble disk and ring roller (Wonderful Orchards Trial Kern R1).