Adding Almond Hull and Shell to a Producing Almond Orchard: Feasibility and Tree Health Impacts

Cameron Zuber[1], David Doll[1], Dani Lightle[2], Rory Crowley[3], and Amelie Gaudin[4]

[1] University of California Cooperative Extension, Merced, CA; [2]University of California Cooperative Extension, Orland, CA; [3]Nicolaus Nut Company, Chico, CA; and [4]University of California, Davis, Davis, CA

Introduction

Larger almond crops due to increased acreage and yields per acre is leading to a biomass management problem of hull and shell at the processors. Hull and shell are sold as prime hulls (less than 15% shell) at a price range of $45 to $65 per ton, hull and shell mix (less than 29% shell) at a price range of $25 to $40 per ton, or pure shell at a price range of $0 to $6 per ton. This does not count the cost of transportation. These prices have a potential to decrease due to economic pressures of an increasing supply due to the growth of the almond industry and a decreasing demand due to the decline of secondary markets that currently purchase hull and shell (e.g., as feed for cows in the dairy industry). There are alternative uses of almond hull and shell, which include a source for pyrolysis into biochar, co-generation of energy, use of biomass for next generation materials, source of sugar extract for ethanol production, and human food consumption. Each of these has their respective challenges and will require several years to develop. An easier management strategy would be to reapply hull and shell back to orchards as organic amendments.

Use of organic amendments is growing increasingly important to improve soil health and orchard productivity; however, current organic amendments have their own perceived benefits and risks. Potential risk of current organic amendments is further compounded by the Food and Drug Administration Food Safety Modernization Act (FSMA). To increase food safety, FSMA rules may restrict the timing, placement, and form of some sources of organic amendments. Almond hull and shell applications have a reduced food safety risk of not being manure based.

Almond hull and shell also have a high nutrient value, which may provide a greater return on value than other soil health amendments. At current fertilizer prices, one ton of hull and shell mix has an estimated value of $46 per ton (Table 1).

Nutrient	Average hull content (%)	Pounds of nutrient per ton	Estimated value[3]
Nitrogen	0.96	17.4	$8.70
Phosphorous	0.10	2.1[2]	$1.70
Potassium	2.00	43.5[2]	$34.80
Calcium	0.20	3.6	$0.90
		Total per ton	$46.10

Table 1. Nutrient value per ton of almond hull assuming 90.6% dry weight[1]

[1] As reported from the Almond Hullers and Processors Website

[2] Pounds of phosphorous and potassium reported as phosphorous and potassium oxide

[3] Prices were determined by contacting sales companies. N, P_2O_5, and K_2O were priced at $0.50, $0.80, and $0.80 per unit, respectively

Due to reduced food safety risk and as a source of nutrients, reapplication of almond hull and shell to orchards should be considered. However, grower sentiment suggest that reapplication could cause tree harm and existing research provide little information on the efficacy of reincorporating almond hull and shell to orchards.

Objectives

This study explores how the application of hull and shell interact with soils and almond trees. This study evaluates tree health and yield to determine if:

1. Almond hulls and shells can be reapplied to orchard floors without impacting production;
2. Rates of almond hull and shell application influence tree performance differently;
3. In-season compost applications are as effective as almond hull and shell application.

The findings from this study will hopefully inform a strategic plan for improving soil health and tree productivity; and address efforts to meet new air quality regulations through measurements of temporary and longer-term carbon storage and sequestration.

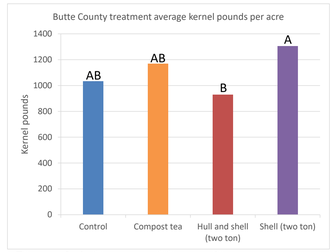

Figure 1. Influence of four soil treatments applications on 2017 yields for Butte County location. Different letters indicate statistical groupings (Tukey, p<0.05)

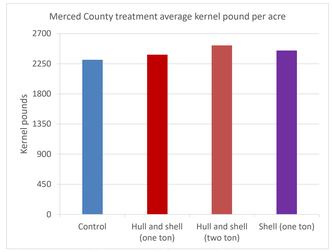

Figure 2. Influence of four soil treatments applications on 2017 yields for Merced County location

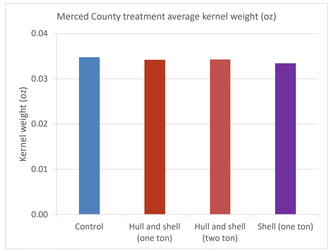

Figure 3. Influence of four soil treatments applications on 2017 kernel weight for Merced County location

Figure 4. Photos of hull and shell one ton per acre (top) and shell one ton per acre (bottom) treatments at Merced County location in 2017 during months of March (left), April (middle), and July (right)

Butte County treatment	N (%)	P (%)	K (%)	S (ppm)	B (ppm)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
Control	2.44	0.11	1.72	1800.0	31.1	3.87	0.80	46.6	66.0	617.0	5.9
Compost tea	2.44	0.11	1.79	1870.0	31.6	3.72	0.75	48.6	63.6	756.5	6.0
Hull and shell (two ton)	2.43	0.11	1.83	1837.5	32.3	3.71	0.76	54.7	66.0	693.5	6.1
Shell (two ton)	2.47	0.11	1.81	1830.0	31.1	3.73	0.76	57.4	69.2	754.5	6.3

Table 4. Leaf nutrient analysis from Butte County location of Nonpareil after application of amendments. Values are reported in total percent (%) or parts per million (ppm)

Merced County treatment	N (%)	P (%)	K (%)	S (ppm)	B (ppm)	Ca (%)	Mg (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
Control	2.40	0.15	3.18	1897.5	40.3	3.17	0.76	68.3	145.7	229.3	7.1
Hull and shell (one ton)	2.28	0.17	2.96	1815.0	39.9	3.22	0.84	65.9	103.7	225.0	6.3
Hull and shell (two ton)	2.36	0.16	3.15	1825.0	41.2	3.35	0.78	62.8	87.3	229.0	6.6
Shell (one ton)	2.22	0.18	3.01	1707.5	42.4	3.22	0.81	58.5	72.4	201.5	5.9

Table 5. Leaf nutrient analysis from Merced County location of Butte after application of amendments. Values are reported in total percent (%) or parts per million (ppm)

Methods

Two locations were established in 2017 in Butte and Merced counties to determine the impact of applying almond hull and shell back to the orchard. The Butte County location was on a third-year-old orchard with Nonpareil, Monterey, and Aldrich varieties grafted to Krymsk-86 rootstock with solid set irrigation. The Merced County location was on a 15-year-old, organically certified orchard with Butte and Padre varieties on Lovell rootstock with hanging double-line drip irrigation. In the beginning of 2017, the soil treatments in Table 2 were applied in the irrigation wetting pattern and as delivered (e.g., not ground into powder) from the local processor.

Butte County	Merced County
Almond hull and shell mix (two ton per acre)	Almond hull and shell mix (one ton per acre)
Almond shell (two ton per acre)	Almond hull and shell mix (two tons per acre)
Locally sourced compost tea	Almond shell (one ton per acre)
Untreated control	Locally sourced compost[1] (one ton per acre)
	Untreated control

Table 2. Treatments applied at study locations

[1] Compost not applied in 2017 due to limited availability

Soil was sampled prior to treatment application and at the end of the year. Multiple soil cores were collected from each treatment and were sampled from a depth of zero inches to six inches. The top two inches were removed from soil cores if excess organic matter (e.g., fertilizer) was present. In April to July, leaves were collected for tissue samples. Leaves were selected form non-fruiting spurs from multiple trees of the same variety within each treatment. Yield data was collected from each location. During harvest, a sub-sample of at least four pounds was collected to determine kernel weight to field weight.

Discussion

Differences between kernel yields occurred at the Butte County location (Figure 1), but not at the Merced County location (Figure 2). There were no difference in kernel size at any location (Figure 3, data not shown for Butte County location).

Observed yield differences at the Butte County location may not be due to treatment application since the material was applied after crop set and there were no differences in kernel size. Hull and shell breakdown occurred rapidly (Figure 4). In Merced County, hull and shell was applied in March (Figure 5) and noticeable decomposition occurred within one month of application with little hull and shell remaining by July.

Nutrient value of applied hull and shell was within expected ranges (Table 3). There were no discernable differences in mid-summer leaf nutrients at either location (Tables 4 and 5).

There does not appear to be a negative impact of hull and shell incorporation, but more data is needed. We suspect long-term application of products may have greater effects on tree performance, nutrient uptake, and soil health.

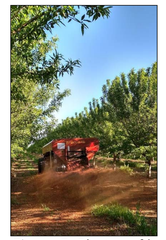

Figure 5. Photos of hull and shell application at Butte County (left) and Merced County (right) locations

Nutrient	Average hull content (%)	
	Hull and shell	Shell
Carbon	45.60	45.50
Nitrogen	0.83	0.74
Phosphorous	0.11	0.08
Potassium	2.91	1.98
Calcium	0.27	0.35

Table 3. Nutrient value of product applied at Merced County location in 2017 assuming 93.9% dry weight

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