2020 Crown Nut Company Hulls & Shells Research Summary

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Research Overview

Almond hulls, shells, and mixes of the two materials are annually stockpiled at Crown Nut Company processing facility. These materials are a source of accessible, nutrient-rich organic matter amendments that are used on nearby orchards. During processing, materials are separated into Nonpareil/Independence hulls, shells from all varieties, and a mix of hulls and shells from pollinizer varieties. There is a need to find new waste streams for hulls and shells since growth in the almond industry is outpacing the dairy industry where these materials are typically sold as cattle feed. In recent years, Crown Nut Company has spread excess shells along roadsides and in orchard alleyways as a mulch. This helps reduce dust and facilitates field access of machinery after rain. In addition to the benefits provided by mulching, almond hulls and shells contain significant amounts of potassium and other nutrients. Following nitrogen, potassium is the nutrient in second highest demand for almond trees. The highest fertilizer costs in almond production tend to be associated with potassium. This research trial asks the question: Can almond hulls and shells be used as a soil amendment over almond tree roots to supply potassium for crop uptake?

We hypothesized that surface applied hulls, mix, and shells can provide mineralized potassium over time as decomposition breaks down these materials. Hulls, shells, and the mix contain different concentrations of potassium and other nutrients and likely release nutrients at different rates. Increased soil exchangeable potassium (XK) under amendments could improve tree nutrient status as measured in July leaf nutrient values over time. In addition, these amendments could have a mulching effect to reduce soil surface evaporation, increase soil moisture, and reduce tree water stress. Together, improved tree nutrition and water use under amendments could potentially improve yield over time.

The trial is a randomized complete block design consisting of five treatments: control (minimal K fertilizer), hulls, shells, a hull-shell mix and K_2SO_4 fertilizer. The latter four treatments were all applied as close as possible to 150 lb/ac K_2O equivalent. Each treatment was applied to both sides of 40 trees in each row across four blocks. Minimal baseline KTS fertilizer applications were applied to all treatments: 4 units of K were applied on March 20, 6 units of K on April 1, 6 units on April 15, 4 units on May 2, 6 units on May 20. The K_2SO_4 fertilizer was applied once in the Fall of 2019. Amendments were applied on February 10, 2020.

Results show that the applied amendments contained on average 2.72, 2.91, and 1.54 percent potassium (Table 3a). Amendments released potassium into the soil quickly following rainfall in mid-March and after the start of irrigation in late April (Figure 2). This indicated that the process of potassium release is driven by water, which is well-supported by other research studies on potassium mineralization from moderately high C:N crop residues. The highest soil XK values were found under the amendments (Figure 2). As %K fell in amendments over the course of the season (Figure 5a), soil exchangeable potassium increased substantially in March and then declined as the season progressed(Figure 5b). %K and soil XK data came from a 6-inch diameter circular sampling area where we measured decomposition rates by dry mass loss (Figure 6). Overall, hulls decomposed by 62% and released 81% of initial K; the mix decomposed by 50% and released 85% K; and the shells decomposed by 22% and released 74% K (Table 6). Potassium cycling is one of several potential crop system benefits provided by this amendment practice, as outlined in Figure 1.

There were no significant differences found across any July leaf nutrient concentrations when comparing treatments. July leaf nutrient averages were within or close to the recommended adequate ranges; there were no deficiencies or toxicities in any nutrients (Table 7). Any potential nitrogen immobilization that could have occurred in the soil under these moderately high C:N amendments did not have detrimental impacts on leaf nitrogen concentrations. In fact, leaf nitrogen was slightly higher under the amendments compared to the control. High leaf potassium was maintained under the amendments, with no significant differences across treatments. The least water stressed trees were found under the mix, shells, and hulls treatments compared to the fertilizer and control treatments, although more complete data is needed (Table 8). There were no significant differences in yield in kernel lbs/ac or crackout percentages (Table 9), although significant amounts of hulls and mix were found in yield samples (Figure 9). Applying in November 2020 (as compared with February application) will increase the time period that the amendments are in the field, potentially increasing total decomposition and total K release next year.

Suggestions for next year:

- It would be good to know the average %K of the amendments before we apply in order to better estimate the K in each material. Would it be possible to separately stockpile the three amendments in September so I can take samples ahead of time for more accurate %K, %moisture, hull:shell in the mix treatment?
- If the irrigation was more consistent, we would be better able to compare effects of the amendments and not effects of irrigation differences. Figures 4 and 7 illustrate potential effects of different soil moistures across blocks. Would it be possible to adjust irrigation so that Blocks 1 and 2 are more consistent with Blocks 3 and 4?
- Could we apply enough K_2SO_4 to more closely match the K from amendments?

Big-Picture Benefits

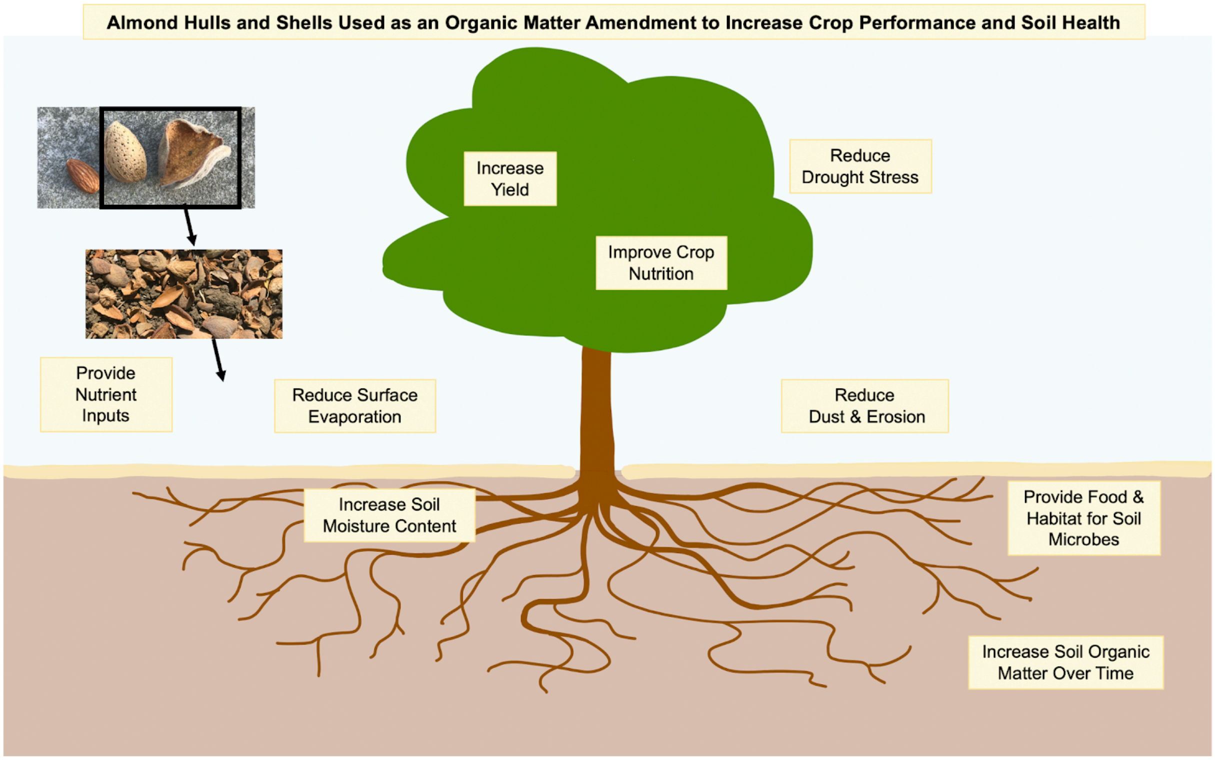

Figure 1. In addition to nutrients and water benefits, this practice has the potential to provide a range of other crop system benefits as pictured in this diagram. This figure was created based on a literature review of the effects of moderately high C:N amendments and crop residues on components of crop performance and soil health. At Crown Nut Company, the primary focus is potassium cycling.

2019 and 2020 Hull, Mix, Shell Initial Nutrient Values Before Application

Table 1a and 1b. Initial average amendment nutrient content sampled in February 2019 in percent and parts per million.

Feb. 2019 Materials	(%)						
	C	N	C:N	P	K	Ca	Mg
Hulls	34.95	0.622	56:1	0.076	2.54	0.234	0.116
Mix	35.78	0.629	57:1	0.064	2.52	0.235	0.113
Shells	40.18	0.536	77:1	0.035	1.30	0.269	0.063

Feb. 2019 Materials	(ppm)							
	S	B	Zn	Mn	Fe	Cu	Na	Cl
Hulls	273	108.0	7	16	377	2.4	153	52
Mix	275	109.8	6	16	322	2.5	155	47
Shells	244	48.4	5	12	299	3.3	109	28

Table 2. Initial average amendment %K content grouped by variety. More sampling would be required to determine if there is an effect of variety on %K.

Feb. 2019 Varieties	Average %K		
	Hulls	Mix	Shells
Independence	2.38	2.26	1.46
Butte/Padre/Aldrich	2.62	2.71	0.95
Monterey	2.62	2.60	1.35
All	-	-	1.35

Table 3a and 3b. Initial average amendment nutrient content sampled in February 2020 in percent and parts per million.

Feb. 2020 Materials	(%)						
	C	N	C:N	P	K	Ca	Mg
Hulls	43.03	0.718	60:1	0.117	2.72	0.232	0.136
Mix	44.40	0.698	64:1	0.093	2.91	0.222	0.111
Shells	45.85	0.510	91:1	0.049	1.54	0.245	0.098

Feb. 2020 Materials	(ppm)					
	S	B	Zn	Mn	Fe	Cu
Hulls	348	179.3	5.7	10.4	127	3.1
Mix	303	158.9	5.8	12.0	126	3.5
Shells	248	73.6	7.4	27.8	1013	4.6

The 2019 %K values shown in Table 1 were used to estimate the required amounts of amendments the February 2020 application. While most macronutrient contents were similar in both years, K concentration was a little higher in all three materials in 2020 as shown in Table 3a. The 2020 materials were sourced from Nonpareil/Independence hulls, mix from pollinizers, and shells from many varieties. Factors that may influence %K include: amount of rainfall onto stockpiles prior to application, variety type, fertilization, irrigation practices, and soil type at the source location. Micronutrients that could potentially cause toxicity (such as boron and salts) fell well below permissible quantities in irrigation water in both years. All July leaf averages for 2020 were within or very close to the recommended adequate ranges suggesting no nutrients from these amendments caused toxicity. However, the boron levels in the 2020 hulls and mix materials were a little higher than FREP's recommended adequate range of 80-150 ppm, so boron might be something to keep an eye on. Next year, I will take hull samples for B at harvest.

Amounts of Each Treatment and Applied Nutrients

Table 4. Potassium applied through each treatment. The average dry biomass factors out moisture weight at the time of application, which was 19%, 18%, and 11% for hulls, mix, and shells, respectively. The average K applied in biomass was found by multiplying the average dry biomass by the %K values (as listed in Table 3a). The goal was to apply minimal K in the control treatment and equal amounts of K in the rest of the treatments to compare them. The actual applied K_2O was found by multiplying the average K applied by the conversion factor 1.2046.

Treatment	Avg Dry Biomass (lb/ac)	Avg K Applied (lb/ac)	Goal K_2O (lb/ac)	Applied K_2O (lb/ac)
1: control, no amendments	27	27	Minimal K_2O	33
2: hulls	4682	127	150	153
3: mix of hulls & shells	5489	160	150	192
4: shells	11298	174	150	210
5: K_2SO_4	205	92	150	111

Table 5. Other nutrients applied in lb/ac, given the average dry biomass (lb/ac) listed for each amendment in Table 4.

Treatment	Average lb/ac Nutrient				
	C	N	P	Ca	Mg
2: hulls	2015	34	5	11	6
3: mix of hulls & shells	2437	38	5	12	6
4: shells	5180	58	6	28	11

Soil Data

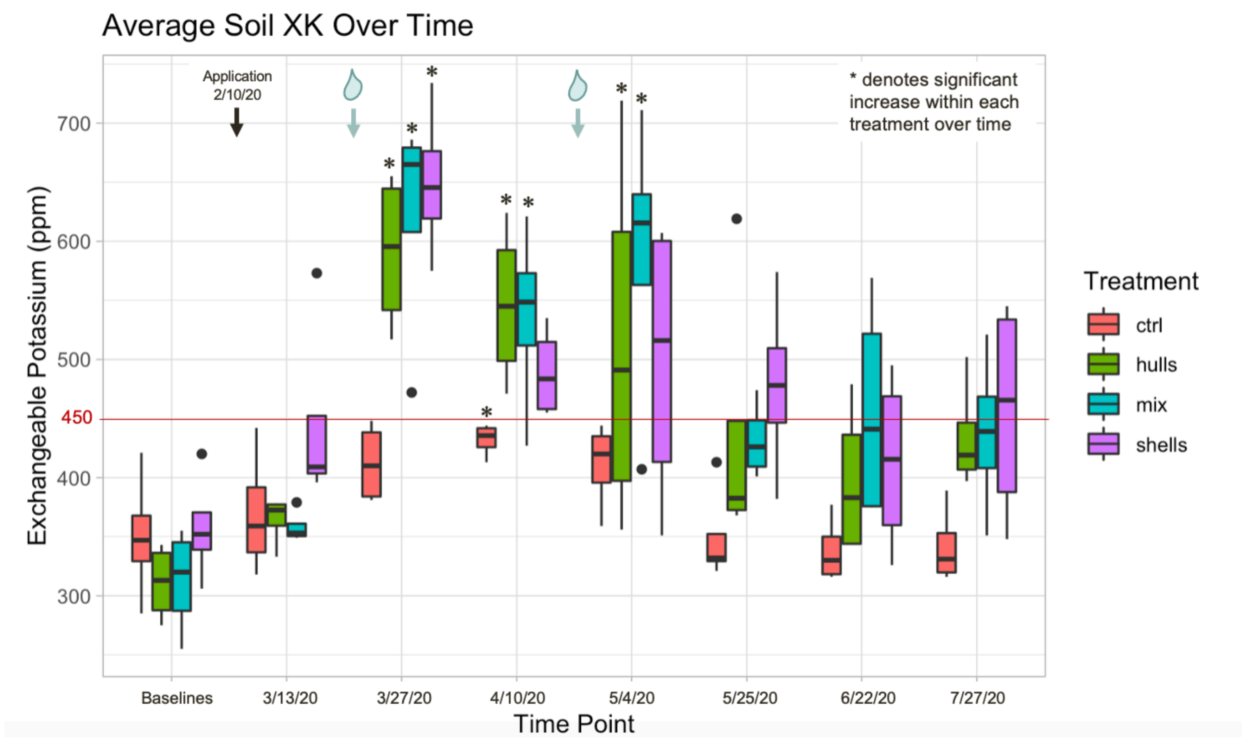

Figure 2. Average soil XK in the top 0-10cm under treatments across time. Asterisks indicate significant increases within each treatment and black points indicate outliers. All values above the red line at 450 ppm were located under the amendments. The timing of K release closely followed mid-March rainfall and the start of irrigation in late April, as indicated with the blue water drops. Prior research shows K release from amendments and crop residues is strongly tied with soil water. As the season continued, XK gradually declined under all treatments until the last time point. These values likely underestimate K release to some degree because root uptake would be occurring throughout this time.

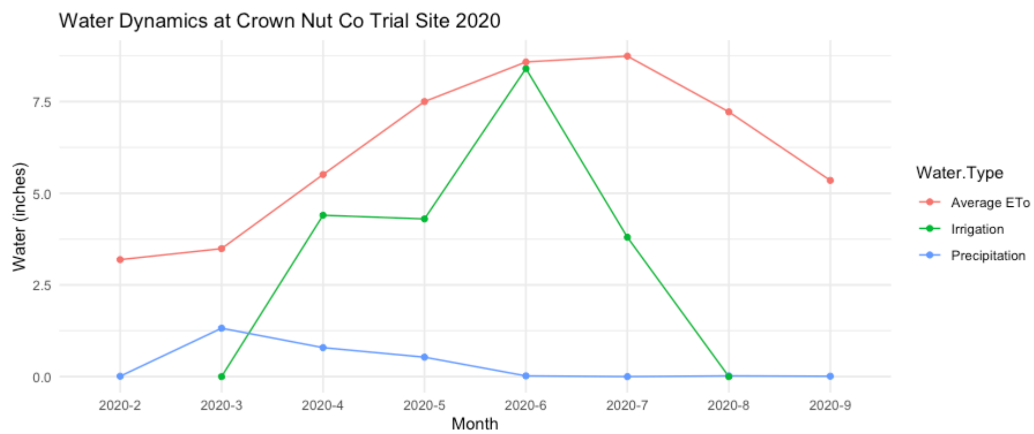

Figure 3. March rainfall coincided with an increase in soil XK across all treatments. Irrigation beginning in April coincided with high soil XK levels as well. Precipitation and average ETo data are sourced from the CIMIS database, and irrigation is based on water meter readings at the pump station.

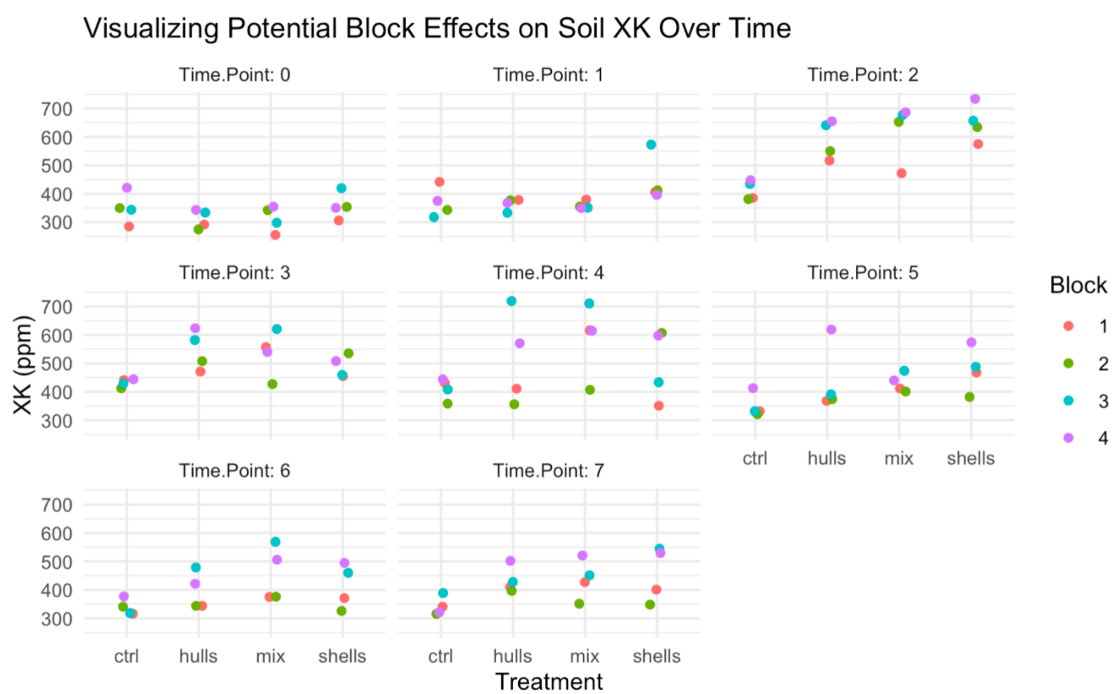

Figure 4. Block differences in soil XK. As the season progressed, Blocks 1 and 2 (orange and green points) tended to have lower soil XK across all treatments, particularly in Time Points 4, 5, 6, and 7. As we were soil sampling, we noticed the soil in blocks 1 and 2 seemed drier than blocks 3 and 4. Soil moisture likely drives K release from the amendments, so these block differences may influence K dynamics.

Changes in Nutrient Contents in Amendments Through the Season

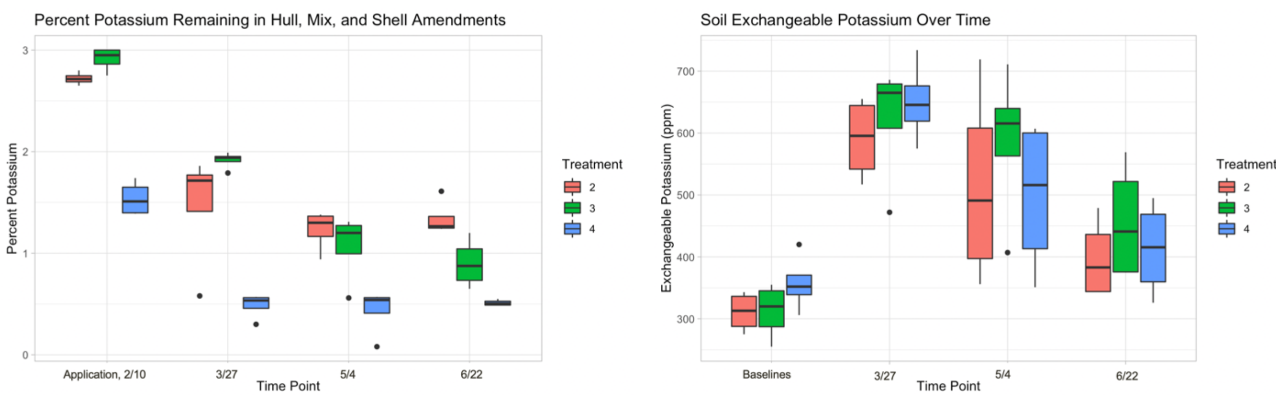

Figure 5a and b. The relationship between %K released from amendments and changes in soil XK. As %K fell in the amendments, soil XK increased initially due to K mineralization in March and then fell throughout the season, likely due to tree uptake and slower K release from amendments over time.

Table 6. Total K release from amendments. From 2/10 to 6/22, average %K and mass dropped across all materials. Samples were taken from within a circular 6-inch diameter sample area. Given the average application rate of each amendment, this translated to 103-135 lb/ac K available in the soil through the decomposition process. Total released K (lb/ac) was calculated as Final Dry lb/ac K – Initial Dry lb/ac K. Dry lb/ac K at the initial and final time points was calculated as %K * Dry lb/ac material for each time point separately.

Amendment	Initial %K	Final %K	Initial Dry lb/ac K	Final Dry lb/ac K	Total % Decomposed (dry weight)	Total Released K lb/ac	Total %K Released
Hulls	2.72	1.35	127	24	62	103	81
Mix	2.91	0.90	160	25	50	135	85
Shells	1.54	0.51	174	45	22	129	74

Decomposition by Mass Loss Through the Season

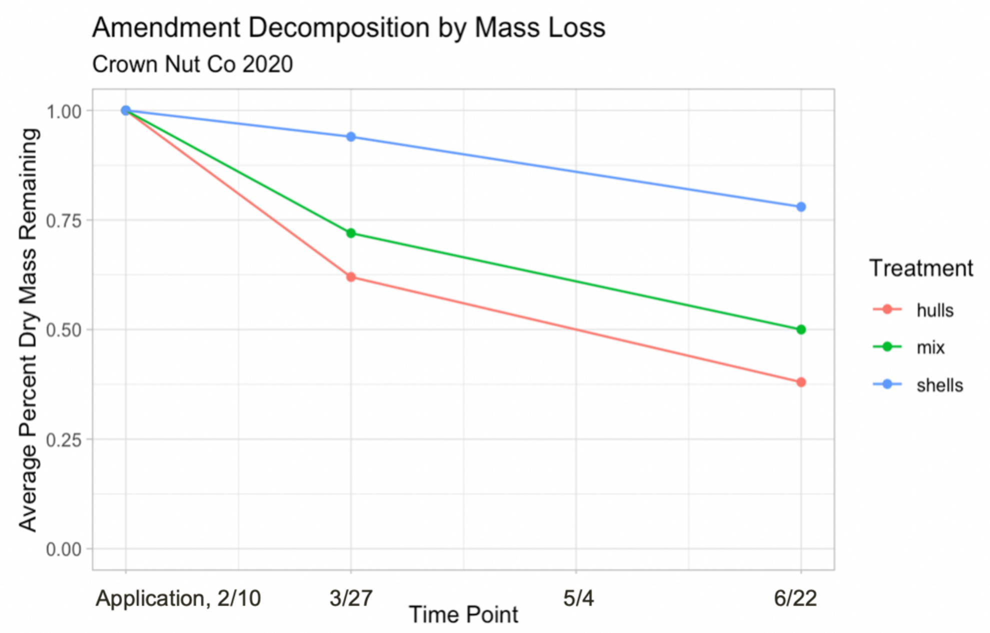

Figure 6. Decomposition measured by percent dry biomass loss over time. By June 22, 62% of the hulls had decomposed, 50% of the mix had decomposed, and 22% of the shells had decomposed.

Raw data suggested that the amendments likely moved in and out of the litter rings that were used to measure mass loss by decomposition, likely by wind, water, etc. In order to reduce variation and attain more accurate decomposition measurements, we switched to using mesh decomposition bags as pictured for 2020-2021. This will exclude litterfall and amendments from moving into and out of the sample area.

Litter rings 2020

Litter litter bags 2020-21

Leaf Nutrients

Table 7. Average leaf nutrients under treatments. There were no significant differences found across any leaf nutrients when comparing all treatments. The nutrients listed below were tested from 12 trees in per treatment (60 sample trees total). This indicates that the amendment treatments did not affect leaf nutrients during this first year. All leaf nutrients under all treatments fall within or slightly above the suggested adequate ranges. Sources for leaf critical value adequate nutrient content ranges: The Almond Production Manual, UC ANR website, and FREP almond fertilization website.

Treatment	(%)					(ppm)					
	N	P	K	Ca	Mg	S	B	Zn	Mn	Fe	Cu
Control	1.98	0.119	2.38	5.78	1.14	1707	50	27	65	84	6
Hulls	2.07	0.117	2.22	5.88	1.19	1704	48	31	68	86	6
Mix	2.03	0.122	2.12	6.05	1.20	1739	49	31	61	79	6
Shells	2.01	0.116	2.07	5.88	1.16	1747	46	28	60	81	5
K2SO4	2.03	0.116	2.14	5.85	1.15	1743	46	32	67	90	6
Adequate Range:	2.2-2.5	0.1-0.3	1.4-2.0	2-4	0.6-1.2	1000	30-65 (use hulls)	15-20	30-80	100	6-10

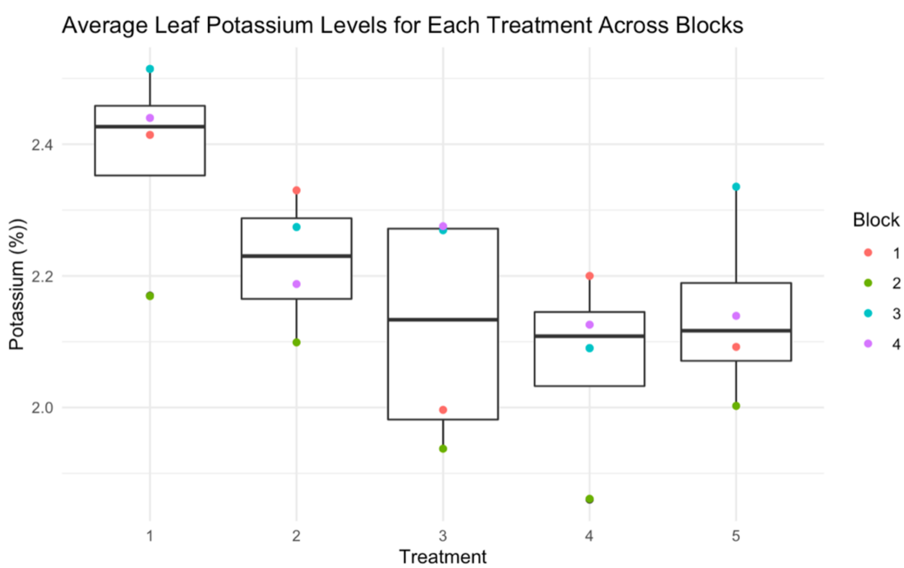

Figure 7. Average leaf %K across treatments. While there were no statistically significant differences between leaf %K, this boxplot color coded for block illustrates that block 2 (shown in green) consistently had the lowest leaf %K. This matches the trend observed in soil XK across blocks (Figure 6), where soil XK tended to be relatively lower in block 2 compared to the other blocks as the season progressed and trees relied more heavily on irrigation. This potential block effect due to differences in irrigation is something we may want to address for next year.

Stem Water Potential

Stem Water Potential on July 27

Treatment	Average SWP in bars
Control	-25
Hulls	-22
Mix	-18
Shells	-21
K2SO4	-23

Table 8. Stem water potential averages on July 27, 2020. The least stressed trees were found under the mix, shells, and hulls compared to the fertilizer and control treatments as evidenced by the less negative stem water potential averages. However, this data is 18% incomplete, so next year we will be sure to obtain a more complete dataset to look more closely at a potential mulching effect.

Yield Data

Table 9. Average yield data response variables measured for each treatment. There were no statistically significant differences in dry kernel lb/ac across the treatments. However, the highest average dry kernel lb/ac was found under the hull treatment. More time in the field from Fall 2020-Aug 2021 next year may lead to greater differences. The standard deviations of dry kernel lb/ac were lower in the amendment treatments compared to the control and fertilizer treatments, indicating that the yield values under amendment treatments were less variable.

Treatment	Average Dry Kernel lb/ac	Standard Deviation Across Blocks (lb/ac)	Avg % Crackout	Avg % Dry HS Trash in Yield Samples (dry weight)
Control	2200	352	31.9	0.88
Hulls	2436	241	30.2	5.29
Mix	2218	228	30.1	4.67
Shells	2240	226	30.2	2.35
K_2SO_4	2403	630	31.2	0.71

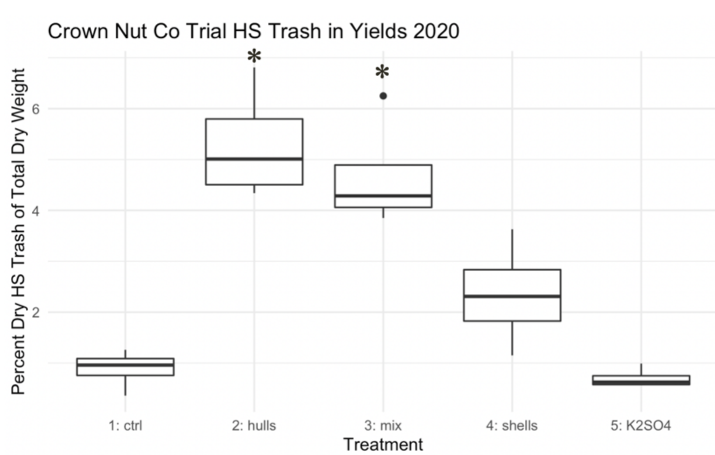

Figure 8. The heavier materials, the hulls and the mix, were found in significantly greater quantities in yield samples. The shells were found to a lesser degree, potentially due to their light weight. Applying in November will provide a longer time frame which could help increase total decomposition and potentially reduce the amount of amendment material found in yield samples.

Pictures

Amendment Materials

Hulls

Mix

Shells

2/10/2020 Application Day

2/26/2020



7/27/2020 shells and hulls 1 week before the sweepers started



8/10/2020 harvest left the ground bare

Field Map

T1	No hulls/shells, apply KTS
T2	95% hulls
T3	60% hulls, 40% shells
T4	100% shells
T5	No hulls/shells, apply K2SO4