The Almond Doctor
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Cover crop research review: How can it help almonds?

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Although cover cropping is compatible with almond production and is often implemented in other orchard systems, this practice has never been widely implemented in California. The potential benefits are recognized by growers, especially their value for pollinator forage and soil health but operational concerns, lack of cost-benefit analyses and unclear best management practices have hampered wide adoption. As cover cropping can provide significant sustainability benefits, there is an urgent need to assess and develop feasible and beneficial cover crop systems for California almond production. Here is some insight gathered by a research team assessing the impacts of multiple cover crop management strategies on: 1) soil health, 2) water use and dynamics, 3) bee visitation and pollination, 4) weed and pest pressure (NOW) and 5) almond yields in four orchards across the Central Valley precipitation gradient.

Cover crop research trial in almond:

Project website: https://almondcovercrop.faculty.ucdavis.edu

Design:

- Three commercial orchards in Corning (Tehama county, 2nd leaf), Merced (Merced county, 16th leaf) and Arvin (Kern county, 16th leaf).
- One experimental station: Kearney (Fresno county).
- Two cover crops: Soil Mix (2 legumes, 2 brassicas & 1 grass), Pollinator Mix (5 brassicas, Project Apis M – https://www.projectapism.org/pam-mustard-mix.html)
- Compared to resident vegetation & to bare soil.
- Cover crop from October to April with two termination dates tested (March to late April).

Figure 1. Soil Mix at the time of termination at the three orchard sites.

Insight from two seasons:

Cover crop management should be site-specific and should be tailored to the grower's objectives and regional climatic conditions. For example, a cover crop established for bee forage could have narrower seeding and an earlier termination than a cover crop used for soil-building objectives. Ultimately, there are multiple designs possible. Testing different designs or mixtures on a few rows will help you find the best option for your orchard. Here are a few general recommendations and resources to guide your cover cropping decisions. Keep in mind that cover cropping has proven to be a long-term investment for which benefits may only be visible after several years.

Expected Main Benefits

Slightly higher almond yields were obtained in the mature orchards after one year of cover cropping: in Merced, +225 lbs/acre compared to resident vegetation/weeds and +217 lbs/acre compared to bare soil. In Kern county, yields in the cover cropped plots were +94 lbs/acre compared to bare soil. These yield increases could be attributed to the potential benefits detailed below.

Building Soil Health:

California almond production is faced with multiple challenges, often tied to degraded and compacted soils, which are frequent in almond orchards across the state. Researchers are quantifying cover crop soil services across different soil health components: physical, such as aggregate stability and water infiltration rate, chemical including major nutrients and chemical properties such as pH and CEC, and biological including amounts of soil microbes, soil food web composition and microbial activities. The evaluation will occur across 3 seasons. As soil health will start to shift, cover crop productivity may also increase thereby creating a higher soil-building potential. This idea of a "virtuous cycle" must be kept in mind when cover cropping: although results may not be visible within the first year, the activation of plant-to-soil feedback processes can provide long-term support for your orchard soil.

Figure 2. Pollinator mix at the time of termination at the three orchard sites.

Soil physical properties:

After a first cover-crop season, soil physical analyses indicated improved aggregate stability trends at all research sites and for both mixes, and especially for the Pollinator Mix at the Kern county orchard, which was heavily compacted. Biological analyses indicated no statistical changes six months after cover crop termination. Early information suggested that considerable improvements in water infiltration can be found during the second cover crop season, with higher

capacity for rainfall to penetrate the soil during the established cover crop, thus suggesting reduced risks of runoff.

Nitrogen credits:

Organic sources of N can offset synthetic fertilizer inputs in the spring if N release from the cover crop is synchronized with tree N demand. When investigating the seasonal pattern of N release from the cover crop, researchers found that C and N turnover from vetch was very rapid. A total of 90% of N was released within 4 weeks of termination under adequate moisture regimes. Almond trees efficiently captured this N, which stabilized at about 30% in existing leaves, and reached 43% in new leaves (Project No 97-AB to 99-AB, A. Berry). A seeded cover crop can contribute more N to your orchard than resident vegetation: in Tehama county, the cover crops contained on average 5.5% N compared to 3.7% N in the resident vegetation and had +4140 lbs/acre more biomass production. In Merced county, the seeded cover crop had 3.1% N compared to 2.4% N in the resident vegetation and had +1535 lbs/acre more biomass. Compared to bare orchards, the N contribution of the cover crop amounted to +82 N lbs/acre in Merced county and +126 N lbs/acre in Kern county.

Providing bee forage:

Research shows that flowering cover crops can support bees by providing habitat and nutrient resources before and during almond bloom (Lundi *et al.,* 2017). However, in California, cover crop flowering often peaks after the start of almond bloom. Planning the timing of cover crop flowering with tree bloom is difficult due to yearly weather changes and mowing. However, early planting (in September-early October) followed by one or two fall irrigations in dry years can help. In the cover crop mixes tested, Brassica species appeared more attractive to bees than other species. The cover crop did not detract from bee visitation in the trees or significantly impact almond nut set.

Controlling weed pressure:

Winter cover crops can be an effective weed management tool in California perennial crops, with the caveat that good cover crop establishment is essential. Poor establishment due to lower rainfall and reduced light in mature orchards can substantially reduce weed suppression benefits. Research results suggest that cover crop competition can reduce overall weed diversity. Both cover crop mixes effectively reduced winter weed populations compared to the standard herbicide treatment.

Suppressing parasitic nematodes:

Brassica species' capacity as a biofumigant has been well-demonstrated. However, the biotoxic activity of brassica and mustard cover crops remains variable and relatively low compared to commercial fumigants. The two cover crop mixes (Soil Mix & Pollinator Mix) were evaluated for their biofumigation potential, as well as other species to identify options and confirm host

potential. Greenhouse assays show that while most species tested suppressed root lesion nematodes, the most suppressive cover crop species were sunn hemp, Balansa clover and medic. The least suppressive was lupine. Cover crops that suppress the root lesion nematode did not necessarily suppress ring nematodes. There was large variability in the suppression potential of the different clover types. However, rose clover was unique in that it effectively suppressed both nematode populations. Compared to the clovers, sunn hemp was less suppressive to the ring nematode. Ultimately, the best-suited cover crop species for biofumigation will depend on your orchard's pre-existing nematode population. It's therefore important to soil sample before selecting your cover crop species.

Potential challenges

Residues at harvest:

Cover crop termination post-bloom using mowing and herbicide was effective; there was no observable cover crop residues at harvest, including potentially problematic species like vetch. As such, cover cropping did not interfere with harvest operations. Conditioners (for example, StickJack by Jackrabbit) can be used right before harvest to help remove any branch residues or other material. For growers who do not have access to a conditioner, additional mowing in the summer can be very effective to accelerate the break-down of residues.

Figure 3. Orchard alleyway in a cover cropped orchard at the time of harvest. There were no observable cover crop residues at that time. As such, cover cropping did not interfere with harvest operations.

Interference with sanitation and NOW pressure:

Cover cropping does not seem to interfere with and can even facilitate NOW sanitation by improving trafficability in the winter for shaking and mowing. Soil cover can provide overwintering sites for beneficial insects and predatory mites and may also negatively impact the overwintering success of navel orangeworm (NOW) in mummy nuts on the ground. However, this does not necessarily translate into higher densities of beneficials in the tree canopy or significant benefits. Previous research has shown mixed results when comparing the impact of 10 cover crop mixes on the numbers of beneficial and parasitic wasps (Project No 1994-00 and monitoring of the BIOS project No 96-BIOS, L. Hendricks). In our study, nut infestation by NOW was the same in bare and cover cropped orchards. Overall, shaking the trees for mummies is still necessary and feasible with cover cropping. It is possible to combine cover crop mowing at termination with flail-mowing of the mummies in the orchard.

Water usage:

Previous research indicated that, although resident vegetation can result in up to 35% more water usage compared bare soil management, the use of selected cover crop species (i.e. bromegrass) results in similar seasonal water usage as in bare orchards (Pritchard *et al*., 1989). Researchers are still investigating mechanisms by which improved water dynamics with cover cropping can secure long-term improvements for water use efficiency. This includes increased water infiltration and reduced runoff, increased water holding capacity through improved soil structure, dew moisture capture by cover crops and the buffering of soil temperatures altering water evaporation and water loss. If terminated on time and controlled around the tree, the competition for irrigation water can be minimal. If you are seeding early in the Fall, prior to the first rains, irrigating (one to two-12h sets) with micro sprinklers will help accelerate germination in seeded alleyways. The rest of the winter, the cover crop can be rain-fed without additional irrigation.

Frost risks:

A main concern is that cover cropping could reduce soil-to-tree heat transfer and therefore, increase damage during sensitive frost nights. In this study, although the cover crop buffered top-soil temperatures, no ambient air temperature differences were found from 3 feet and above, which suggests that cover cropped orchards may not experience higher frost risks. However, this is based on one season of data. It has been shown that winter ground cover can significantly increase surface soil temperatures compared to bare soils in windy situations (Project No 87-O7, R. Snyder). Mowing of the cover crop and irrigating for frost control can be done anytime, if the threat of frost occurs.

Cover crop management: how to get maximum benefits and minimize tradeoffs?

Selecting the right mix for your objectives

Keep in mind that what you seed is not necessarily what you get: in this study, an identical seed mix produced three different cover crops across the Central Valley. The Soil Mix was composed of 60% white mustard in the Tehama County orchard, whereas it was composed of 59% ryegrass in Merced. As a result, their C:N ratios varied from 10:1 to 18:1. However, it is also important to note that compared to resident vegetation, the seeded cover crop produced up to 300% more dry matter biomass with the same amount of water. This must be considered when selecting cover crop species for a particular purpose in an orchard. Aside from seed mix selection, managing the cover crop may be key in obtaining desired benefits. Furthermore, having a high species diversity will increase your cover crop system's adaptability to seasonal climate variation and will improve your chances of obtaining adequate biomass and groundcover.

Criteria to consider when choosing species:

- Your main objectives: pollinator habitat, pest control, soil health
- Orchard's irrigation system & water demand of cover crop species
- Soil type & tillage
- Biodiversity & functions of the cover crop
- Price & availability of seeds

Seeding and soil preparation

- **Seeding time:** September-November: it is preferable to seed right before the first rains in the Fall to improve trafficability, avoid compaction and avoid seeding during mummy shake. Especially for growers interested in having bee forage prior to and during almond bloom, seeding early in the Fall (September-early October) is important to ensure that the cover has enough time to get to the bloom stage.
- **Soil preparation:** Especially if you are cover cropping for the first time, consider seed bed preparation to optimize the seed-to-soil contact. This will be especially helpful for smaller seed mixes (i.e. mustard mixes). Very light disking (1-2 inches of depth) can be used for soil preparation. However, we found that disking can leave uneven ground, which has to be relevelled for harvest. We found that using an orchard mulcher set at 1 inch of depth was successful at both preparing the seed bed and keeping the ground even. For no-till seeding, mow any vegetation to limit competition at cover crop germination.
- **Seeding width:** Consider that your orchard may have different soil conditions depending on your management practices. In orchards in which berms are cleaned and residues piled in the alleyways, higher C and N contents were found in alleyways compared to the berms. Similarly, the location of your irrigation wetting zone may affect soil biological activity and create differences in soil health in your orchard. If you are looking to improve water infiltration and/or soil health in your orchard, consider where you are placing the cover crop. A wider seeding, which overlaps with your irrigation wetting zone and is closer

to the berms has more potential to impact your orchard's soil health and address water infiltration problems.

- **Seeders:** For younger orchards, we were able to use regular forage grain seeders (John Deere 750 No-till grain drill – 15 feet wide) with only one pass per middle. For mature orchards, avoiding damage to the branches is the key challenge. We used compact drills (Schmeiser Compact No-Till drill – 6 feet wide or the Great Plains No-Till Seeder NTS2511 – 11 feet wide) and did two passes to get wide cover crop seeding (up to 20 feet wide) whilst avoiding branch damage. If your seeder has no press-wheels, drag a chain behind the drill or roll the field following seeding to improve the seed-to-soil contact.

Stand management and termination

Mowing in the winter can be necessary to control the cover crop stand height but this is not frequent. However, for sanitation purposes, growers will need to flail-mow the mummies during the winter season. To favor cover crop growth and ensure flowering during almond bloom, flail-mowing either early in the season at first rains and/or late in the season, at cover crop termination is best. Cover crops might also need to be mowed to decrease frost risks post-dormancy. Cover crops can be terminated by spraying herbicides, mowing or rolling. For termination, a successful strategy is to mow and spray with a herbicide after approximately 1 week. Cover crop termination (March-April) was successful at all research sites and left no residues at harvest in this study.

Available Resources: There are numerous ways to manage cover crops: disked green manure systems, mowed perennial systems, self-reseeding cover crops, etc… To consider other cover cropping options, here are a few resources below.

For species selection:

- Cover Crop Chart: Cover Crops for California: https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmctn13333.pdf
- Cover Crop Database: Sustainable Agriculture and Research and Education Program, UC Davis: https://asi.ucdavis.edu/programs/ucsarep/research-initiatives/are/nutrient-mgmt/cover-crops
- Cover Crop Seed and Native Seed Vendors for California. PMC Tech Note 85. 2016. Available at: https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmctn12954.pdf
- Pacific Northwest Cover Crop Selection Tool. USDA NRCS Plant Materials Program: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/plantmaterials/technical/toolsdata/plant/?cid=nrcseprd894840
- USDA Plants Database: https://plants.usda.gov/java/

For orchard cover cropping guidelines:

- Orchard Cover Crops Guide from the Community Alliance with Family Farmers (CAFF) Available at: http://cesutter.ucanr.edu/files/102662.pdf
- Managing Cover Crops Profitably, Third Edition, SARE, Available at: http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition
- Cover cropping in Orchards and Vineyards, SAREP. Available at: http://cestanislaus.ucanr.edu/files/111327.pdf
- Yolo county perennial cover crops in orchards and vineyards guide, RCD. Available at: http://www.yolorcd.org/documents/perennial_cover_crops.pdf

For cover cropping for soil & water conservation:

- USDA-NRCS Cover crops & Soil Health: Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1077238
- Orchard Floor Management Practices to Reduce Erosion and Protect Water Quality http://anrcatalog.ucdavis.edu/pdf/8202.pdf
- Jackson, L.E., Wyland, L.J., Klein, J.A., Smith, R., Chaney, W.E., & Koike, S.T. (1993) Winter Cover Crops can decrease soil nitrate, leaching potential. *California Agriculture*, 47 (5): 12-15. PDF available at: http://calag.ucanr.edu/Archive/?article=ca.v047n05p12
- Mitchell, J.P., Shrestha, A., & Irmak, S. (2015) Trade-offs between winter cover crop production and soil water depletion in the San Joaquin Valley, California. PDF available at: http://casi.ucanr.edu/files/239977.pdf
- Pritchard, T.L., Sills, W.M., Asai, W.K., Hendricks, L.C. & Elmore, C.L. (1989) Orchard water use and soil characteristics. *California Agriculture*: 23-25. PDF available at: http://ucmanagedrought.ucdavis.edu/PDF/Prichard%20et%20al%201989.pdf

For cover cropping for pest management:

- National IPM Database: https://ipmdata.ipmcenters.org/
- Statewide Integrated Pest Management Program. 2018. University of California Agriculture and Natural Resources. http://ipm.ucanr.edu

For cover cropping for bee forage:

- Almond Board Guide for Pollination Stakeholders: Available at: http://www.almonds.com/sites/default/files/ALM_189395_HBBrochure_ForWebsite_8_5x11_F5.pdf
- Almond Board BMP Quick Guide: Available at: http://www.almonds.com/sites/default/files/ALM_189395_ALM_Quick%20Guide7x10_F3.pdf

- Almond Board BMP Quick Guide for Applicators. Available at: http://www.almonds.com/sites/default/files/ALM_189395_ALM_AppGuide7x10_F2.pdf
- Project Apis Guide for Honey Bee Forage Crops: Available at: https://www.projectapism.org/uploads/1/0/5/7/105706229/forage-resource-guide-v5.pdf
- Xerces Society-NRCS Cover crop for Pollinators Guide: Available at: http://www.xerces.org/wp-content/uploads/2012/11/ConservationCoverInstallationGuide_CACentralValley.pdf
- Lundi, O., Ward, K., Artz, D.R., Boyle, N.K., Pitts-Singer, T.L., & Williams, N.M. (2017) Wildflower plantings do not compete with neighboring almond orchards for pollinator visits. *Environmental Entomology* 46:559-564. Available at: https://doi.org/10.1093/ee/nvx052

Research Team - A team of UC Davis, UC Berkeley, UC Riverside and UCCE researchers have been collectively evaluating the benefits-to-tradeoffs of cover cropping compared to conventional bare soil and resident vegetation. This work is funded by the Almond Board of California. For the full description of the project, visit: https://almondcovercrop.faculty.ucdavis.edu/

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More here:

To follow the on-going Almond Cover Crop Benefits-to-tradeoffs Assessment, visit https://almondcovercrop.faculty.ucdavis.edu/.