The Role of Liquid, Solid and Green Manures and Wastes to Provide Nutrients and Organic Matter – A Grower-Oriented Analysis

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Objectives:

- To determine if organic matter amendments impact tree nutrition, fruit quality and yield.
- To identify if organic matter amendments alter soil biology, chemistry or physical properties.
- To uncover practical knowledge of organic matter amendments in the scientific literature.
- To solicit opinions from researchers and farm advisors about organic matter amendments.
- To conduct assessments of organic matter amendment use during focus groups.
- To describe how growers use organic matter amendments through a mail and online survey.

Interpretive Summary:

There is a large excess of organic matter amendments including liquid, solid and green manures and wastes in California and a lack of knowledge of how these materials may be used to benefit almond production. An exploratory project was conducted to improve our

understanding of the potential benefits and concerns with the use of organic matter amendments. These materials are excellent sources of nutrients and organic matter that could benefit tree health and soil quality, but significant concerns exist. Our effort focuses on outcomes that balance benefits to tree nutrition, fruit quality, yield and soil biology, chemistry and physical properties with concerns for food safety, cost & logistics and nutrient availability.

A review of scientific literature provides clear evidence for positive impacts of organic matter amendments on tree health and soil quality; however, there are significant concerns worthy of further investigation specific to California almonds. Many researchers and farm advisors echo the same benefits and concerns found in the scientific literature with greater specificity. For example, dairy lagoon water is high is macronutrients and may be delivered through irrigation systems but may also harbor human pathogens or excess salts. Composting animal manure eliminates the concern for food safety and other pests like weed seeds but often may lead to lower nutrient content and the need for higher volumes of material to be applied at greater cost. Green waste compost may offer a solution for organic matter if nutrients are utilized from supplementation, but growers may have issues with poor access. Each scenario presents its own challenges, and further research is required for approaches to become more applicable.

Focus groups with certified crop advisors were conducted and used to identify valuable agronomic implications for the use of organic matter amendments in California permanent crops. These focus groups informed the design and specificity of the mail survey that was distributed to all California almond growers. The preliminary response rate for the survey was 14% covering 216,300 acres. The center of organic matter amendment use during any stage of orchard development is in Stanislaus and Merced counties. Survey participants identified soil biology (48%) as the main benefit to an orchard from use, followed by tree nutrition (40%). Responses show no differences in the timing of application with the vast majority of materials being applied from postharvest to bloom (80% - 95%). However, differences were more apparent from placement and management of composted manure and green waste compost on the tree berm (53% and 58%) compared to the alleyway with a greater incidence of no-tillage (76% and 80%). Growers report better access to animal manure compared to green waste. For composted manure, green waste compost, raw manure and uncomposted green waste, they identify food safety as the greatest issue of concern, with nutrient availability playing a secondary role, and cost & logistics being the least issue of concern of the three.

Literature Review:

The scientific literature details both the benefits and concerns for the use of organic matter amendments in tree crops. The following review is designed to determine the impacts on tree nutrition, fruit quality and yield as well as to identify alterations to soil biology, chemistry and physical properties from the use of organic matter amendments. In addition, this reviews aims to identify concerns from use including food safety, cost & logistics, and nutrient availability. The widespread use of organic matter amendments in composted and uncomposted forms presents both an opportunity and a challenge for permanent crops like almond in California.

Tree Nutrition
One of the most well documented benefits of organic matter amendments is as a fertilizer that delivers essential macronutrients to crops. Sheep and cow manure, as well as composted poultry litter, have all provided abundant nitrogen (N) to permanent crops including peach and fig (Mordoğan et al. 2013; Preusch and Tworkoski 2003). In apples, bark mulch decreased leaf N while boosting leaf phosphorus (P) and potassium (K), but maintaining all three within acceptable ranges (Neilsen et al. 2014). In some cases, organic matter amendments provide lower concentrations of macronutrients than do conventional ones, but still improve crop performance. In Pacific Northwest apples, compost mulch led to lower leaf N than conventional fertilizer, but within an acceptable range (Mathews et al. 2002). On the other hand, manure was found to be a less efficient N source in southern California orange groves than were various rates of urea spray and calcium nitrate (Harding et al. 1963).

Organic matter amendments can also be relied upon to supply the microelements. In permanent crops, fertilizing with macadamia nut husk mixed with composted or raw animal manure resulted in leaf nutrient composition comparable to those given by chemical fertilizers or untreated controls, even as yields increased in both cases (Bittenbender et al. 1998; Mordoğan et al. 2013). Furthermore, research has shown organic matter amendments can help correct micronutrient deficiency. An irrigated zinc- (Zn) deficient cotton-wheat rotation recovered from stagnating yields and took up Zn more readily when fertilized with Zn sulfate in combination with 25% conventional N and 75% manure N compared to 100% conventional N (Ejaz et al. 2012). Iron (Fe) sulfate sown in with grass or combined with manure has proven effective in regreening leaves affected by iron deficiency chlorosis in Mediterranean fruit crops (Tagliavini et al. 2000). Finally, manure application increased concentrations of Ca, Fe, and Zn in irrigated nut crops while direct application of Fe increased yield of split pistachios, implying that both are useful for improving fruit quality (Roosta and Mohammadi 2013).

Under field conditions, organic matter amendments have demonstrated the ability to support adequate and even improved yields, as compared to conventional chemical fertilizers. Green waste compost increased nectarine yield over both mineral fertilizer and cow manure in an irrigated Mediterranean orchard (Baldi et al. 2010). Cow manure, poultry manure, alfalfa hay mulch, and mulch combined with fertigated N all increased yields in irrigated and unirrigated permanent crops (Amiri and Fallahi 2009; Forge et al. 2013; Sanchez et al. 2003). Often, organic matter amendments do not increase yield compared to conventional fertilizer (Neilsen et al. 2014). While fruit yield may remain unaltered during transition from conventional to integrated or organic practices, various aspects of soil quality may improve (Peck et al. 2011).

Soil Quality
Organic matter amendments play an important role in soil quality and can change soil biology, chemistry and physical properties. The incorporation of green waste compost with or without animal manure is effective in the reduction of soil bulk density and compaction (Arvanitoyannis and Kassaveti 2007; Cayuela et al. 2004; Mujdeci 2011; Peck et al. 2011). A soil quality index devised for Pacific Northwest apple orchards determined that organic management practices resulted in lower bulk densities (Glover et al. 2000). Organic matter amendments are also a practical solution for issues with infiltration, porosity, and water holding capacity. Straw and manure have demonstrated a higher effectiveness than ground cover at water retention in

apples (Walsh et al. 1996). In contrast, in a study comparing irrigated and nonirrigated crops, manure did not alter the water holding capacity of three different soils (Wu et al. 2003).

Heavily cultivated landscapes with coarse-textured soils in mild climates are at the highest risk for soil carbon (C) deficits (Angers et al. 2011). In many irrigated permanent crops, organic matter amendments have been shown to increase soil C in organic and mineralizable forms (Bittenbender et al. 1998; Canali et al. 2004; Neilsen et al. 2014; Sanchez et al. 2003). Many different organic matter amendments are also capable of supplying both macro and micronutrients (Baldi et al. 2010; Cayuela et al. 2004) as well as including cation exchange capacity (Amiri and Fallahi 2009; Arvanitoyannis and Kassaveti 2007; Cayuela et al. 2004; Miller et al. 2013). Even though immature poultry manure compost has been implicated in P runoff (Adler and Sikora 2003), there is more evidence to suggest that organic matter amendments function better than conventional fertilizers in preventing N leaching (Avila-Quezada et al. 2010). Similarly, mulch, cover crops, and compost all resulted in less N leaching compared to N fertigation with herbicide (Harding et al. 1963; Sanchez et al. 2003).

To maximize the impact of organic matter amendments on soil quality, researchers have seen changes in beneficial soil fauna. Animal and green manures increased microbial populations and diversity in irrigated permanent crops leading to increased mineralization (Forge et al. 2013; Iglesias Briones et al. 2011). In apples, poultry manure compost mulch increased populations of predators and detritivores (Mathews et al. 2002). Nonetheless, the influence of these materials on soil biology has limits. In Mediterranean avocado, animal and green waste compost did augment microbial communities; however, the original soil substrate was the main determinant of microbial diversity (Bonilla et al. 2012). In Mediterranean citrus, there was no difference in the microbial communities between composted animal manure, green waste compost and conventional fertilizer compared to an untreated control (Canali et al. 2004).

Organic matter amendments are used to control pests and suppress disease like root lesion nematodes in irrigated permanent crops (Forge et al. 2013; Sanchez et al. 2003; Stirling et al. 1995). Similarly, poultry manure compost was as effective as herbicides for weed suppression, and had the added benefit of increasing predatory insect populations in apples (Brown and Tworkoski 2004). A combination of composted animal manure with a cover crop and a green manure with soil solarization was as effective as methyl bromide in controlling replant disease in apples (Braun et al. 2010; Mazzola and Mullinix 2005). While success in pest and disease management of permanent crops with organic matter amendments appears to be variable, its viability as a practice that can yield additional co-benefits should not be ignored.

Food Safety
Stakeholders worry about food safety issues associated with untreated amendments of animal origin, the cost and logistics of acquisition and application, and whether these materials can supply crops with accessible forms of nutrients. The use of organic matter amendments has faced limitations due to the perception by consumers and within the industry that there is greater potential for contamination of produce by human pathogens. For example a majority of conventional Midwest vegetable growers surveyed believed that practices like the use of organic matter amendments were more likely to lead to contamination, even though they themselves might use manure or composted manure (Lewis Ivey et al. 2012). Yet as research into plant pathology and food safety becomes more multidisciplinary and targeted to specific cropping systems, the goal is that both fear and outbreaks will subside (Fletcher et al. 2013).

To mitigate risk the of organic matter amendment use, efforts should focus on disinfecting major pathogens like *Salmonella* and *E. coli* at the source. Manure can be disinfected with heat treatment above 50ºC, composting, aerobic thermophillic stabilization of liquid manure and anaerobic biogas production within an artificially heated reactor (Bijlsma et al. 2013; Gong 2007; Martens and Bohm 2009). Depending on the temperatures used, processes like these can inactivate *E. coli*, *Salmonella*, *Enterococcus*, and other pathogenic species, yet maintain decomposing and other beneficial bacteria (Gong 2007). Additives like urea and ammonia have also been used to disinfect pig slurry of multiple strains of both *Salmonella* and *Yersinia enterocolitica* (Bolton et al. 2013). Ultimately, pre-application treatments are one feasible option for preventing organic matter amendments from contaminating produce.

Failure to treat amendments prior to application increases the risk of field persistence of contaminants. Once applied, it is possible for human pathogenic bacteria including *Salmonella* and *E. coli* to survive in both soil and plants. Bacteria find their way into crops via several modes, all of which have been demonstrated *in vitro*. Pathogens can enter a crop through its root system or through surface scars, can adhere long-term using biofilms, and can persist in all plant tissues and organs (Avila-Quezada et al. 2010). Unfortunately, conditions that are beneficial for other agricultural processes have been implicated in higher rates of contamination. For example, favorably high moisture for crops has been shown to increase the growth of *Salmonella* in poultry manure up to 100-fold (Eriksson de Rezende et al. 2001).

There are many management steps that can be used to further reduce the risks posed by organic matter amendments after application. Multiple studies have confirmed that incorporating manure into the soil and lengthening the interval between application and harvest lower the risk of contamination for permanent and annual crops (da Cruz et al. 2006; Duffy and Schaffner 2002). In lettuce, the use of subsurface drip irrigation has been shown to decrease the risk of *E. coli* contamination as compared to both overhead sprinkler and furrow irrigation. If these irrigation systems are used, however, effects can still be ameliorated by halting irrigation a few days prior to harvest (Fonseca et al. 2011). As might be expected, apples harvested directly from the tree showed lower *E. coli* contamination than those dropped to the ground (Duffy and Schaffner 2002). With the multitude of both risks and potential mitigations, attention to the unique food safety issues on each orchard situation is crucial.

Cost & Logistics

While produce contamination is a concern shared by producers and consumers alike, the financial cost associated with the use of organic matter amendments figures strongly among growers. Concern over the cost of necessities like transport and treatment can limit adoption and render the application of organic matter amendments no longer cost-effective (Burton and Martinez 2008). A compost of manure and macadamia nut husk, while successful at improving yield, was deemed too expensive to be practical (Bittenbender et al. 1998). At a diverse farm in Spain, vermicompost and humic acid solutions both failed to improve soil quality when applied at rates judged financially reasonable. However, sheep manure improved soil quality at a price point lower than conventional options (Albiach et al. 2000).

The concern of practical usability of organic matter amendments comes into question because they often require high application rates in order to realize benefits to plants and soil. Cattle manure applied at extremely high rates increased CEC and salinity to such an extent that extra leaching would be needed (Hao and Gang 2002). Only a very high rate of composted poultry litter mulch was able to suppress weeds in peach orchards, yet the amendment also increased water-extractable P, and increased risk of leaching (Preusch and Tworkoski 2003). In a similar outcome, commercial compost applied at a rate high enough to increase yield also heightened soil NO_3^- to levels that would be at risk for leaching. However, this increase only occurred during a few days of the season (Baldi et al. 2010). Tradeoffs between the intent and the outcomes of the use of organic matter amendments appear to be ever-present.

Nutrient Availability

Supposing that organic matter amendments can be employed safely and at reasonable cost, many still doubt that their agronomic value is comparable to that of conventional fertilizers. The ability to apply organic matter amendments at the right quantity of macro and micronutrients was confirmed above, yet there is insufficient research to determine when these nutrients are available. If not carefully timed, some organic matter amendments can render added nutrients unavailable by contributing to immobilization. In corn, even though organic matter amendments increased the total N pool, it immobilized N for a period of time, resulting in decreased yields (Fortuna et al. 2003). In a similar experiment, cattle slurry N was immobilized at a higher rate and remineralized at a lower rate than was mineral fertilizer N (Sørensen 2004). More information is certainly needed to manage the subtle balance of immobilization and mineralization specific to permanent crops under microirrigation in California.

Summary

There is ample evidence to suggest that the use of organic matter amendments when applied under ideal conditions and management can favorably influence soil biology, nutrient cycling and retention. There is an equally large body of literature to suggest that use in an incorrect fashion may have no beneficial value and may indeed increase nutrient loss and compromise food safety. While the promise for greater use of organic matter amendments is substantial there has been no integrated research conducted under field conditions in California for almonds. In addition, the biological, agronomic and industrial acceptability of these materials remains unknown. More information is needed to manage immobilization and mineralization so as to improve both nutrient availability and retention in permanent crops of California.

Associate Interviews:

Interviews were conducted with researchers, farm advisors and industry representatives to identify the key issues of concern with greater use of organic matter amendments in almond. The goal was to identify key agronomic, logistical and financial constraints limiting greater use.

Researchers

Experts conducting research on permanent crops echo much of what is presented in the literature. From an economic perspective, widespread application would depend on whether the supply of organic matter amendments matches demand from almond growers (Sumner *personal communication*). How does the quantity of manure available from dairies and elsewhere compare with proximal acreage available for application? Are projections altered by a changing dairy industry or declining cotton and silage acreage? Answers to these questions are critical to understanding the potential for greater use of organic matter amendments.

Untreated animal manure poses the greatest food safety concern. Human pathogens causing foodborne illness are present in these materials and can contaminate crops. Almonds are at particular risk for contamination due to exposed kernels and harvest operations (Kokal and Thorpe 1969). Bacteria identical to *Salmonella* have been found on nuts before harvest, implying that many avenues of contamination may exist (McGarvey *personal communication*). Postharvest mixing of almond constituents at hulling and shelling facilities adds further complexity to food safety concerns (Harris *personal communication*).

A reduction in contamination is possible using available technologies, but requires further research, investment, education and practical know-how. Disinfection of lagoon water with radiofrequency technology is emerging as a commercial-scale treatment option (Lagunas-Solar et al. 2005). However, researchers acknowledge there are logistical challenges associated with dairy lagoon water (Campbell-Mathews *personal communication*). Composting is a sure option to reduce pathogens to safe levels. Yet many agronomic questions remain including nutrient synchronicity, delivery to the root zone without volatilization and surface residues under no-tillage (Crohn *personal communication*).

Both N and K found in all forms of cow manure are in need of disposal by dairy farmers to avoid buildup in their own soil (Cullor *personal communication*). Orchard crops such as almond present an opportunity because of high N and K crop requirements (Brown *personal communication*). The extent of this opportunity is constrained because California soils retain low levels of organic matter. However, application beyond these levels could result in a sustainable source of N as any excess C is mineralized (Horwath *personal communication*).

Farm Advisors
Eleven farm advisors for permanent crops from counties extending from the Sacramento Valley to the San Joaquin Valley as well as the North Coast were contacted and requested to fill out an interview questionnaire. Part one asked to describe field experiences with regard to the use of organic matter amendments and suggest motivations of the growers who use them. Part two asked to share concerns with the use of organic matter amendments as well as the largest challenge to their widespread use. A qualitative assessment was conducted where key words and phrases were coded and tallied for their frequency (Tracy 2013).

All farm advisors encountered at least one grower using organic matter amendments, mainly in the composted form. Sacramento Valley and North Coast advisors cited poultry manure as the most commonly used amendment, whereas several San Joaquin Valley advisors had witnessed the use of green waste and other composts. About one third of the advisors specified that the timing of use was either at planting or during postharvest. The most unique experience with organic matter amendments occurred where cattle manure and lagoon water were produced in excess by the dairy industry. Manure was spread on crops as a disposal method, creating an affordable fertilizer source with several negative outcomes, including weed problems and Zn deficiencies. Two other advisors in the San Joaquin Valley noted attempts with green waste in various forms to supplement young trees, but found it to be either more expensive and logistically difficult or less effective, resulting in smaller trees.

Organic certification was described by more than half of advisors as a motivation for the use of organic matter amendments. Advisors chronicled the limited fertilizer options available to certified organic growers, noting that they used composted and raw poultry and dairy manure at planting and at various times of the season. An equally common factor behind grower motivations was the desire to improve soil structure, with a particular focus on improving water infiltration and soil organic matter. This view was shared by advisors across the Central Valley. Nearly half of the advisors believe growers use organic matter amendments to supply trees with micro or macronutrients including N and P. A few of the advisors cited low cost and slower nutrient release as a substitution for needing multiple applications. Two advisors mentioned the need for disposal of excess animal manure from dairy farms also motivated growers.

Nearly all advisors described food safety as one of the main concerns, particularly as it relates to raw manure. Some believed this concern is amplified by the fact that compost may be incompletely processed. Other concerns shared by a few advisors included the higher costs associated with transportation, application, and other logistics. Even in areas with good to excellent access to animal manure and low transport costs, advisors worry that the additional processing steps prohibitively increase cost. Some advisors also mentioned the absence of incorporation in no-till orchards could lead to volatilization or higher persistence of pathogens at harvest. Concerns that were present but not widely shared included worker safety, soil salinity, odor from manure, P loading from poultry-derived amendments, low agronomic value of green waste, poor access to animal manure and green waste, and the potential for increased organic matter to act as an herbicide suppressor and weed seed reservoir.

The most discussed challenge to widespread use of organic matter amendments was the high cost of transportation and application. Many advisors saw this cost as especially limiting because growers must pay more money for less value in terms of nutrients. About one third of advisors felt that use of organic matter amendments is significantly limited by poor access, a view most prominent in the Sacramento Valley area. A few also felt that the absence of incorporation in no-till orchards was not simply a concern, but a significant challenge to adoption. Still others, from the San Joaquin Valley and the North Coast cited the fact that the volume of material required to achieve adequate nutrition and benefits is often impractically large for widespread implementation. Other obstacles to adoption mentioned by advisors were a general lack of understanding of the nutrient values as well as a sense that spreading and incorporation run counter to the recent trend toward fertigation.

Focus Groups:

Focus groups were conducted in the form of group interviews with certified permanent crop advisors (CCAs) while attending the Nitrogen Workshops sponsored by the California Association of Pest Control Advisors (CAPCA) conducted January through March 2014. The goal was to test the validity and rationale of questions for design of the grower mail survey (See ‘Grower Survey’ section). The focus groups consisted of polling participants who remotely responded with clickers (Turning Technologies, Youngstown OH). This technology allows each participant to answer each question once, and then displays the results in real time with the response percentages to each answer choice and the total number of responses. In order to ensure adequate coverage of the CCA service area, focus groups were held in Modesto, Woodland, Fresno and Tulare. Up to 278 total active focus group participants were polled. Results were aggregated to ensure an adequate sample size, and response percentages are reported as weighted means and weighted standard errors.

The first series of questions asked focus group participants if they work with growers that use or do not use organic matter amendments. Response percentages show the use of all forms of organic matter amendments in permanent crops including composted manure (63%), raw manure (39%) and green waste (41%) as well as lagoon water (22%), cover crops (76%) and chopped prunings (95%). The organic matter amendment with the highest use was composted manure with an even greater use of cover crops and chopped prunings. The lowest use was lagoon water perhaps due to the cost & logistics of its delivery or the food safety risk (**Table 1**).

Additional questions included use of manure and green waste during planting, non-bearing and/or bearing stages, application during postharvest to bloom and/or spring to summer, placement in the tree berm and/or alleyway and management including incorporation, light disking or no-tillage. Management differences of animal manure and green waste varied. The practice of no-tillage with animal manure (59%) was lower than green waste (72%). Placement in the tree berm (48% and 55%) and across the whole orchard (36% and 31%) demonstrates growers target organic matter amendments near the root zone. Timing from postharvest to bloom (76% and 77%) aims to maximize the interval between application and harvest. The majority of organic matter amendments were applied at planting and during the non-bearing stage (53% and 40%) as well as at all stages (37% and 47%) of orchard development. Fewer participants reported use during the bearing stage only (10% and 13%) (**Table 2**).

Participants were also polled on their management of cover crops, chopped prunings and chipped wood. The use of chopped prunings coincided with minimum or no-tillage (90%). Cover crops were either tilled in (54%) after being seeded and grown for biomass or maintained as ground cover under no-tillage (46%). Burning tree wood after orchard life was minimal (6.4%) with the majority of wood being hauled away (72%) after chipping (**Table 2**).

Finally, participants were asked to rank issues of concern for the use of animal manure and green waste including food safety, cost & logistics and nutrient availability. Food safety was the greatest concern (52%) for animal manure and less of a concern for green waste (38%), while uncertainty in nutrient availability was the secondary concern (42%) for both materials (**Table 3**). These results suggest approaches that minimize the risk of food safety and enhance nutrient availability are important considerations with cost & logistics also playing a role.

Table 1. Response percentages from focus group participants who were polled if they work with a grower who uses or does not use organic matter amendments in different forms, lagoon water, cover crops and chopped prunings - Data reported as weighted means +/- standard errors.

	Use			Not Used		
Composted Manure	63%	±	6%	37%	±	8%
Raw Manure	39%	±	6%	61%	±	7%
Green Waste	41%	±	2%	59%	±	3%
Cover Crops	76%	±	3%	25%	±	3%
Chopped Prunings	95%	±	2%	5.1%	±	2%
Lagoon Water	22%	±	7%	78%	±	7%

Table 2. Response percentages from the focus group participants who were polled during what stage of orchard development, timing of application, placement and management are used for animal manure or green waste - Data reported as weighted means +/- standard errors.

	Plant and Non-bearing			Bearing Only			All Stages		
Animal Manure	53%	±	11%	10%	±	3%	37%	±	10%
Green Waste	40%	±	6%	13%	±	4%	47%	±	10%
	Postharvest to Bloom			Spring to Summer			All Year		
Animal Manure	76%	±	8%	14%	±	5%	9%	±	4%
Green Waste	77%	±	4%	10%	±	2%	13%	±	4%
	Tree Berm			Alleyway			Whole Orchard		
Animal Manure	48%	±	9%	16%	±	3%	36%	±	11%
Green Waste	55%	±	10%	14%	±	1%	31%	±	11%
	Incorporation			Light Disking			No-tillage		
Animal Manure	20%	±	3%	21%	±	1%	59%	±	4%
Green Waste	17%	±	3%	12%	±	2%	72%	±	6%
Cover Crops	20%	±	1%	34%	±	5%	46%	±	6%
Chopped Prunings	10%	±	3%	7.4%	±	2%	83%	±	4%
	Haul Away			Left in Field			Burn		
Chipped Wood	72%	±	1%	22%	±	5%	6%	±	4%

Table 3. Response percentages from focus group participants for how they would rank food safety, cost & logistics and nutrient availability as the greatest, secondary or least issue of concern with regard to the use of animal manure or green waste - Data reported as weighted means +/- standard errors.

Animal Manure	Food Safety			Cost & Logistics			Nutrient Availability		
Greatest	52%	±	3%	31%	±	3%	17%	±	1%
Secondary	20%	±	3%	38%	±	5%	42%	±	4%
Least	28%	±	4%	30%	±	5%	42%	±	5%
Green Waste	Food Safety			Cost & Logistics			Nutrient Availability		
Greatest	38%	±	5%	38%	±	4%	24%	±	3%
Secondary	23%	±	2%	35%	±	6%	42%	±	6%
Least	39%	±	6%	28%	±	6%	33%	±	7%

Grower Survey:

To understand the use of organic matter amendments in almond, a mail survey was developed to reach the population of California almond growers using membership lists provided by the Almond Board of California and by the Blue Diamond Growers. The final survey was delivered to 6,786 addresses. The survey opened with a question about what areas benefit from the use of organic matter amendments and was followed by questions in chronology of an orchard life cycle including practices at planting, non-bearing and bearing stages. A greater emphasis was made to separate the timing, placement, management and issues of concern for composted and raw animal manure as well as green waste compost and uncomposted green waste. A question was included about grower access to animal manure or green waste. Tables are constructed with percentage responses, and the figure is a map with frequency of response by zip code for the use of organic matter amendments during any stage of the orchard life cycle.

Preliminary results were gathered and analyzed on July 31st 2014. The total number of replies was 928 out of a total of 6,656 mailings for a 14% response rate. The number of surveys returned was 725 with 60 completed over the internet and the remainder by mail. The difference of 203 were opt outs. The response rate in acreage was higher at 23% or 216,300 acres out of ~940,000 reported in the 2013 almond acreage report. The center of participants indicating the use of organic matter amendments during any stage was Stanislaus and Merced counties. From 1-10 use responses were found in other parts of the Central Valley (**Figure 1**).

Participants were asked to rank what benefits including soil biology, tree nutrition and water holding capacity are expected from the use of organic matter amendments. The greatest benefit was attributed to soil biology (48%) followed by tree nutrition (40%) and water holding capacity as the least benefit of the three (**Table 4**). There was greater use of composted materials than uncomposted ones during all orchard stages (**Table 5**). Responses for the timing of application, placement and management differ between composted or uncomposted organic matter amendments. The vast majority of materials were applied from postharvest to bloom (80% - 95%). The placement of composted manure (53%) and green waste compost (58%) on the tree berm was greater than raw manure and uncomposted green waste. Furthermore, there was greater incidence of no-tillage being used with composted manure (76%) and green waste compost (80%) compared to raw manure (46%). No-tillage practices were also used with cover crops (82%) and chopped prunings (79%) by growers (**Table 6**).

Growers reported good or better access to animal manure (64%) compared to green waste (41%) (**Table 7**). Furthermore, growers noted a greater incidence of burning of tree residues (23%) compared to what was reported during the focus groups. Food safety was the issue of greatest concern, followed by nutrient availability as secondary and cost & logistics as the least concern of the three with no differences between composted and uncomposted materials.

Growers attributed soil biology benefits to the use of organic matter amendments. They also appeared to use greater amounts of composted compared to raw or uncomposted materials. Grower use of composted materials fits with no-tillage practices and targets greater placement in the tree berm. Composting may resolve the greatest concern of food safety. Yet a secondary concern remains in terms of nutrient availability from the compost as well as how the compost interacts with other fertilizers. This issue may further interact with soil biology.

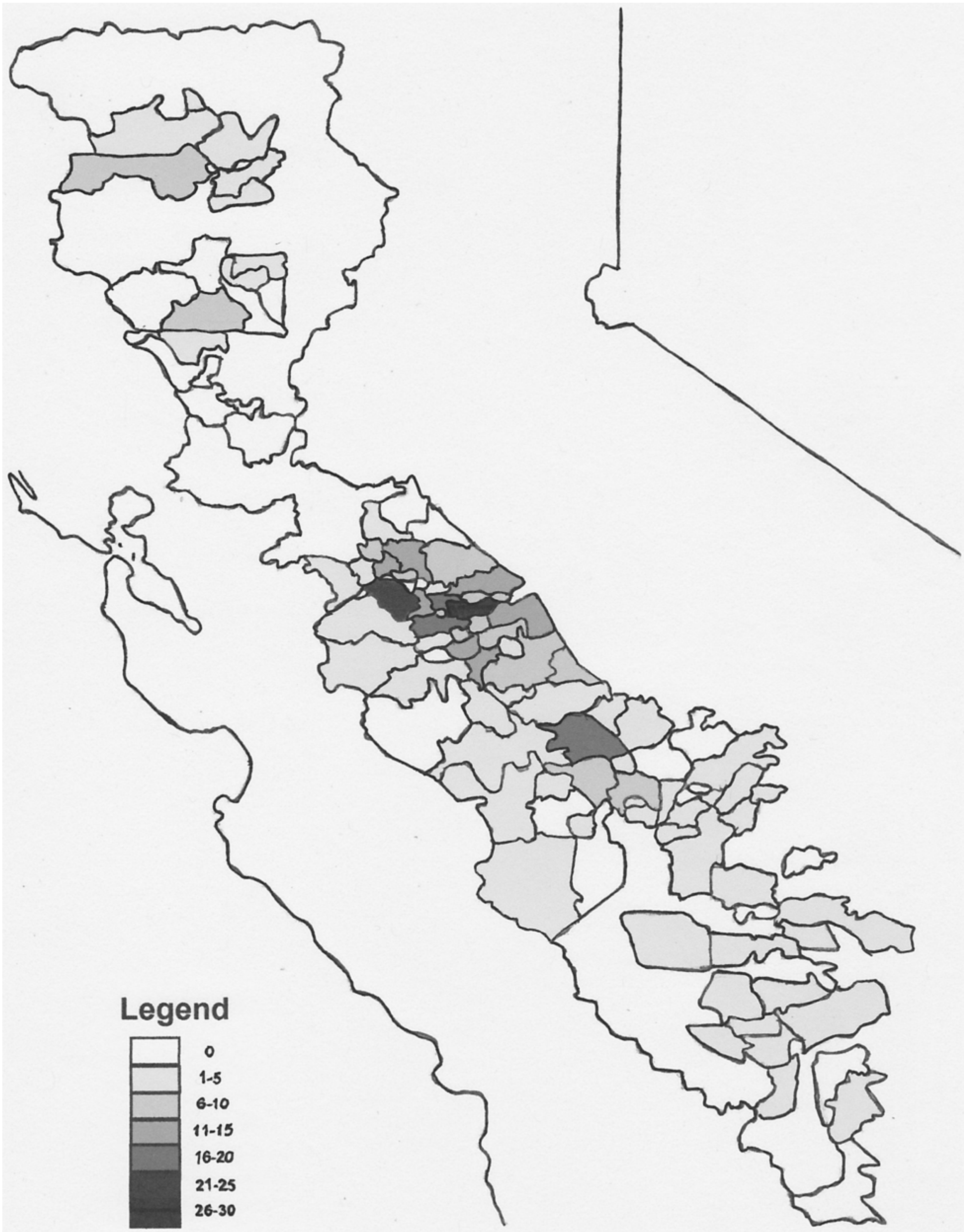

Figure 1. Frequency of responses where participants indicated the use of organic matter amendments during any stage of orchard life including planting, non-bearing or bearing stages presented geospatially using zip codes.

Table 4. Response percentages for the ranking of soil biology, tree nutrition and water holding capacity as greatest, secondary or least benefit to an orchard from the use of organic matter amendments.

	Soil Biology	Tree Nutrition	Water Holding Capacity
Greatest	48%	40%	12%
Secondary	36%	33%	31%
Least	16%	27%	57%

Table 5. Response percentages for the use of organic matter amendments in different forms during planting non-bearing and bearing stages of orchard development.

	Planting	Non-bearing	Bearing
Composted Manure	43%	46%	43%
Green Waste Compost	33%	29%	28%
Raw Manure	21%	20%	18%
Uncomposted Green Waste	3%	5%	11%

Table 6. Response percentages for use of organic matter amendments in different forms during stages, timing, placement and management including cover crops, chopped prunings and chipped wood.

	Postharvest to Bloom	Spring to Summer	All Year
Composted Manure	95%	2%	3%
Green Waste Compost	86%	7%	7%
Raw Manure	94%	3%	3%
Uncomposted Green Waste	80%	10%	10%
	Tree Berm	Alleyway	Whole Orchard
Composted Manure	53%	30%	17%
Green Waste Compost	58%	23%	19%
Raw Manure	24%	55%	21%
Uncomposted Green Waste	17%	73%	10%
	Incorporation	Light Disking	No-tillage
Composted Manure	14%	10%	76%
Green Waste Compost	11%	9%	80%
Raw Manure	32%	22%	46%
Uncomposted Green Waste	22%	14%	64%
Cover Crops	8%	10%	82%
Chopped Prunings	14%	7%	79%
	Haul Away	Left in Field	Burn
Chipped Wood	62%	15%	23%

Table 7. Response percentages for how growers rank their access to animal manure and green waste as poor to fair, good or very good to excellent

Access	Animal Manure	Green Waste
Poor to Fair	46%	59%
Good	29%	24%
Very Good to Excellent	25%	17%

Research Effort Recent Publications:
None.

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