Comparison of Production Costs and Resource Use for Organic and Conventional Production Systems

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The USDA established the National Organic Program (NOP) to develop national standards for organically produced agricultural products and establish an organic certification program as required by the Organic Foods Production Act (OFPA) passed by Congress in 1990. Organic crop production excludes conventional pesticides, petroleum – based fertilizers, and sewage sludge based fertilizers with some notable exceptions. OFPA also required the establishment of the "National List of Allowed and Prohibited Substances" for use in organic agriculture. The National List includes allowed synthetic substances and prohibited non-synthetic (natural) materials.

The NOP crop standards require that soil fertility and crop nutrients be managed through tillage and cultivation practices, crop rotations and cover crops, supplemented with animal and crop waste materials, allowed mined substances, and synthetic materials allowed on the National List. Similarly, crop pests, weeds, and diseases are required to be controlled primarily through cultural practices such as tillage and cultivation, hand weeding, crop rotations, sanitation, and the introduction of predators or parasites. When these methods prove to be insufficient, growers may use approved natural or synthetic

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substances on the National List. Therefore, contrary to popular perceptions, NOP regulations do not require organic production practices to be void of fertilizers and pesticides. In practice, the use of allowable supplemental fertilizers and pesticides varies from crop to crop depending on pest pressures, the cost, efficacy, and availability of control materials, and the value of the crop.

In this paper we compare the farming practices used for a range of California crops with respect to inputs employed (materials, fuel, and labor) and the related costs. We determine the types of substitutions made for synthetic fertilizers and pesticides by organic farmers. In particular, we identify the circumstances under which cultural practices are insufficient and allowed fertilizer supplements and pesticides are employed, illuminating the complexity of organic production and its unique challenges.

Methodology

A model of the cost of production and resource use for individual farms is applied to a set of hypothetical commercial organic and conventional farms in California for both organic and conventional production for field crops (alfalfa, processing tomatoes, and corn in the Sacramento Valley), vegetable crops (broccoli and lettuce in the Salinas Valley), nut crops (almonds and walnuts in the San Joaquin Valley and Sacramento Valley, respectively) and fruit crops (raisin grapes and strawberries in the San Joaquin Valley and Salinas Valley, respectively). The inputs to the model include a calendar of operations and the corresponding labor, materials, and equipment for each operation for each of the organic and conventional crops based on extensive interviews with established farmers,

University of California Cooperative Extension Farm Advisors, and local input suppliers and buyers.

For each production practice, the model calculates the hours per acre of labor and equipment required based on the size of the implement and the speed of the tractor. Labor is assumed to be 20 percent higher than field operating time to account for equipment setup and breaks. The quantity and costs of materials (pesticides, fertilizer, seed, etc.) are entered into the model based on prices from local suppliers.

Equipment repair costs are based on purchase price, annual hours of use, total hours of life, and repair coefficients developed by the American Society of Agricultural Engineers (ASAE) (Hahn and Rosentreter 2003). Fuel and lubrication costs are also determined by ASAE equations based on maximum power – take – off (PTO) horsepower and fuel type. Prices for diesel and gasoline are west coast prices reported by the (U.S. Department of Energy, Energy Information Administration.

Comparison of Organic and Conventional Crop Production Systems

Organic and conventional systems are compared for a complete range of crops including field crops (alfalfa, processing tomato, and field corn), vegetables (broccoli and lettuce), fruit (strawberries, and raisin grapes), and tree nuts (almonds and walnuts). For each crop, the differences and similarities in the methods and related costs of fertility and pest and disease control are detailed. Fertility and control costs include materials, labor, fuel, lube, and repairs on equipment used. Equipment ownership, taxes, insurance, and housing are not included in the cost estimates. Resource use is also compared in terms of gallons of fuel, hours of machine and non – machine labor, and water.

Field Crops

Fertility for organic processing tomatoes and field corn relies on the incorporation of compost and a leguminous cover crop to supply nitrogen and other nutrients (table 1). In contrast, conventional production utilizes preplant and sidedress synthetic fertilizer. The compost is roughly twice as expensive as synthetic fertilizer. It should also be noted that the amount of nutrients supplied by cover crops and compost varies widely and is a source of uncertainty for organic growers. Further, cover crops serve the additional benefits of weed control and providing food and habitat for natural enemies. Therefore, it can be argued that charging all of the cover crop costs to fertility is not appropriate. Cover crop costs range from $40 to $120 per acre and vary depending on the number of operations used for land preparation, the type of seed, and the number of operations used to mow and/or incorporate the cover crop prior to planting the cash crop.

Comparison for alfalfa is complicated by the fact that alfalfa is a perennial crop. Therefore, there are differences in stand establishment and production years. Organic alfalfa uses compost at establishment but not in subsequent years. Conventional establishment uses synthetic fertilizer. Allowable pesticide materials are available for armyworm control in organic alfalfa but not alfalfa weevils. Growers rely on shorter intervals between cuttings for control but this can lead to lower yields. Aphids are controlled by planting resistant varieties. Conventional production typically includes three pesticide applications per year. Therefore, conventional pest control costs for these three pests are higher than in production, $64 vs. $40 (table 1). Weeds are arguably the biggest challenge for organic alfalfa production. Organic growers are limited to crop

rotation, disking before planting, and possibly winter grazing for weed control. Conventional growers depend on synthetic herbicides. Weed pressure can shorten the life of an organic alfalfa stand, therefore spreading the cost of establishment over fewer years than in conventional production.

Vegetable Crops

Organic vegetable producers manage fertility with a combination of cover crops, compost (manure and green waste), bonemeal, bloodmeal, and liquid fertilizers from plant material. Conventional growers also apply manure, albeit at a lower rate, to improve water infiltration and improve soil tilth rather than supply nutrients. Basic nutrients are supplied with synthetic fertilizers (table 2).

In California vegetable growers typically plant 1.5 to 2.5 vegetable crops per year. Therefore, the inclusion of a cover crop will reduce the number of cash crops from a given piece of land. To mitigate the decrease in income, growers plant a cover crop only every other year resulting in four organic cash crops compared to five conventional cash crops over the two year period.

Organic growers often interplant insectary plants such as alyssum to control aphids. Up to nine percent of the crop area may be devoted to insectary plants depending on the pest pressure and rental rate of the land. Organic growers make one application of a spinosad pesticide, derived from a naturally – occurring, soil – dwelling bacteria, to control worms compared to four pesticide applications for worm and aphid control by conventional growers. Disease control for organic vegetable production depends primarily on crop rotation and resistant varieties thus limiting planting options. In

contrast, conventional growers utilize multiple materials for mildew control, with four sprays for our representative farm at a cost of $259 per acre for lettuce. Weed control for both organic and conventional production is similar with several mechanical cultivations followed by hand weeding. Conventional production also relies on a preplant herbicide (table 2).

Fruit Crops

Arguably, the most extreme difference between organic and conventional fruit and nut production is the use of fumigation in conventional production costing over $1,200 per acre. Fumigation is the standard practice prior to planting for some conventional annual crops such as strawberry production and prior to planting of vineyards and orchards. Essentially, soil fumigation is a soil sterilization process that kills weed seeds, nematodes, arthropods, and soilborne fungi and plant pathogens. Fumigation allows conventional strawberries to be planted continuously without rotation to another crop and trees and vines to be planted immediately after the removal of the preceding orchard or vineyard. Although not allowed in organic production, the site of an orchard or vineyard planted for organic production can be fumigated prior to planting. By the time the orchard or vineyard comes into marketable production three or more years later, the required three year transition period will be completed.

Fertility in organic strawberry production relies on a cover, crop, compost, and several liquid and foliar fertilizers. The liquid fertilizer is applied through the drip system to supply nitrogen, phosphorous and other nutrients. Foliar sprays include seaweed and calcium. Conventional strawberry production utilizes the same biological control

methods as organic for mites and worms early in the season but then uses synthetic materials. Predatory mites are released twice by conventional growers followed by five applications of miticide. In contrast, organic growers make four releases of predatory mites in April and May. Conventional growers apply Bacillus thuringiensis (Bt) to control worms early in the season one time, while organic growers will make several applications in the spring. In addition, conventional growers spray several times for lygus bug control. Disease control for conventional growers is comprised of multiple applications of several fungicides for a total of eight applications using seven different materials on our representative farm. Organic growers follow the same disease control schedule but only have sulfur at their disposal for powdery mildew control and no materials to control botrytis. Hand culling and disposal of diseased fruit is the only available control beyond planting resistant varieties, adding substantially to cost (table 3).

Pest control is less intensive for raisin grapes than strawberries. Conventional growers utilize a range of synthetic pesticides to control specific pests depending on pressures. Four or more applications are common. Organic growers commonly use Bt at bloom for leafroller control. Good irrigation practices, good nutrition, and avoiding dust are pest control methods available to all growers but are even more critical to organic growers who do not have a broad range of pesticide materials available in their tool bag. As with strawberries, disease control for organic and conventional raisins follows the same schedule. Both make use of sulfur and copper but conventional growers make use of additional fungicides not allowed in organic production.

Weed control between the vine rows is often identical for organic and conventional growers. When cover crops are used, the middles are mowed. If not, disking is the standard. Cover crops are more commonly planted by organic growers. Conventional growers apply herbicides along the vine rows while organic growers use a plow designed to cultivate around vines. Perhaps the biggest difference is the use of plant growth regulators in conventional production for thinning in May and to accelerate maturity in July. Organic growers can hand thin clusters and pull leaves to hasten maturity but have no growth regulator materials available.

Tree Crops

Disease and insect control in organic almond production is particularly challenging with organic yields ranging from 50 to 80 percent of conventional yields depending on pest and disease pressure. Disease problems escalate in wet years. Both organic and conventional almond production rely on winter orchard sanitation comprised of removing any remaining nuts on the trees for navel orange worm (NOW) control and dormant oil to control San Jose scale. Both systems apply additional pesticides to control peach twig borer and NOW but the materials used by organic growers are less effective than those available to conventional growers. In addition, conventional growers may spray to control mites and ants. Similarly, both systems spray during the dormant season to control disease and scab but the materials used differ (table 4).

For walnuts, flowering much later in the spring, disease and pollination are not as challenging as in almonds. Walnut husk fly is the primary pest controlled by multiple

sprays in organic production of spinosad and synthetic insecticide in conventional production. Both systems rely on copper products to control walnut blight.

Fertility in the organic orchards relies on both a cover crop and compost while the conventional orchards apply synthetic fertilizer through the irrigation system. In addition, foliar sprays of zinc and boron are applied in both systems. Weed control in orchard middles is disking in orchards without cover crops and mowing in orchards with cover crops. Along the tree rows, organic growers hand weed with a hoe or a string trimmer for walnuts and flame for almonds.

All Crops

Both organic and conventional systems utilize crop rotations, tillage, and cultivation. Cover crops are planted for all organic crops except alfalfa and strawberries. Animal or crop waste compost is applied for all organic crops except raisins and on conventional vegetables. Other animal and plant materials are applied to organic vegetables and strawberries and mined substances to fruit and nut crops. Table 5 summarizes the costs per acre from tables 1 – 4. The sample costs for the representative farms show the fertilizer costs for organic production to be higher for organic production than conventional production for all crops except alfalfa. The largest difference is for vegetable production, $632 per acre for organic broccoli and $910 per acre for organic lettuce compared to $260 and $382 for conventional broccoli and lettuce, respectively.

Both systems managed weeds in part with tillage and cultivation. Hand weeding is used on all crops except alfalfa and corn for both systems. All of the conventional and none of the organic systems used herbicides. Herbicide costs per acre ranged from $59

per acre for raisins to $138 per acre for almonds. Weed control costs are higher than conventional for all organic crops dependant on hand weeding and lower for the two crops using no hand weeding, corn and alfalfa. Weed control costs are similar for the nut crops for both systems.

Disease control for both systems includes sanitation for almonds and raisins. Introduction of predatory mites is used for both strawberry systems. Tomato, vegetables, and nut crops supplement control with allowable pesticides. Nonetheless, organic insect and mite control costs are lower than conventional in all cases except almonds ($452 vs. $307) with organic tomato and corn applying no insecticides or miticides. For disease control processing tomatoes, walnuts, and almonds all show higher costs for the organic system. In contrast, disease control is lower cost for both organic fruit crops. In sum, the total cost of fertility, weed, pest, and disease control is higher for the organic systems than the conventional systems except for strawberries and lettuce due to the fumigation of strawberries and the high use of synthetic pesticides in lettuce.

Comparison of Resource Use for Organic and Conventional Production

Table 6 reports the resource use for each crop and system. Hand weeding is used in both systems for all vegetable and fruit crops, processing tomatoes, and walnuts. In each of these cases the cost of hand hoeing is greater in the organic system than the conventional system that also employs herbicides. For broccoli and lettuce the hours of hand weeding are at least twice that of the conventional system (21 vs. 8 hours per acre for broccoli and 12 hours vs. 6 hours for lettuce). For processing tomatoes the difference is even greater with 30 hours for the organic system versus only six hours for the conventional system.

Machine labor is comparable between systems except for lettuce due to the high number of pesticide applications for conventional production. Fuel, machine labor, lube and repairs, did not differ importantly between organic and conventional systems with the exception of organic almonds, using 50 gallons of propane for flaming. Relative fuel use is highly dependent on whether or not cover crops are planted and the number of pesticide applications.

Discussion

Expected yields are comparable for organic and conventional production with the notable exception of lower expected output for organic strawberries and almonds making the profitability of these crops highly dependent on price premiums for organic products. Organic alfalfa yields are comparable to conventional on an annual basis but the stand life is shortened due to mounting weed pressure which raises production costs. Organic vegetables produce fewer crops over a two year period from an acre of land than conventional production reducing revenue even when yields are the same. Therefore, organic vegetables and alfalfa are also dependent on organic price premiums to realize the same profits as conventional production. We anticipate that these results will provide a useful foundation for further inquiry and more extensive statistical modeling.

References

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Table 1. Farming Practices and Costs for Organic and Conventional Field Crops

Crop	Practice	Operations	Organic ($/A)	Conventional ($/A)
Alfalfa	Fertility	Compost - 4 tons	59	
		Fertilizer		76
	Weed control	Harrow	3	
		Herbicide		44
	Pest control	Insecticide	40	64
Tomato	Fertility	Cover Crop	72	
		Compost	184	
		Preplant and side dress		86
	Weed control	Cultivate and mulch	34	34
		Hand hoe	379	67
		Herbicide		114
	Disease control	Sulfur	65	33
	Pest control	Insecticide		40
		Pest control subtotal	65	73
Corn	Fertility	Cover crop	34	
		Compost	171	
		Synthetic fertilizer		99
	Weed control	Cultivate	29	15
		Herbicide		69

Table 2. Farming Practices and Costs for Organic and Conventional Vegetables

Crop	Practice	Operations	Organic $/A	Conventional $/A
Broccoli	Fertility	Cover crop 1x every 2 years	20	
		Compost	119	38
		Bloodmeal and bonemeal	493	
		Preplant and sidedress fertilizer		222
	Weed control	Cultivate and furrow	16	16
		Hand hoe	254	94
		Herbicide		51
	Pest control	Insectary planting	3	
		Insecticides	23	397
Lettuce	Fertility	Cover crop	50	
		Compost and pelleted manure	426	64
		Bloodmeal	347	
		Liquid fertilizer	87	80
		Preplant synthetic fertilizer		238
	Weed control	Cultivate and mulch	34	8
		Hand hoe	219	80
		Pre-emergent herbicide		575
	Pest control	Insectary planting	4	
		Pesticides	91	302
	Disease control	Fungicide		272

Table 3. Farming Practices and Costs for Organic and Conventional Fruit Crops

Crop	Practice	Operations	Organic $/A	Conventional $/A
Strawberry	Fertility	Compost	147	
		Bloodmeal	237	
		Foliar	275	
		Liquid fertilizer	346	187
		Preplant fertilizer		674
	Weed control	Cultivate	15	
		Hand hoe	2,070	760
	Pest control	Predatory mites	251	258
		Bt	69	28
		Pesticide		594
	Disease control	Fungicide	68	487
	Fumigation	Weed, pest, and disease control		1,270
Raisins	Fertility	Cover crop	65	
		Liquid fertilizer		16
		Zinc foliar		5
	Weed control	Mow middles	31	
		Vine row plow	112	
		Vine row herbicide		59
	Pest control	Miticide	62	
		Insecticide		108
	Disease control	Fungicides	203	225
	Growth regulator	Thin fruit and fruit set		17

Table 4. Farming Practices and Costs for Organic and Conventional Nut Crops

Crop	Practice	Operations	Organic $/A	Conventional $/A
Almonds	Fertility	Compost	282	
		Foliar zinc and boron	20	19
		Potassium nitrate		92
		N fertilizer - Urea		120
	Weed control	Mow middles	26	26
		Flame tree rows	134	
		Herbicide middles		32
		Strip herbicides		106
	Pest control	Winter sanitation	145	145
		Oil	184	
		Bt, Spinosad, and boric acid	123	
		Synthetic insecticides		162
	Disease control	Sulfur	131	
		Fungicide		78
Walnuts	Fertility	Manure pellets	75	
		Compost and gypsum	117	
		Foliar zinc	29	
		Liquid fertilizer		59
	Weed control	Mow middles	26	26
		Hand weed tree rows	36	
		Strip herbicide and spot spray		47
	Pest control	Insecticide	86	42
	Disease control	Copper foliar	60	32

Table 5. Summary of Fertility, Weed, Pest, and Disease Management Costs for Organic and Conventional Practices

Crop	Fertility		Weed Control		Pest Control		Disease Control		Other[a]	Total of costs	
	Organic	Conven-tional	Organic	Conven-tional	Organic	Conven-tional	Organic	Conven-tional	Conven-tional	Organic	Conven-tional
	$ per Acre										
Alfalfa	59	76	3	44	40	64				102	184
Tomato	256	86	413	215		40	65	33		734	374
Field Corn	205	99	29	84						234	183
Broccoli	632	260	270	161	26	397				997	685
Lettuce	910	382	253	229	95	302		259		1,258	1,627
Strawberries	1,005	861	2,085	760	320	880	68	487	1,270	3,478	4,258
Raisins	65	21	143	21	62	108	203	225	17	473	392
Almonds	302	231	160	164	452	307	131	78		1,045	780
Walnuts	221	59	62	73	86	42	60	32		429	206

[a]Other costs are fumigation for strawberries and growth regulators for raisins

Table 6. Labor, Fuel, and Water Use for Organic and Conventional Practices

	Machine Labor (hrs/Acre)		Hand Labor (hrs./Acre)		Fuel (Gallons/Acre)		Water Acre Inches/Acre	
	Organic	Conven-tional	Organic	Conven-tional	Organic	Conven-tional	Organic	Conven-tional
Alfalfa	0.9	0.83	1.5	1.1	2.17	1.53	42	42
Tomato	7.1	6.5	35.8	11.9	56.9	51.2	42	42
Field Corn	4.2	4.4	1.3	1.3	32.9	37.3	36	36
Broccoli	5.9	3.3	29	14.5	49.3	33.6	30	30
\Lettuce	8.6	15.1	43.3	10.7	69.1	73.9	17	17
Strawberries	24.8	34.4	427.1	183.2	64.48	54.1	28	28
Raisins	18.47	15.17	37	35.4	53.9	40.3	28	28
Almonds	12.8	10.1	20.1	20.3	78.69	21.6	44	44
Walnuts	8.7	10.1	11.1	8.1	22.2	19.5	24	24