An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa

Kathleen Delate[1], Michael Duffy[2], Craig Chase[3], Ann Holste[2], Heather Friedrich[1], and Noreen Wantate[1]

[1]Department s of Agronomy & Horticulture, 106 Horticulture Hall, Iowa State University, Ames, IA 50011-1100
[2]Department of Economics, Heady Hall, Iowa State University, Ames, IA 50011-1100
[3]Iowa State University Extension Service , Iowa State University, Waterloo, IA

A version of this paper (using metric units) has been published in the American Journal of Alternative Agriculture Vol. 18 (2): 59–69. Journal paper No. 19802 of the Iowa Agriculture and Home Economics Expt. Sta., Ames, Iowa. We would like to thank the Leopold Center for Sustainable Agriculture and the Neely-Kinyon Farm Association for their support of this project.

Additional index words: Organic rotations, conventional rotations, agricultural profitability, economic returns, labor requirements, production cost comparisons

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Abstract
Based on an interest by organic and conventional farmers in Iowa for a long-term analysis of organic systems, the Neely-Kinyon Long-Term Agroecological Research site was established in 1998 to examine the agronomic and economic performance of conventional and organic systems, using certified organic production practices. We report here the results of the economic analysis from three years of production (1999–2001). Returns for corn within the organic corn-soybean-oat and corn-soybean-oat-alfalfa rotations were significantly greater than conventional corn-soybean rotation returns at $51/acre. Corn returns were not significantly different between the two organic rotations at $264/acre and $272/acre, respectively. Returns for soybean within the organic corn-soybean-oat and corn-soybean-oat-alfalfa rotations were not significantly different at $470/acre and $505/acre, respectively. Organic soybean returns were significantly greater than conventional soybean crop returns ($95/acre) in the corn-soybean rotation.

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Introduction

Sales of organic products are expected to reach $8 billion industry in the U.S. in the year 2001, continuing a 20% annual growth rate (OTA, 2000; Greene, 2000). The most recent U.S. census in 1994 identified 1.5 million acres of organic production in the U.S. with 4,050 farmers. The Organic Farming Research Foundation placed the number of organic farmers at 10,000 in 1997 (Walz, 1999). In 1999, Iowa farmers reported 120,000 acres of organic production to the Iowa Department of Agriculture and Land Stewardship survey (IDALS, 2000). This figure reflects only acreage reported by those farmers who returned their survey; thus, many more acres are believed to go unreported. This increase represents a doubling in organic acres from the previous year, and a six-fold increase from 1996.

European consumers have led the demand for organic products, particularly in areas such as the Netherlands and Scandinavia. Two percent of all German farmland, 4% of Italian farmland and 10% of Austrian farmland, respectively, is managed organically (Zerger and Bossel, 1994). The world market for organic products is listed at $45 billion. While the desire for genetically modified (GM)-free foods has contributed to this increase in organic food consumption, U.S. consumers also perceive health benefits from organic foods (Wilkins and Hillers, 1997), with 90% of U.S. citizens willing to consider including organic foods in their diets (Hartman Report, 2001).

Economic Sustainability of Organic Systems

In addition to producers, governmental and financial institutions are interested in the economic sustainability of organic systems. As shown in the Table 1, scientific studies across the U.S. have demonstrated the economic viability of organic cropping systems. The majority of these studies describe economic benefits of organic systems without government support and premium prices. In addition, different levels of experience with organic production create discrepancies when analyzing crop production between systems. Accounting for externalities associated with agricultural production, such as costs associated with run-off, spills, or the depletion of natural resources, are also lacking. Thus, additional economic benefits could be assumed with experienced organic farmers receiving certified organic premiums in a society willing to compensate farmers for conservation practices.

Long-Term Agroecological Research (LTAR) in Iowa

In 1998, the Leopold Center for Sustainable Agriculture identified the need for dedicated lands throughout Iowa where research on organic practices could be conducted over the long term (Delate and DeWitt, 1998). The Neely-Kinyon (N-K) Long-Term Agroecological Research (LTAR) site was established in 1998 to examine the agronomic and economic performance of conventional and organic systems, using required practices for certified organic production. We report here the results of the economic analysis from three years of production (1999–2001).

Materials and Methods

The Neely-Kinyon Farm Association dedicated a 17-acre block for this long-term study. After meeting with focus groups and the N-K Farm Association, we developed an experimental design to evaluate typical rotations in the surrounding area (Delate, 2002). Treatments in the LTAR experiment were established in a completely randomized design with four replications, and included conventional

Corn-Soybean (C-Sb), organic Corn-Soybean-Oats/Alfalfa (C-Sb-O), organic Corn-Soybean-Oats/Alfalfa-Alfalfa (C-Sb-O-A) and soybean-winter rye (Sb-R) where fall-planted rye was incorporated in the spring prior to planting soybeans. All crops in all rotations were grown each year on 0.25-acre plots using farm-size equipment and practices. Crop variety selection and planting methods from 1999–2001 followed the recommendations of the N-K Farm Association, which included the most suitable corn, soybean, oat and alfalfa hybrid varieties for the area. Untreated seed was used in the organic fields, per certification requirements. Oats were underseeded with leafhopper-tolerant alfalfa for the first year of the O/A-A rotation, followed by a pure stand of alfalfa in the second year. Harvests occurred within the normal harvesting period for each crop, using standard farm equipment, such as combines and hay rakes for alfalfa. Following harvest of the organic corn plots, winter rye was no-till drilled at a rate of 1 bu/acre. A hay crop (alfalfa, fescue and oats), seeded in 1998 in the 30-ft border strips around each plot and around the perimeter of the experiment, was periodically mowed and maintained as the required buffer between conventional and organic production, per certification standards.

Organic fields were fertilized to provide equivalent rates of nitrogen as in conventional fields (120–150 lb/acre N, depending on stalk nitrate results from previous years) with locally-produced swine hoop-house compost from the ISU Armstrong Research and Demonstration Farm. Weeds were managed in the organic corn and soybean fields through cultivation. Because rye provides natural allelopathic chemicals that mitigate weed seed establishment in soybean production, a winter rye crop was planted prior to soybean. In addition, soybean fields "walked" (large weeds above soybean canopy hand-pulled in a continuous walking movement across fields) to remove any potentially staining weeds that would reduce the market value of the clear-hilum varieties destined for the tofu market.

Conventional fields were fertilized and pests were managed following Iowa State University recommendations. As an example, the pest management regime for conventional corn and soybean in 2000 included the following practices: Harness® and Atrazine®, both at 2 pt/acre, were applied to conventional corn plots on April 24, 2000. Conventional corn plots received Buctril® (1pt/acre), Accent® (67 oz/acre), AMS® (1.25 lb/acre), and NIS® (25 pt/acre) on May 25. Prowl® at 3pt/acre was applied on May 16, 2000, to conventional soybean plots, and 2 pt/acre each of Galaxy®, Prestige®, COC®, and AMS® was applied on June 14. In 1998, Force 1.5 G® was applied for corn rootworm control at a rate of 9 lb/acre at planting in the conventional corn plots, but not warranted in 1999 and 2000, based on sampling.

Field operations and hours

Pre-plant tillage consisted of a field cultivator in the conventional corn rotation and a disk in the soybean rotation (Table 2). Fertilization was applied in the spring. Pre-emergence and post-emergence pesticide applications were made every year. Post-emergent mechanical weed control using a row cultivator was common, per local conventional practices.

Corn operations were identical in the organic rotations. The primary tillage implement following alfalfa was a moldboard plow followed by a tandem disk and field cultivator. Alfalfa and surface-applied compost were incorporated simultaneously with moldboard plowing prior to annual corn crops in the organic fields. Post-emergent mechanical weed control consisted of a harrow, rotary hoe, row cultivator, and propane flame cultivator. Corn stalks were disked and rye planted in the organic rotations following the corn harvest in September-October.

The organic soybean weed-management program began with disking and field cultivating rye prior to soybean planting. Post-emergence weed control consisted of rotary hoeing, row cultivating and "walking" in the organic fields. Alfalfa was seeded with the oat crop for both organic rotations.

The choice and timing of all cultural practices were decided through recommendations of area organic farmers and by the research farm manager. All labor requirements excluding hand labor was estimated from engineering estimates provided by Iowa State University (Chase and Duffy, 1991).

Results

Production costs

The conventional C-Sb rotation incurred lower fieldwork requirements than the organic rotations at 1.87 hr/acre (Table 3). The conventional soybean crop did include 2 hours of hand-labor per acre per year due to the need to "walk" conventional food-grade soybeans. Because this is atypical in a non-food grade conventional C-Sb system, the labor hours used in all forthcoming returns calculations will omit the hand-labor hours (resulting in a rotational average of 0.87 hr/acre). The organic C-Sb-O and C-Sb-O-A rotations incurred 2.6 hr/acre and 2.38 hr/acre, respectively. Within each of the organic rotations, corn and soybeans required the most hours to grow and harvest crops. The application of compost at 12 T/acre and mechanical weed control for corn contributed a vast majority of the fieldwork time needed, whereas hand labor (2 hrs/acre) and mechanical weed control contributed to the soybean hours.

Machinery and input cost of production were determined by applying standardized cost estimates to the cultural practices in each rotation using Duffy (2001, 2000, 1999). This publication is updated and revised yearly. The standardization of costs per operation eliminates differences from purchasing discounts of inputs and machinery repairs and depreciation, among others, and focuses on practices. Herbicide and insecticide price data were obtained from unpublished price lists from suppliers where inputs were purchased. Cost of compost application in the organic C-Sb-O and C-Sb-O-A system was calculated at the cost of application only since compost was received from local sources, per normal organic farming operations in the area of study.

Production costs by crop and rotation are presented in Table 4. Total production costs for the corn in the conventional rotation are substantially higher (46%) than the organic rotations ($198 for C-Sb versus $136 for C-Sb-O and C-Sb-O-A, respectively). The organic rotations did not incur any pesticide or fertilization costs, but did incur higher machinery expenses, as pest management was handled mechanically. Seed expense was higher in the organic rotations due to higher seeding rates.

Total production costs for soybeans in the conventional rotation are higher (12%) than the organic rotations ($128 for C-Sb versus $114 for C-Sb-O and C-Sb-O-A). The major contributing factor was the cost of chemical versus mechanical weed control between the conventional and organic rotations. Seed expense was higher in the organic rotations, however, due to the seeding of rye following corn and prior to soybean planting.

Average production costs for the conventional C-Sb rotation were $33/acre higher than the organic C-Sb-O rotation ($163 versus $130) and $48/acre higher than the organic C-Sb-O-A rotation ($163 versus $115). In these rotations, the cost of seeding the alfalfa crop is included with the cost of oat seed. Savings from the absence of fertilization and pesticide costs in the organic rotations were greater than overall increased machinery and seed expenses.

Yields

Average treatment yields for the 3-year period were tested for statistical significance using analysis of variance (ANOVA). Following determination of significance, Tukey's multiple range test (HSD) was used for testing statistical differences among individual crops.

Individual year yields and average yields by crop and rotation are reported in Table 5. All crops were grown every year; thus the averages cover the entire 3-year period. Variation in weather, varieties, and other conditions did affect the variability in yields from year to year. The differences among rotations, however, remained relatively stable, resulting in poor ANOVA modeling results and the inability to make statistically significant comparisons and statements. The conventional C-Sb average corn yield of 138 bu/acre was not significantly higher than the organic C-Sb-O average corn yield of 130 bu/acre or the organic C-Sb-O-A yield of 133 bu/acre. Soybean yield averages ranged from 41 bu/acre (C-Sb-O) to 44 bu/acre (C-Sb-O-A). Oat yield averages ranged from 75 bu/acre (C-Sb-O-A) to 78 bu/acre (C-Sb-O). Alfalfa yield averaged 2.9 tons/acre.

Returns

The analysis of returns is divided into an analysis of returns to land, labor, and management; and an analysis conducted with a labor charge subtracted to estimate a return to land and management. Land charges are not considered in this study due to the experimental farm ownership. Thus, this study compares organic versus conventional crop production on the same farm, assuming that debt charges, equity charges, real estate taxes, and other land ownership costs would not be affected by the rotation system selected.

Farm labor is typically provided by the owner/operator. The value associated with this labor will depend upon the types of enterprises and operations involved, outside opportunities available, and other variables. Therefore, we present results with no labor charge and three alternative labor charges ($10, $20, and $50 per hour). Operations for the conventional and organic systems and three rotations were implemented by one farm manager. We assume there were no differences among systems and rotations in managerial ability required.

Average conventional corn and soybean prices were below the average corn and soybean loan rates as determined by the government program during 1999 through 2001. For this reason, we took into consideration potential loan deficiency payments and assumed the conventional producer received the corn loan rate of $1.80 per bushel and soybean loan rate of $5.20 per bushel. Iowa organic corn and soybean prices were received by a local elevator source and varied from year to year. Organic corn prices were $3.00 per bushel for 1999 and 2000 and $3.20 per bushel for 2001. Organic soybean prices were $15.00 per bushel, $13.00 per bushel, and $14.00 per bushel for 1999, 2000, and 2001, respectively, from the local organic elevator (Heartland Organic Marketing Cooperative, Stuart, Iowa). Organic oat and alfalfa prices were received by a local source and assumed to be more stable at $2.00 per bushel and $120.00 per ton for each year, respectively. Organic oat straw average price was $50/ton. Gross revenues were calculated by multiplying annual commodity prices by annual yields.

Economic returns were calculated by subtracting production costs from gross revenues on an annual (by replication) basis. The annual returns were tested for statistical significance through an ANOVA procedure. Because returns were first calculated on an annual basis prior to statistical analysis, yearly variability remained in the analysis. Following determination of overall significance, Tukey's multiple range test (HSD) was used for testing statistical differences among individual treatments (SAS, 1988).

Returns to land, labor, and management

Average returns to land, labor, and management for each system are presented in Table 6. Returns for corn within the organic C-Sb-O and C-Sb-O-A rotations were not significantly different at $264/acre and $272/acre, respectively. Both returns were significantly higher than the return for the conventional C-Sb rotation ($51/acre).

Returns for soybeans within the organic C-Sb-O and C-Sb-O-A rotations were not significantly different at $470/acre and $505/acre, respectively. Again, both organic returns were significantly higher than the return for the conventional C-Sb rotation ($95/acre).

Analysis of the returns to the rotations over 3 years revealed that the organic C-Sb-O and C-Sb-O-A rotations were not significantly different at $286/A and $290/A, respectively. The average returns to the conventional C-Sb rotation was significantly lower at $73/A.

Returns to land and management – various labor charges

This section presents returns to land and management, with varying labor charges. As discussed previously, labor charges for the farm owner/operator can only be determined individually, because of the wide variability in opportunity costs for labor. Hourly rates of $10, $20, and $50 were chosen to cover a typical range for Iowa farmers. Returns to land and management by various labor charges are presented in Table 7. With a labor charge of $10/hr, the organic C-Sb-O and C-Sb-O-A rotations produced the highest average returns for corn, at $238/acre and $246/acre, respectively. The conventional C-Sb corn returns were significantly lower at $42/acre. This was also true for labor at $20/hr and $50/hr. Increasing the labor charge did not change the statistically significant relationships that existed at $10/hr.

The organic C-Sb-O and C-Sb-O-A rotations produced the highest average returns for soybeans, at $434/acre and $469/acre, respectively, at a $10/hr wage rate. The conventional C-Sb soybean returns were significantly lower at $86/acre. This was also true for labor at $20/hr and $50/hr. Increasing the labor charge did not change the statistically significant relationships that existed at $10/hr.

For the rotational average with a $10/hr labor charge, the organic C-Sb-O and C-Sb-O-A rotations resulted in similar returns at $260/acre and $267/acre, respectively. The conventional C-Sb returns were significantly lower at $64/acre. These relationships held through the range of labor costs used.

Returns to land and management – various compost costs

This section presents returns to land and management, with varying compost costs and a constant wage rate of $10/hr. For a diversified crop-livestock farm, the cost for compost may be limited to application rates. This was the assumption made in the previous sections of this analysis. However, in the case of a producer requiring a purchase of compost, additional costs will accrue, with final cost dependent upon compost availability and location.

Returns to land and management by various compost costs are presented in Table 8. With a compost cost of $20/T, the conventional C-Sb rotation produced the highest average return for corn at $42/acre. The organic C-Sb-O and C-Sb-O-A rotations were significantly lower at –$2/acre and $6/acre, respectively. This relationship was also true for compost at $40/T and $60/T.

Compost was not applied to the organic soybean crop. Thus, the relationship among the various rotations is the same as the $10/hr results previously presented. For the rotational average with a $10/hr labor charge and $20/ton compost charge, the organic C-Sb-O-A rotation had the highest return at $187/acre. The organic C-Sb-O return was not significantly different at $154/acre. The conventional corn-soybean return was significantly lower than the C-Sb-O-A at $64/acre. The organic C-Sb-O rotational return was not significantly different than the conventional rotation.

The ANOVA models for the $40/T and $60/T treatments incurred poor results and no significant relationship statements could be made. With a compost charge of $40/T, the organic C-Sb-O-A rotation produced the highest average return at $107/acre. The conventional C-Sb rotation was substantially lower at $64/acre, followed by the organic C-Sb-O rotation at $47/acre. The conventional C-Sb rotation resulted in the highest returns when compost costs rose to $60/T at $64/acre. The C-Sb-O-A return was less than half that amount at $27/acre, whereas the C-Sb-O rotational average was -$60/acre.

Returns without organic premiums

Arguments for and against the inclusion of organic premium prices and/or government program payments in economic analyses are apparent in the alternative agriculture literature (Smolik et al., 1995; Welsh, 1999). One of the motivations for growing organic crops, however, is receiving price premiums (Delate, 2002). We have included organic premium prices and government loan payments in our analysis to reflect the economic reality of Iowa's organic farmers (J. Boes, Heartland Organic Marketing Cooperative, 2002). With corn and soybean government payments for all crops in our analysis, the organic rotations held an economic advantage under average labor and compost costs. Even when we excluded organic premiums (Table 9), the organic rotations were more economical. Returns to land, labor, and management were higher in the organic rotations regardless of whether an organic price premium was received or not.

Discussion

Organic agriculture requires a systems approach of more complexity than conventional farming (Brumfield et al., 2000), with managerial ability significantly affecting economic returns in the organic system. Conventional or transitioning organic farmers may experience a "learning curve" that may impact weed and crop management in their initial years. Transition years are often considered the most challenging in organic production, with lower yields ("yield drag") reported in the first two years of transition from conventional to organic production (Brusko, 1989; Liebhardt et al., 1989; MacRae et al., 1993). Organic and conventional soybean yields at the Neely-Kinyon LTAR site, however, were similar in all three years of the study. These yields were obtained under relatively high managerial ability for producing diverse crops and accurately operating various implements in the organic system. Our results contrast with those of Lockeretz et al. (1981) and Hanson (1997), where the agronomic productivity of organic systems was lower than conventional farming systems. In Pennsylvania, however, yields were equivalent in the conventional and organic system after the 3-year rotation (Hanson et al., 1997). Dobbs and Smolik (1996) also obtained higher yields in the conventional soybean fields but conventional fields were planted at different densities than the organic system.

Organic corn yields in our study were similar to conventional yields when yellow feed corn was grown. White corn, grown in 1999 for a specialty food market, is generally a lower-yielding hybrid and did not perform as well as conventional without additional fertilization. In all years, corn yields were greatest following two years of alfalfa. Our results compare with survey results reported by the Organic Farming Research Foundation (OFRF, 2001), where organic corn yields averaged 95% of conventional yields. Organic corn yields obtained in this study were greater than those from earlier studies in Iowa (Chase and Duffy, 1991; Duffy, 1991) where the average ten-year organic corn yield equaled the average conventional continuous corn yield, but was less than the conventional corn yield in the C-S rotation. Weeds were considered the primary cause for reduced yields in organic systems in California (Clark et al., 1998), but organic premium prices compensated for the yield reduction.

Returns for the three-year organic C-S-O rotation at the Neely-Kinyon LTAR were also greater than an earlier reported Iowa organic C-O-A rotation. When the net present value of the early Iowa organic crops was computed by Welsh (1999), a 35.4% premium price was required for the C-O-A rotation to equal the conventional C-S rotation. This contrasted with our results, where the organic C-S-O rotation returns, without any organic price premiums, were greater than the conventional C-S rotation. Government payments may narrow the gap between organic and conventional returns, as shown in the Kansas State University comparison of organic and conventional rotations (Diebel et al., 1995). Organic returns were 143% greater than conventional without government payments and 78% greater with government payments. In another study with federal farm payments, organic costs were lower in organic (excluding labor) and gross income was highest (Smolik and Dobbs, 1991). With a lower cost structure, the individual crops in our organic rotations did not incur substantially lower returns than their conventional counterparts.

In the case of soybean, the organic rotations resulted in significantly higher returns under all situations. Because of higher soybean returns in the organic rotations, the overall rotational average returns to the organic rotations were significantly greater than the conventional system. This observation verifies local farmer knowledge regarding the importance of including soybean in any organic rotation. Olson and Mahoney (1999) achieved similar results when soybean was included in the organic C-S-O-A rotation, obtaining a mean net return of $172 acre/acre compared to the conventional C-S rotation return of $156/acre.

The issue of off-farm compost costs warrants further investigation. The goal of an organic farm is the establishment of a self-regulating, closed nutrient cycling system. One of the key factors of economic and environmental sustainability is improving soil quality (Wander et al., 1994) and weed management (Temple et al., 1994). Dobbs and Smolik (1996), for example, reported an increase in organic matter in their organic system over the 8-year period. If livestock and compost are available on-farm, economic returns will significantly favor organic systems. When purchased compost costs above $20/T were imposed in this study, the organic C-S-O rotation lost the economic advantage over the conventional C-S rotation. As the cost of compost increased to $40/T and $60/T, the conventional C-S rotation became more competitive. Additional research is needed to determine the average cost of purchasing, transporting and spreading compost for producers without livestock. We anticipate, however, that soil quality will improve over time in the organic systems, thus lowering nutrient input costs. Improvements will occur in organic systems through additional organic matter from longer crop rotations and from compost (on-farm or purchased) and cover crops (Delate and Cambardella, 1999). We also expect to see a reduction in pest management costs as longer crop rotations lead to reduced nematode, weed, insect, and disease populations in organic systems (Altieri, 1995). Clark et al. (1998) reported a 50% reduction in pesticide use in organic and low-input systems without a decrease in corn yields.

Conclusions

Our study indicates that organic rotations are competitive with conventional C-S rotations under normal conditions of on-farm labor and management. If the cost of purchased compost can be limited to less than $20/T, the economic advantage to organic rotations remains. As compost costs increase from $20/T to $40/T, the addition of alfalfa (C-S-O-A) in the organic rotation is necessary to remain competitive with conventional C-S rotations. Increasing labor charges from $10 hr^{-1} to $50 hr^{-1} did not affect the rankings of the rotations' returns. Additional labor required by the organic system did not significantly affect the lower production cost advantage.

Our results were predicated on 1) adequate soil fertility in the organic system, 2) timely pest management (particularly, for weed control), and 3) higher organic corn and soybean seeding rates to compensate for losses due to rotary hoeing for weed management. Farms with less fertility or inadequate expertise in organic practices may experience a longer "transitional effect" in which organic yields remain substantially lower than conventional yields.

As organic farming strives to improve the "health and productivity of interdependent communities of soil life, plants, animals and people" (USDA-AMS, 2002), an assessment of long-term community benefits (e.g., increased tax base from value-added production; improved quality of life with less exposure to pesticides; increased farm income after transition to organic production; and greater environmental protection through organic practices) is needed to fully evaluate the long-term effects of adopting organic farming systems. Accounting for externalities associated with agricultural production and compensating farmers for their organic and conservation practices through organic transition, cost-share and organic price premium payments can help increase the sustainability of agriculture in the US.

Table 1. Yield and economic comparisons of conventional and organic farming systems.

U.S. State	Year	Crops	Yields	Economics
South Dakota (Dobbs and Smolik, 1996)	1985-92	Corn (Zea mays *L.)*	No statistical difference between conventional and organic; Higher in organic in drought years	Cost of production (C.O.P.) similar to conventional; organic premiums were not calculated
South Dakota (Dobbs and Smolik, 1996)	1985-92	Soybean (Glycine max L.)	No statistical difference between conventional and organic	C.O.P. similar to conventional; organic premiums were not calculated
Pennsylvania (Hanson et al., 1997)	1981-95	Soybean	No statistical difference between conventional and organic after 3 yr. rotation; higher in organic in drought years	C.O.P. 12% lower in organic across all rotations; organic premiums were not calculated
California (Clark et al., 1999)	1989-96	Tomatoes (Lycopersicon esculentum Mill.)	No statistical difference between conventional and organic	C.O.P. 5% higher in organic, but with organic premiums, superior economics with organic
New Jersey (Brumfield et al., 2000)	1991-1993	Tomatoes, pumpkin (Cucurbita pepo L.), sweet corn (Zea mays L. var. saccharada)	Higher average in conventional (statistics not shown)	C.O.P. higher in organic when previous crop costs (cover crops) and additional management over conventional (staking) included; net return per unit 5-16% higher in organic with organic premiums

Table 2. Field operations, by rotation[1]

	C-Sb		C-Sb-O			C-Sb-O-A			
Operation	Corn	Sb	Corn	Sb	Oat	Corn	Sb	Oat	Alfalfa
Fertilizer (N)	x								
Fertilizer (Compost)			3x		x	3x		x	
Fall-disk Stalks				x			x		
Fall-plant Rye				x			x		
Disk Rye				2x			2x		
Plowed (moldboard)			x			x			
Tandem Disk		x	x			x			
Harrow									
Spray	x								
Field Cultivate	x		x	x	x	x	x	x	
Plant/Drill	x	x	x	x	x	x	x	x	
Cultipack[2]					x			x	
Spray	x	x							
Harrow			x	x		x	x		
Row Cultivate	x		3x	3x		3x	3x		
Rotary Hoe		x	x	x		x	x		
Flame Cultivation			x			x			
Harvest[3]	x	x	x	x	x	x	x	x	x

[1] Operations varied among years. Operations listed are those typically performed.
[2] This implement consists of roller bars that compress soil over the oats and alfalfa seed to improve seed-to-soil contact.
[3] Corn, soybean, and oats were harvested with a combine whereas alfalfa was harvested by a mower, then raked and baled. Oat straw was raked and baled. Alfalfa was harvested 3 times.

Table 3. Estimated fieldwork, by crop and rotation, 1999-2001[1]

Rotation/Crop	Fieldwork (hr/A)
Corn-soybean	
Corn	0.85
Soybean	2.88
Average	1.87
Corn-soybean-oat	
Corn	2.61
Soybean	3.60
Oat	1.60
Average	2.60
Corn-soybean-oat-alfalfa	
Corn	2.61
Soybean	3.60
Oat	1.60
Alfalfa	1.70
Average	2.38

[1] Based on on Duffy and Smith (1999, 2000, 2001)

Table 4. Annual production costs ($/A), by crop and rotation, 1999-2001[1]

Rotation	Corn	Soybean	Oat	Alfalfa	Average[2]
Corn-soybean					
Machinery	64	42			53
Seed	29	30			30
Chemical	62	40			50
Fertilizer	22	0			11
Miscellaneous	21	16			19
Total	198	128			163
Corn-soybean-oat					
Machinery	89	64	67		73
Seed	31	36	67		45
Chemical	0	0	0		0
Fertilizer	0	0	0		0
Miscellaneous	16	14	6		12
Total	136	114	140		130
Corn-soybean-oat-alfalfa					
Machinery	89	64	65	65	71
Seed	31	36	67	0	34
Chemical	0	0	0	0	0
Fertilizer	0	0	0	0	0
Miscellaneous	16	14	6	6	11
Total	136	114	138	71	115

[1] Corn machinery expenses include field operations, drying, handling, and hauling. Machinery expenses for all other crops include field operations, handling, and hauling. Land and labor costs are not included.
[2] Totals rounded to the nearest dollar.

Table 5. Yields by crop and rotation, 1999-2001

Rotation/Crop	1999	2000	2001	Avg. 1999-2001
Corn-soybean				
Corn	161	141	112	138
Soybean	48	40	40	43
Corn-soybean-oat				
Corn	122	141	128	130
Soybean	45	36	43	41
Oat	89	63	81	78
Corn-soybean-oat-alfalfa				
Corn	120	148	131	133
Soybean	48	37	47	44
Oat	81	61	83	75
Alfalfa	3.2	2.8	2.6	2.9

Table 6. Returns to land, labor, and management ($/A), by crop and rotation, 1999-2001[1]

Rotation	Corn	Soybean	Oat	Alfalfa	Average
C-Sb	51b	95b			73b
C-Sb-O	264a	470a	125		286a
C-Sb-O-A	272a	505a	112	272	290a

[1] Returns within columns followed by the same letter are not significantly different (Analysis of variance, Tukey's test, p=0.05).

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Table 7. Returns to land and management ($/A) for various labor charges, by crop and rotation, 1999-2001[1]

	Labor Charge per hour		
Crop/Rotation	**$10**	**$20**	**$50**
Corn			
C-Sb	42b	34b	8b
C-Sb-O	238a	212a	133a
C-Sb-O-A	246a	220a	142a
Soybean			
C-Sb	86b	77b	51b
C-Sb-O	434a	398a	290a
C-Sb-O-A	469a	433a	325a
Oat			
C-Sb-O	109	93	45
C-Sb-O-A	96	80	32
Rotational Average			
C-Sb	64b	55b	29b
C-Sb-O	260a	234a	156a
C-Sb-O-A	267a	243a	172a

[1] Returns within columns followed by the same letter are not significantly different (Analysis of variance, Tukey's test, p=0.05).

Table 8. Returns to land and management ($/A) for various compost costs, by crop and rotation, 1999-2001[1]

	Compost Cost per ton		
Crop/Rotation	**$20**	**$40**	**$60**
Corn			
C-Sb	42a	42a	42a
C-Sb-O	-2b	-242b	-482b
C-Sb-O-A	6b	-234b	-474b
Soybean			
C-Sb	86b	86b	86b
C-Sb-O	434a	434a	434a
C-Sb-O-A	469a	469a	469a
Oat			
C-Sb-O	29	-51	-131
C-Sb-O-A	16	-64	-144
Rotational Average			
C-Sb	64b	64	64
C-Sb-O	154ab	47	-60
C-Sb-O-A	187a	107	27

[1] Returns within columns followed by the same letter are not significantly different (Analysis of variance, Tukey’s test, p=0.05).

Table 9. Rotational returns without organic premiums (US$/acre), 1999-2001.				
Rotation	**Return to land, labor and management**	**Return to land and management (US$10/h wage)**	**Return to land and management (US$20/h wage)**	**Return to land and management (US$10/h wage, US$20/T compost)**
C-S[1] (conventional)	73	54	35	54
C-S-O (organic)	96	70	44	-37
C-S-O-A (organic)	114	90	67	10

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