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Reganold, J.P., Glover, J.D., Andrews, P.K. & Hinman, H.R. Sustainability of three apple production systems, *Nature* **410**, 926–930 (2001).

Table A1. Market grades of apples from three production systems. Prior to 1998, all fruit was sold for processing. Differences between values in a year followed by different letters are significant at the 0.05 level (LSD).

Grade	Year	Organic	Conventional	Integrated
Washington Extra Fancy (%)	1998	0.00	0.00	0.00
	1999	73.24 a	70.06 a	74.18 a
Washington Fancy (%)	1998	26.62 a	33.65 a	28.97 a
	1999	0.00	0.00	0.00
Processed (%)	1998	73.38 a	66.35 a	71.03 a
	1999	26.76 a	29.94 a	25.82 a

Table A2. Leaf tissue nutrient analyses of three apple production systems. Differences between values in a year followed by different letters are significant at the 0.05 level (LSD).

Nutrient	Year	Organic	Conventional	Integrated
Nitrogen (%)	1995	2.57 a	2.63 a	2.64 a
	1996	2.41 a	2.42 a	2.66 b
	1997	2.86 a	2.94 a	2.92 a
	1998	2.25 a	2.37 a	2.34 a
	1999	2.23 a	2.36 a	2.38 a
Phosphorus (%)	1995	0.25 a	0.24 a	0.24 a
	1996	0.21 a	0.18 b	0.19 ab
	1997	0.18 a	0.19 a	0.20 a
	1998	0.16 a	0.16 a	0.16 a
	1999	0.21 a	0.18 b	0.17 ab
Potassium (%)	1995	1.95 a	2.03 b	1.95 a
	1996	2.23 a	2.00 a	2.08 a
	1997	1.25 a	1.38 a	1.58 b
	1998	1.40 a	1.73 b	1.75 b
	1999	1.83 a	1.85 a	1.90 a
Sulfur (%)	1995	0.21 a	0.23 a	0.24 a
	1996	0.19 a	0.21 a	0.20 a
	1997	0.17 a	0.17 a	0.16 a
	1998	0.11 a	0.11 a	0.12 a
	1999	0.15 a	0.16 a	0.14 a
Calcium (%)	1995	1.62 a	1.71 a	1.62 a
	1996	1.68 a	1.84 b	1.69 a
	1997	1.74 a	1.73 a	1.68 a
	1998	1.70 a	2.09 a	1.93 a
	1999	1.83 a	1.86 a	1.87 a
Magnesium (%)	1995	0.32 a	0.35 b	0.35 b
	1996	0.37 a	0.38 a	0.37 a
	1997	0.34 a	0.31 b	0.32 b
	1998	0.38 a	0.41 a	0.40 a
	1999	0.34 a	0.31 a	0.33 a
Boron (ppm)	1995	22.75 a	24.50 ab	25.25 b
	1996	21.50 a	26.00 b	22.25 a
	1997	27.75 a	25.75 a	26.25 a
	1998	20.50 a	23.00 a	20.50 a
	1999	18.75 a	17.75 a	17.50 a
Zinc (ppm)	1995	11.75 a	13.25 ab	14.50 b
	1996	15.75 a	25.25 b	14.50 a
	1997	10.75 a	12.75 a	12.00 a
	1998	10.75 a	13.00 b	12.50 b
	1999	14.25 a	15.00 a	14.75 a
Manganese (ppm)	1995	51.00 a	59.25 a	58.75 a
	1996	51.75 a	58.75 b	56.25 ab
	1997	61.75 a	60.75 a	58.75 a
	1998	61.50 a	59.00 a	63.75 a
	1999	47.75 a	46.25 a	50.25 a
Copper (ppm)	1995	9.00 a	8.75 a	8.75 a
	1996	9.50 a	10.25 a	9.25 a
	1997	8.50 a	8.25 a	8.00 a
	1998	8.50 a	8.00 a	8.25 a
	1999	8.50 a	8.50 a	9.00 a
Iron (ppm)	1995	188.00 a	138.75 ab	122.50 b
	1996	281.75 a	354.75 a	247.50 a
	1997	159.00 a	135.75 ab	116.25 b
	1998	190.75 a	172.50 a	188.75 a
	1999	315.50 a	259.25 a	296.50 a

Table A3. Fruit tissue nutrient analyses of three apple production systems. Fruit was not analyzed for tissue content in 1996. Differences between values in a year followed by different letters are significant at the 0.05 level (LSD).

Nutrient	Year	Organic	Conventional	Integrated
Nitrogen (%)	1995	0.36 a	0.40 a	0.40 a
	1997	0.26 a	0.32 ab	0.35 b
	1998	0.40 a	0.47 ab	0.54 b
	1999	0.30 a	0.40 b	0.41 b
Phosphorus (%)	1995	0.135 a	0.130 a	0.140 a
	1997	0.070 a	0.088 b	0.075 ab
	1998	0.090 a	0.100 a	0.100 a
	1999	0.073 a	0.080 b	0.075 ab
Potassium (%)	1995	0.97 a	0.95 a	1.00 a
	1997	0.72 a	0.85 b	0.80 ab
	1998	0.83 a	0.90 a	0.85 a
	1999	0.80 a	0.88 a	0.88 a
Calcium (%)	1995	0.04 a	0.03 a	0.03 a
	1997	0.04 a	0.04 a	0.05 a
	1998	0.06 a	0.07 a	0.06 a
	1999	0.10 a	0.10 a	0.09 a
Magnesium (%)	1995	0.05 a	0.04 b	0.05 ab
	1997	0.04 a	0.04 a	0.04 a
	1998	0.05 a	0.05 a	0.05 a
	1999	0.05 a	0.05 a	0.05 a
Boron (ppm)	1995	7.75 a	7.75 a	9.75 b
	1997	6.75 a	15.50 b	13.75 b
	1998	5.00 a	7.00 ab	7.25 b
	1999	7.75 a	11.50 b	7.50 a
Zinc (ppm)	1995	3.75 a	2.00 b	3.00 a
	1997	4.25 a	5.00 a	4.50 a
	1998	4.50 a	5.25 a	4.50 a
	1999	4.25 a	6.75 a	5.00 a

Table A4. Fruit maturity analyses of apples from three production systems (a) at harvest, (b) following 3 months' controlled atmosphere storage, and (c) following 6 months' controlled atmosphere storage. Analyses were not carried out prior to 1998. Differences between values in a year followed by different letters are significant at the 0.05 level (LSD).

Fruit Maturity	Year	Organic	Conventional	Integrated
(a) At Harvest				
Firmness (N)	1998	58.03 a	52.84 b	50.44 b
	1999	66.91 a	65.53 ab	64.82 b
Soluble Solids (Brix)	1998	15.32 a	15.53 a	14.58 b
	1999	14.61 a	14.05 b	14.59 a
Titratable acidity (%)	1998	0.77 a	0.83 ab	0.85 b
	1999	0.71 a	0.74 b	0.75 b
Ratio of soluble solids to titratable acidity	1998	19.81 a	18.81 ab	17.10 b
	1999	20.71 a	19.15 b	19.44 b
(b) 3 Months' Storage				
Firmness (N)	1998	57.11 a	56.15 a	56.09 a
	1999	58.00 a	57.01 b	57.34 ab
Soluble Solids (Brix)	1998	14.77 a	14.42 a	13.77 a
	1999	15.59 a	14.96 b	15.24 ab
Titratable acidity (%)	1998	0.63 a	0.66 ab	0.71 b
	1999	0.59 a	0.62 b	0.61 b
Ratio of soluble solids to titratable acidity	1998	23.53 a	21.88 a	19.46 b
	1999	26.81 a	24.19 b	24.87 b
(c) 6 Months' Storage				
Firmness (N)	1998	56.22 a	57.84 a	58.24 a
	1999	56.37 a	53.40 b	54.66 ab
Soluble Solids (Brix)	1998	14.27 a	15.01 a	14.34 a
	1999	15.61 a	14.90 b	15.56 a
Titratable acidity (%)	1998	0.56 a	0.61 ab	0.64 b
	1999	0.42 a	0.43 ab	0.44 b
Ratio of soluble solids to titratable acidity	1998	25.87 a	24.88 ab	22.56 b
	1999	36.90 a	34.55 b	35.21 b

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Table A5. Consumer taste preferences of apples from three production systems (a) at harvest and (b) following 6 months' controlled atmosphere storage. Preference tests were conducted only in 1999. Differences between values in a test category followed by different letters are significant at the 0.05 level (LSD).

Taste Parameter	Organic	Conventional	Integrated
(a) At Harvest			
Overall Acceptance (1 = Dislike extremely; 9 = Like extremely)	6.3 a	6.8 a	6.2 a
Texture (1 = Dislike extremely; 9 = Like extremely)	6.6a	7.1 a	6.7 a
Flavor (1 = Dislike extremely; 9 = Like extremely)	6.3 a	6.6 a	6.1 a
Firmness (1 = Very soft; 9 = Very hard)	6.3 a	6.3 a	6.1 a
Sweetness (1 = Not at all sweet; 9 = Extremely sweet)	5.5 a	5.3 a	5.0 a
Tartness (1 = Not at all tart; 9 = Extremely tart)	4.6 a	5.6 b	5.5 b
(b) 6 Months' Storage			
Overall Acceptance (1 = Dislike extremely; 9 = Like extremely)	6.1 a	6.0 a	6.5 a
Texture (1 = Dislike extremely; 9 = Like extremely)	6.1 a	5.9 a	5.9 a
Flavor (1 = Dislike extremely; 9 = Like extremely)	6.0 a	5.9 a	6.7 b
Firmness (1 = Very soft; 9 = Very hard)	5.5 a	5.3 a	5.1 a
Sweetness (1 = Not at all sweet; 9 = Extremely sweet)	5.6 a	5.0 b	5.6 a
Tartness (1 = Not at all tart; 9 = Extremely tart)	3.6 a	4.7 b	4.8 b

Table A6. Cumulative environmental impact ratings of four apple production systems from 1994 to 1999. Total points = A X B X C. In some cases, the total points may appear not to equal the product of A X B X C due to rounding errors.

Treatment	Product name	Chemical name	(A) No. of applications	(B) Rate (amount application^{-1} ha^{-1})	(C) Points per unit amount	Total points
Organic	Dipel	*Bt*	5	2.2 kg	7.28	81.5
	Isomate C	Pheromone	4	988.0 ties	0.015	59.3
	Microthiol	Sulfur	11	11.2 kg	2.32	285.3
	Superior Oil	Oil	5	18.7 liters	0.42	39.5
	Total					**465.6**
Conventional	Captan	Captan	1	14.0 liters	4.02	56.3
	Dipel	*Bt*	4	2.2 kg	7.28	65.2
	Ethrel	Ethephon	7	2.1 liters	2.33	34.2
	Guthion	Azinphos methyl	16	2.2 kg	17.64	632.3
	Isomate C	Pheromone	4	988.0 ties	0.015	59.2
	Lorsban	Chlorpyrifos	7	1.2 liters	10.57	86.5
	Microthiol	Sulfur	9	11.2 kg	2.32	244.5
	Provado	Imidacloprid	3	0.1 liters	274.84	57.8
	Procure	Triflumizole	4	0.6 kg	18.70	41.9
	Rally	Myclobutanil	7	0.4 liters	131.92	323.7
	Roundup	Glyphosate	23	4.7 liters	9.51	1022.6
	Rubigan	Fenarimol	1	0.4 liters	83.52	33.4
	Simazine	Simazine	3	2.3 liters	8.25	57.8
	Sevin	Carbaryl	2	1.8 liters	13.53	47.4
	Solicam	Norflurazon	3	2.2 kg	10.81	90.8
	Superior Oil	Oil	5	18.7 liters	0.42	39.5
	Total					**2,893.2**
Integrated	Captan	Captan	1	14.0 liters	4.02	56.3
	Dipel	*Bt*	4	2.2 kg	7.28	65.2
	Ethrel	Ethephon	7	2.1 liters	2.33	34.2
	Guthion	Azinphos methyl	16	2.2 kg	17.64	632.3
	Isomate C	Pheromone	4	988.0 ties	0.015	59.2
	Lorsban	Chlorpyrifos	7	1.2 liters	10.57	86.5
	Microthiol	Sulfur	9	11.2 kg	2.32	244.5
	Provado	Imidacloprid	3	0.1 liters	274.84	57.8
	Procure	Triflumizole	4	0.6 kg	18.70	41.9
	Rally	Myclobutanil	7	0.4 liters	131.92	323.7
	Roundup	Glyphosate	11	4.7 liters	9.30	480.8
	Rubigan	Fenarimol	1	0.4 liters	83.52	33.4
	Sevin	Carbaryl	2	1.8 liters	13.53	47.4
	Superior Oil	Oil	5	18.7 liters	0.42	39.5
	Total					**2,211.1**
Non-PMD Conventional	Guthion	Azinphos Methyl	14	2.2 kg	17.64	553.3
	Dipel	*Bt*	8	2.2 kg	7.28	130.4
	Carbaryl	Carbaryl	6	2.1 liters	13.5	170.7
	Lorsban	Chlorpyrifos	4	4.7 liters	10.6	197.6
	Ethrel	Ethephon	3	2.1 liters	2.33	14.7
	Rubigan	Fenarimol	6	0.3 liters	114.38	200.4
	Roundup	Glyphosate	8	4.7 liters	9.51	355.7
	Provado	Imidacloprid	5	0.1 liters	274.8	96.3
	Lime Sulfur	Lime Sulfur	11	37.4 liters	2.11	869.4
	Supracide	Methidathion	1	0.6 liters	9.85	5.8
	Rally	Myclobutanil	5	0.4 liters	131.9	231.2
	NAA 200	NAA	3	0.2 liters	76.1	34.7
	Amid Thin	NAA-Amide	3	0.6 kg	0.9	1.5
	Surflan	Oryzalin	6	4.7 liters	3.59	100.8
	Gramoxone	Paraquat	6	2.3 liters	28.75	403.1
	Superior Oil	Petroleum oil	5	18.7 liters	0.42	39.5
	Princep	Simazine	4	4.7 liters	3.17	59.3
	Total					**3,464.4**

Table A7. Management practices for three apple production systems. For a complete list of products used for weed, pest, and disease control, fruit thinning, and growth regulation, see Table A6.

	Year	Organic	Conventional	Integrated
Soil Amendment	1994	Compost (919 kg ha^{-1})	Calcium nitrate (186 kg ha^{-1})	Calcium nitrate (93 kg ha^{-1}) Compost (459 kg ha^{-1})
	1995	Compost (919 kg ha^{-1})	Calcium nitrate (186 kg ha^{-1})	Calcium nitrate (93 kg ha^{-1}) Compost (459 kg ha^{-1})
Foliar Nutrients	1995		3-18-18 (N-P-K) Urea	3-18-18 (N-P-K) Urea
	1996	Calcium chloride Zinc sulfate Boron	Calcium chloride Zinc sulfate Boron 3-18-18 (N-P-K)	Calcium chloride Zinc sulfate Boron 3-18-18 (N-P-K)
	1997–1999	Calcium chloride Boron	Calcium chloride Boron 3-18-18 (N-P-K) Zinc	Calcium chloride Boron 3-18-18 (N-P-K) Zinc
Weed Control	1994	Bark mulch	Glyphosate	Bark mulch; glyphosate
	1995	Landscape fabric	Glyphosate	Glyphosate
	1996	Landscape fabric	Glyphosate	Glyphosate
	1997	Surface weed cultivator	Glyphosate	Glyphosate
	1998	Surface weed cultivator	Glyphosate; pre-emergence herbicide	Glyphosate
	1999	Mowed cover crop	Glyphosate; pre-emergence herbicide	Glyphosate

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Figure A1. Fruit size of apples from three production systems. Differences between values in a year followed by different letters are significant at the 0.05 level (LSD).

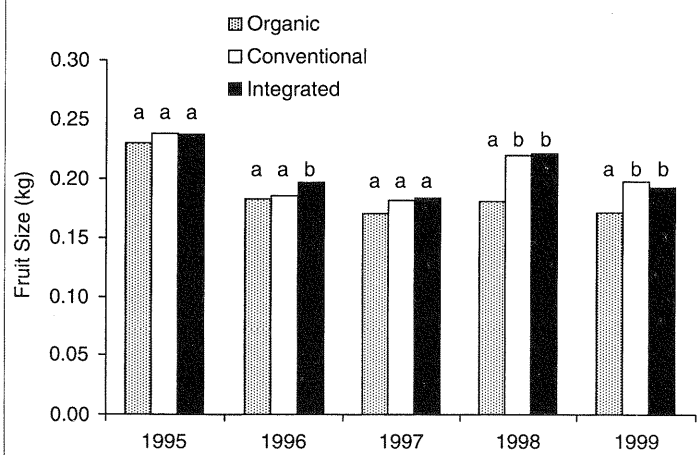

Figure A2. Size distribution of apples in 1998 and 1999 from three production systems. The difference between the organic and conventional fruit size distributions resulted in an average 20% reduction in organic fruit value.

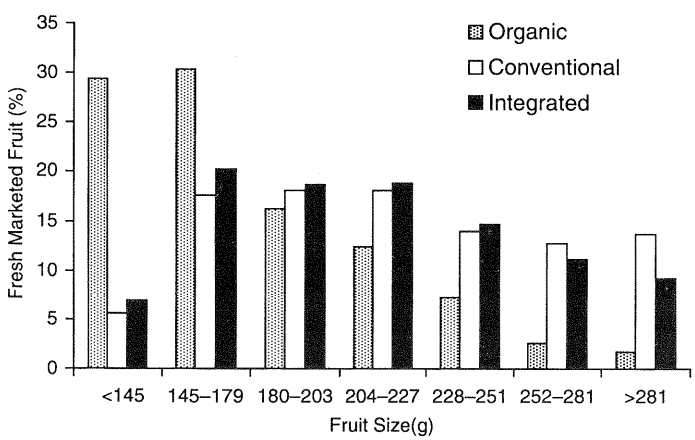

Figure A3. Trunk cross-sectional area (TCSA) of apple trees grown in three production systems. No differences in growth were detected in any year between treatments at the 0.05 level (LSD).

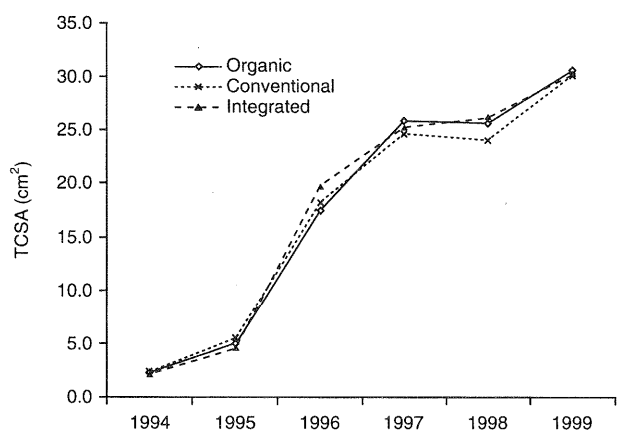

Figure A4. The study area of four replicate plots for each of the three apple production systems. Each plot contains four rows of approximately 80 trees per row trained on a two-wire trellis system. Trees were planted at a spacing of 1.4 m within rows and 3.2 m between rows for a density of 2,240 trees per hectare. The soil on all 12 plots is a coarse-loamy, mixed, mesic Xerifluventic Haplocambid (FAO: Haplic Cambisol). We kept the size of the study area to 1.7 hectares to maintain uniformity of this one soil type. Extending the study area to the west or north would have included different soil types. Permanent pasture areas to the east and south belonged to a neighbor. Prior to installation of the experimental orchard, the site had been in grass pasture which was tilled to a depth of 30 cm in January 1994. Soil samples were taken from each of the designated plots following the planting of trees, but prior to implementation of management treatments. Analyses of pertinent soil morphological, physical, chemical, and biological properties revealed no significant differences between treatments at that time. Grass corridors (5 m wide) surround the study area and another one cuts through the middle of the study area. These grass corridors act as buffers from the conventional commercial orchards to the north and west and as passageways to beneficials from pastures to the south and east (Thies, C., Tscharntke, T., Landscape structure and biological control in agroecosystems, *Science*, **285**, 893–895, 1999). As an additional buffer, the two treatments (conventional-1 and integrated-4) farthest to the west had an additional fifth row of trees. In these two plots, soil and plant samples were taken in the third and fourth rows from the western edge. With grass corridors, tree-row buffers, and sampling in middle rows only, the efficacy of pest control and fertilization for each treatment was not compromised by plot size. The 20 cm of average annual precipitation at the site is supplemented with an under-tree sprinkler irrigation system.