ORGANIC FARMING RESEARCH FOUNDATION

Project report submitted to the Organic Farming Research Foundation:

Project Title:

Long Term Vegetable Rotation Systems Using Organic Production Methods and Conservation Tillage

FINAL PROJECT REPORT

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Funding provided by OFRF: $5,157, awarded spring 2001

Project period: 2001 - 2003

Report submitted: October 2004

Overview

This experiment is a long term study comparing continuous tomatoes with vegetable rotation under five possible production systems to determine which system is most viable for each vegetable commodity produced. Some vegetables in the southeast can be grown easily with organic production methods (sweet corn, cabbage, broccoli, peppers, etc.) but others have numerous problems (foliar diseases in tomatoes) that will require changes in production strategies. By rotating vegetable crops we are able to see which crops also can be grown under conservation tillage. Both tillage cultures will have organic production methods (and traditional chemical methodologies) to further develop understanding of how cultivation or surface residues affect these production systems.

Many of the organic growers in the southeast are adding plant materials (such as soybean meal) as a fertilizer source because manure use may not be feasible (distance, hauling, etc.). Although our soils are relatively poor in plant nutrients, there are a number of legume species that grow well in both the summer and winter season, and nitrogen fixation and uptake may exceed 200 lbs N/acre. Another major problem in the southeast is the highly erodible soils from steep slopes and erosive types of soil surfaces. Conservation tillage has become necessary on many of these slopes. Many studies show increased organic matter in the surface soil from residue management (lack of plowing increases organic matter). Another focus of this experiment is to look at conservation tillage systems that do not use herbicides yet are practical for large farm operations (5-50 acres of vegetables). Insect species may increase with conservation tillage (realizing that some increases are from beneficial insects), thus fruit from each treatment will be examined for species affect on tomato fruit. This will give a better understanding to the insect pressure that may change with conservation tillage or with organic production methods. Poor availability of pest materials for disease control on tomatoes may be the greatest obstacle for fresh market organic tomato production in the southeast.

Objectives

Compare conventional tillage with conservation tillage, vegetable crop rotation vs continuous tomato production, and traditional pest management strategies with organic vegetable production for tomato and pepper yield, fruit quality, insect pressure, weed biomass, and plant nutrient cycling. In 2001 tomatoes were grown in the continuous tomato subplots and peppers in the rotated vegetable subplots to determine the best systems for production (previous cropping history will be discussed in the methods section).

Methods

We established a long-term experiment in 1995 to evaluate alternative tillage systems and pest management practices in rotated and continuous tomatoes. Field plots with four replications were established using the following systems:

1. Conventional tillage with synthetic pest control methods and fertilizers, including fumigation.
2. Conventional tillage with organic pest control methods and winter legume/added soybean meal as a fertilizer source.

3. Conservation tillage with conventional synthetic pest control and fertilizers (no fumigation).

4. Conservation tillage with organic pest control methods and winter legume/added soybean meal.

5. A control plot that was plowed, disced, and planted with no additional inputs.

Within each of these 5 systems is a subplot of rotated vegetables and continuous tomatoes. The rotation consisted the first six years of 2 three-year rotations of sweet corn/fall cabbage, cucumbers /fall cabbage, and tomatoes. Continuous tomatoes were planted to tomatoes every year. On year seven, the year of this grant, we established a new rotation for three years of the following: peppers, yellow squash/fall broccoli, and tomatoes for the years 2001, 2002, and 2003.

Conventional tillage was established with a plow and multiple discing operation each spring. All conventional treatments had the cover crop plowed, then disked twice, and plastic laid in those crops requiring plastic (tomatoes, peppers, squash, cucumbers). Conservation tillage was produced with a no-till planter for seeded crops and a Bushhog Ro-till for strip-tilled transplanted crops. The strip-tilled implement created a tilled area 8 to 12 inches wide. Tomato plants (var. Mtn. Fresh) were planted 5 ft between rows with plants 18 inches in-row. Pepper plants (var. Excalibur) were planted in double rows 15 inches apart with in-row spacing of 14 inches. Plants were staggered between rows. Each set of double rows was 5 ft apart. Cabbage and broccoli were set with a no-till transplanter. Sweet corn was planted with a John Deere Maximerge no-till planter. Beds were produced with black plastic on the conventional and organic plowed plots. Winter cover crops in the chemical treatments had rye planted in all plots.

Cover crops were planted each fall after fields were cleaned up from the previous crop. Cover crops for conservation-tilled treatments were planted by either a no-till grain drill or by hand seeding between rows (in the fall broccoli or cabbage). The cover crops were grown until about mid-April for the plowed chemical treatment and early May for the plowed organic treatment. In the conservation-tilled treatment they were grown until mid-May in the organic treatment (at which time the flail chopper was used) or chemically killed the second week in May for the conservation-tilled chemical treatment. All summer crops were planted the 3rd or 4th week of May.

Conventional pest control included labeled pesticides for tomatoes and peppers with fumigation for each crop in treatments with conventional tillage. Synthetic fertilizers were used to supply 150 lbs N/acre and P, K, and limestone as needed. Organic production methods included materials approved by OMRI (Organic Materials Review Institute), but these plots were not certified organic plots. All efforts were made to conform to organic standards. Fertilizer inputs in the organic treatments included a winter cover crop of hairy vetch. Soybean meal was used at an application rate equal to 150 lbs N/acre. We assumed that 100% of the nitrogen in the soybean meal was available, thus the full amount of nitrogen in the soybean meal was used in the calculation for N. Plots were 40 by 80 ft in length, with 40 by 40 ft subplots for each vegetable. A 40-ft grass border separated each plot on all sides. Irrigation was applied with trickle tape as needed in all treatments except the control.

Results and Discussion

Cover Crop Biomass and Nutrient Content

Cover crop biomass samples were taken just before plowing (conventional tilled plots) or before killing with pesticides (chemical treatment) or flail chopping (organic treatment) for the conservation tillage treatments. Plant samples were ground, analyzed for nutrient content, and nutrient uptake estimated by multiplying percent of nutrient by total biomass (Table 1). Biomass measurements for both the rotation and continuous locations were in the following order for the various systems: conventional chemical > strip-till organic > strip-till chemical > conventional organic (Table 1). The control treatment was not sown to a cover crop and had very few winter weeds (biomass was not collected this year from the control treatment). Chemical treatments (both conventional and conservation tillage) had rye in the plots during the winter. Increased biomass in the conventional chemical treatment was from the good growth of the small grain compared to the hairy vetch legume in the organic treatments. Overall, both winter covers produced the same amount of nutrient uptake in the above ground biomass for all the Continuous subplots and for most of the Rotation subplots (Table 1). Conventional tillage chemical systems had statistically more P and K than the other treatments, but variability was high for all the treatments. Carbon/nitrogen ratio did show higher C:N ratios in the conventional tilled chemical treatments. Cover crops in the spring of 2001 did not have as much growth as most years. Cool fall weather the year before produced slow growing during the fall, and a cold winter for our location reduced or stopped growth through the winter. C:N ratios in the winter cover crop were as low as 10:1 to 23:1, producing residue that should have decomposed during the summer, especially in the plowed treatments.

Tomato Growth and Fruit Yield

Tomato growth in the various tillage and pest control systems produced consistent results as previous years. Tomato vine growth was measured midseason (Table 2). Biomass was greatest in the conventional black plastic/fumigated treatment, with statistically similar biomass weights in the conventional organic and strip-till chemical treatments. The strip-till organic and control treatments produced lower vine weights at this preharvest time. Root growth was similar among the treatments. Green fruit counts for the entire plant indicated greater numbers in the chemical treatments. Tomato vine weights at final harvest produced similar growth habits as midseason, with the two chemical treatments and the conventional organic system with similar statistical weights, and the control and strip-till organic treatments with lower weights (Table 3). Roots had similar weights for all treatments.

Tomato yields followed a similar pattern as vine growth, with the conventional tillage black plastic treatment greatest in marketable yield (Table 4). The strip-till chemical treatment followed with lower statistical yields (both tonnage and numbers of fruit) than the plowed chemical treatment, and the two organic treatments (plowed and strip-till) below the chemical treatments. Lower yields for the organic treatments were due to the severe disease pressure of early (*Alternaria solani*) and late (*Phytophthora infestans*) blight. Vine growth at mid season and during early fruit harvest was similar for the chemical and organic treatments, but as disease pressure appeared, leaf loss in the organic treatments probably led to the lower fruit yields from these treatments.

Insect Pressure on Tomato Fruit

Fruit was inspected at harvest for fruit damage from fruit worms and stink bugs. Variability was high and all treatments but the control were low and had similar numbers (Table 5). Elevated number of both fruit worms and stink bugs in the control treatment indicated the prevalence of these pests.

Nitrogen Uptake by Tomato Plant

Midseason tomato N uptake was similar in the conventional tillage and conservation tillage treatments for each production method (Table 6). This may have been a consequence of delayed nitrogen availability to the organic tomato treatments, for these treatments required decomposition of the winter cover crop and soybean meal to have nitrogen available. Final harvest plant nitrogen had a similar pattern of nitrogen uptake by the various plant components for the treatments, but the uptake pattern difference at final harvest was probably a result of the disease pressure on the organic tomato foliage, and the resulting reduction of biomass N and tomato fruit N (Table 7). A major component for N removal from the plots was from fruit harvest.

Phosphorus Uptake by Tomato Plant

Four to seven lbs of P were accrued in the tomato plant by midseason, with little differences occurring from the various systems (Table 8). At final harvest similar P uptake was seen in the plant foliage as in the midseason sampling period, but the phosphorus removed by the fruit was substantial (Table 9). This amount is similar to what a corn silage crop would remove from the same location. Similar statistical results were seen among the system treatments for the P uptake in the fruit.

Potassium Uptake by Tomato Plant

Potassium uptake by the tomato plant at midseason was similar statistically in the chemical treatments compared to the organic treatments and between tillage systems (Table 10). Potassium uptake followed a similar pattern as biomass at midseason. Final harvest plant potassium was similar to lower in total plant K in the foliage and root (Table 11). Some movement of K from the plant went into the greater plant K sink, the fruit. Fruit K removal by all treatments was very high, again equaling the K removed by a corn silage crop. Treatments again had high variability and little differences were seen among the tillage and organic systems.

Calcium Uptake by Tomato Plant

Midseason calcium uptake was very low in the tomato roots with no differences among treatments (Table 12). Above ground plant calcium measurements showed greater Ca in the chemical treatments, although statistically the organic treatments were similar to the strip-till chemical treatment. All systems received the same limestone application about every two to three years, depending on soil test. Soil test calcium has been similar among treatments (data not shown). Addition calcium uptake was seen in the final harvest plant-sampling period (Table 13). Calcium measured in the fruit was minimal.

Magnesium Uptake by Tomato Plant

Very low amounts of magnesium were measured in the roots of the midseason tomato plants (Table 14). Chemical treatments had slightly higher amounts of Mg in the vine portion of the plant compared to organic treatments, with the organic conventional and conservation tilled treatments with similar uptake. Final harvest Mg in the plant showed little differences in the fruit, however, strip-till organic treatment tomato plants did have lower Mg in the vine (Table 15).

Sulfur Uptake by Tomato Plant

Sulfur uptake by the tomato plant at midseason showed no differences among the different tillage and production systems treatments (Table 16). Very low quantities of S were measured in the roots for both midseason and harvest sampling (Table 17). Sulfur uptake followed similar patterns to the other elements uptake, with the chemical treatments taking up slightly higher quantities of S compared to the organic treatments (mostly related to the biomass of the plants).

C:N Ratio of the Tomato Plant

Both midseason and final harvest C:N ratio for the various tomato plant components were very similar for each treatment (Tables 18 and 19). Final harvest ratios were low enough to predict that decomposition of the tomato vine should proceed fairly rapidly for the following crop year, supplying nutrients that were tied up in plant components during the fall.

Pepper Growth and Fruit Yield

Pepper plants were sampled at harvest to measure the biomass and plant nutrients within the plant (Table 20). Biomass measurements showed little differences among the various system treatments. This similarity occurred for both the leaf/stem and root plant component. Pepper fruit yield (both number of fruit and tons/acre) had a similar pattern as biomass with similar yields throughout the treatments (Table 21).

Nitrogen Uptake by Pepper Plant

Nitrogen accrued to over 200 kg N/ha in the pepper plants (Table 22). Roots contributed less than 10 kg/ha with no statistical difference occurring among the various systems except the control. Although biomass showed little differences among the treatments, N uptake in the stem/leaf component was greater in the conventional tilled chemical treatment compared to all other treatments. High N uptake also occurred for the conventional tilled chemical treatment fruit. Similar fruit N uptake was measured by the two organic treatments and the strip-till chemical treatment. Carbon: nitrogen ratios for the pepper plants at harvest were similar for the various systems treatments (Table 23). Leaf/stem components had a lower C: N ratio than the roots or fruit. All plant material had C: N ratios low enough to provide adequate decomposition and nutrient release for the following year.

Phosphorus Uptake by Pepper Plant

Phosphorus uptake by pepper roots was very low (<1 kg P/ha) (Table 24). Leaf/stem P uptake also was less than the P removed by the fruit. Although some treatments showed statistical differences for each plant component, overall total P uptake was similar.

Potassium Uptake by Pepper Plant

Potassium was taken up by the plant in similar quantity as nitrogen and was similar in relationship with the biomass (Table 25). All production treatments had similar uptake of K, with the control treatment showing the non-fertilized soil having 46 kg K/ha available. Removal of up to 100 kg K/ha by the fruit shows the importance of continual K fertilizer input into these systems.

Calcium Uptake by Pepper Plant

Calcium uptake was retained in the stem/leaf component of the plant (Table 26). Fruit Ca removed less than 5 kg Ca/ha from the plots. No statistical differences were seen among the production treatments.

Magnesium Uptake by Pepper Plant

Fruit magnesium was similar to fruit Ca with less than 7 kg Mg/ha moving from the field plots (Table 27). Less Mg than Ca was measured in the leaf/stem component, with little differences among the production treatments.

Sulfur Uptake by Pepper Plant

Sulfur uptake followed P, Ca and Mg uptake with only small amounts of S in the plant (Table 28). The conventional tilled chemical treatment had the greatest S uptake of all treatments. All production treatments did not vary but by a few kg of S, indicating that this plant required element was available in the soil even though it was not being inputted by fertilization. As seen with the other minor elements, root sulfur was very low.

Weed Biomass and Nutrient Uptake
Weed biomass was measured at the end of the growing season (Table 29). The control treatment had no weed control the entire growing season, thus the plants were mature and seeding. Herbicides were used in the chemical treatments (conventional and conservation tillage) so weed biomass numbers were lower than the organic and control treatments. Organic production had a cultivator early in the season to reduce weeds, but late in the growing season a self-propelled mower was used to reduce weed growth. This machine was not used the last two weeks of the season because of reduced pepper yield in all treatments, thus the greater amount of biomass in the organic treatments. This additional growth of weeds was used as a fall plow down when we

flail chopped the pepper crop and weeds and then planted the winter cover crop. Weed biomass at vegetable final harvest was almost as great as the winter cover crop in the spring (Tables 1 and 29). The organic treatments (both the conventional and the conservation tillage treatments) had from 49 to 60 kg N/ha being plowed under in the fall for the cover crop to utilize once decomposed. The 17 to 19 C: N ratio for this material should allow this material to decompose at a reasonable rate, even though cooler soil temperatures would slow down the process. Potassium recycling was even greater in the organic treatments with 57 to 75 kg K/ha being recycled to the soil.

Table 1. Cover Crop Biomass and Nutrient Uptake in the Various Production Systems, 2001.

Tillage system	Production system	Cover crop biomass and nutrient uptake							
		Biomass[z]	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulfur	C/N Ratio
		---------------- kg/ha ----------------							
Rotation subplot									
Conventional	Organic	2803 c	111 a	7.9 b	67 b	34 a	8.6 b	7 b	10.6 c
Conventional	Chemical	6770 a	140 a	18.9 a	150 a	24 a	10.0 ab	13 a	20.6 a
Strip-till	Organic	4444 b	144 a	11.3 b	99 b	43 a	13.5 a	10 ab	13.4 b
Strip-till	Chemical	3477 bc	136 a	10.6 b	75 b	37 a	10.5 ab	10 ab	10.9 bc
LSD (*P* = 0.05)		1246	ns(42)	4.8	39	ns(19)	4.3	4	2.6
Continuous subplot									
Conventional	Organic	2471 a	107 a	7.3 a	63 a	21 a	6 a	7 a	9.8 b
Conventional	Chemical	4649 a	84 a	12.2 a	95 a	17 a	6 a	8 a	23.7 a
Strip-till	Organic	3701 a	100 a	9.3 a	82 a	30 a	9 a	8 a	17.7 b
Strip-till	Chemical	3209 a	131 a	10.0 a	68 a	31 a	9 a	9 a	10.0 b
LSD (*P* = 0.05)		ns(2229)	ns(56)	ns(6.1)	ns(52)	ns(16)	ns(4)	ns(4)	6.6

[z] Biomass removed before plowing or killing/flail chopping in conservation tillage.

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 2. Tomato Plant Biomass and fruit numbers at midseason, July 26, 2001 for the various production systems.

Tillage system	Production system	Plant biomass for each plant component: Stem/leaf	Root	Total plant	Tomato Fruit
		------------ kg/ha ---------------			number/vine
Control	None	1262 c	94 a	1356 c	12.5 bc
Conventional	Organic	1665 abc	77 a	1742 abc	10.0 c
Conventional	Chemical	2144 a	96 a	2240 a	20.0 ab
Strip-till	Organic	1539 bc	75 a	1614 bc	14.8 bc
Strip-till	Chemical	1845 ab	112 a	1957 ab	24.5 a
LSD (*P* = 0.05)		484	ns(39)	514	9.3

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 3. Tomato Plant Biomass at final harvest, September 29, 2001 for the various production systems.

Tillage system	Production system	Plant biomass for each plant component: Stem/leaf	Root	Total plant
		------------ kg/ha ---------------		
Control	None	827 b	119 a	946 b
Conventional	Organic	2279 a	147 a	2426 a
Conventional	Chemical	2636 a	131 a	2766 a
Strip-till	Organic	1247 b	104 a	1351 b
Strip-till	Chemical	2543 a	146 a	2690 a
LSD (*P* = 0.05)	862	ns(49)	889	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 4. Tomato yield in the various production systems, 2001.

Tillage system	Production system	Yield of fruit[z] Combination	Marketable	Total	Combination	Marketable	Total
		----------- Number/acre --------		----------- Tons/acre ----------			
Control	None	9293 c	22506 c	90169 c	2.34 c	4.49 d	13.68 c
Conventional	Organic	44480 b	68937 b	101863 c	12.13 b	16.56 c	22.14 b
Conventional	Chemical	92347 a	131116 a	154202 a	23.76 a	31.70 a	35.66 a
Strip-till	Organic	46900 b	70858 b	109481 bc	11.65 b	15.87 c	21.07 bc
Strip-till	Chemical	74423 a	107367 a	140537 ab	17.58 b	23.71 b	28.30 ab
LSD (*P* = 0.05)	21821	27358	31871	6.18	7.09	7.81	

[z] Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 5. Insect control in the various tomato production systems, 2001.

Tillage	Production	Percent of total fruit with insects[z]			
system	system	Fruit worms	Stink bug	Fruit worms	Stink bug
		---------- % ---------		------- #/acre ------	
Control	None	13.46 a	34.25 a	12197 a	31218 a
Conventional	Organic	2.82 b	3.87 b	2759 b	3920 b
Conventional	Chemical	1.69 b	0.20 b	2614 b	290 b
Strip-till	Organic	3.56 b	8.11 b	4066 b	8131 b
Strip-till	Chemical	0.53 b	1.23 b	726 b	1597 b
LSD (*P* = 0.05)		5.00	8.35	5738	9871

[z] Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 6. Biomass nitrogen uptake by tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass N for each plant component: Stem/leaf	Root	Total plant
		------------ kg N/ha ----------------		
Control	None	32.5 b	1.7 b	34.2 b
Conventional	Organic	53.2 ab	2.0 b	55.2 ab
Conventional	Chemical	75.3 a	2.4 ab	77.7 a
Strip-till	Organic	54.9 ab	1.8 b	56.7 ab
Strip-till	Chemical	72.1 a	3.0 a	75.1 a
LSD (*P* = 0.05)	23.4	0.9	24.0	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 7. Biomass and fruit nitrogen uptake by tomatoes in the various production systems, September 29, 2001.

Tillage system	Production system	Plant biomass N for each plant component: Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg N/ha ----------------			
Control	None	80.4 c	10.7 b	1.74 c	92.9 d
Conventional	Organic	115.4 bc	58.5 a	4.14 a	178.0 bc
Conventional	Chemical	178.3 a	73.5 a	3.36 ab	255.2 a
Strip-till	Organic	112.6 bc	31.1 b	2.34 bc	146.0 cd
Strip-till	Chemical	155.1 ab	75.8 a	4.37 a	235.3 ab
LSD (*P* = 0.05)		51.2	27.0	1.15	67.1

[z] Nitrogen removed by tomato fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 8. Biomass phosphorus uptake by tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass P for each plant component		
		Stem/leaf	Root	Total plant
		------------ kg P/ha -------------		
Control	None	3.9 b	0.19 ab	4.1 b
Conventional	Organic	6.4 a	0.20 ab	6.6 a
Conventional	Chemical	6.6 a	0.21 ab	6.8 a
Strip-till	Organic	5.6 ab	0.16 b	5.8 ab
Strip-till	Chemical	6.9 a	0.27 a	7.2 a
LSD (*P* = 0.05)	2.3	0.10	2.4	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 9. Biomass and fruit phosphorus uptake by tomatoes in the various production systems, September 29, 2001.

Tillage system	Production system	Plant biomass P for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg P/ha ----------------			
Control	None	15.4 b	1.47 c	0.16 c	17.1 b
Conventional	Organic	19.1 ab	5.28 ab	0.34 a	24.8 ab
Conventional	Chemical	24.6 a	5.45 ab	0.25 ab	30.3 a
Strip-till	Organic	17.1 ab	3.85 b	0.22 bc	21.2 ab
Strip-till	Chemical	21.1 ab	6.47 a	0.30 ab	27.8 a
LSD (*P* = 0.05)	8.9	2.29	0.09	10.6	

[z] Phosphorus removed by tomato fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 10. Biomass potassium uptake by tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass K for each plant component		
		Stem/leaf	Root	Total plant
		----------- kg K/ha ------------		
Control	None	50.5 b	2.4 ab	52.9 b
Conventional	Organic	76.1 ab	2.1 ab	78.2 ab
Conventional	Chemical	92.0 a	2.2 ab	94.2 a
Strip-till	Organic	70.9 ab	1.7 b	72.6 ab
Strip-till	Chemical	83.7 ab	2.8 a	86.5 ab
LSD (*P* = 0.05)	35.3	1.1	36.1	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 11. Biomass and fruit potassium uptake by tomatoes in the various production systems, September 29, 2001.

Tillage system	Production system	Plant biomass K for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg K/ha ----------------			
Control	None	122.1 b	27.5 a	2.3 a	151.8 b
Conventional	Organic	159.7 ab	55.3 a	3.0 a	217.9 ab
Conventional	Chemical	220.5 a	55.1 a	2.2 a	277.8 a
Strip-till	Organic	143.7 ab	33.0 a	2.0 a	178.7 ab
Strip-till	Chemical	190.4 ab	61.3 a	3.1 a	254.7 ab
LSD (*P* = 0.05)	83.7	34.3	ns(1.3)	112.3	

[z] Potassium removed by tomato fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 12. Biomass and fruit calcium uptake by tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass Ca for each plant component: Stem/leaf	Root	Total plant
		----------- kg Ca/ha ----------------		
Control	None	29.0 c	1.1 a	30.1 c
Conventional	Organic	40.9 bc	1.0 a	41.9 bc
Conventional	Chemical	57.5 a	1.0 a	58.5 a
Strip-till	Organic	33.8 bc	0.8 a	34.6 bc
Strip-till	Chemical	47.3 ab	1.1 a	48.4 ab
LSD (*P* = 0.05)		14.6	ns(0.47)	14.9

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 13. Biomass and fruit calcium uptake by tomatoes in the various production systems, September 29, 2001.

Tillage system	Production system	Plant biomass Ca for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg Ca/ha ----------------			
Control	None	3.1 c	15.8 b	2.33 a	21.3 b
Conventional	Organic	4.1 bc	59.3 a	2.52 a	66.0 a
Conventional	Chemical	6.8 a	67.5 a	2.03 ab	76.3 a
Strip-till	Organic	3.5 bc	32.6 b	1.46 b	37.6 b
Strip-till	Chemical	5.5 ab	76.1 a	2.10 ab	83.7 a
LSD (P = 0.05)		2.3	25.9	0.69	27.4

[z] Calcium removed by tomato fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 14. Biomass and fruit magnesium uptake by tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass Mg for each plant component		
		Stem/leaf	Root	Total plant
		----------- kg Mg/ha ------------		
Control	None	8.7 c	0.45 ab	9.1 c
Conventional	Organic	14.7 b	0.34 b	15.1 b
Conventional	Chemical	21.4 a	0.40 ab	21.8 a
Strip-till	Organic	13.3 bc	0.35 b	13.7 bc
Strip-till	Chemical	16.8 ab	0.76 a	17.6 ab
LSD (*P* = 0.05)	5.5	0.40	5.7	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 15. Biomass and fruit magnesium uptake by tomatoes in the various production systems, September 29, 2001.

Tillage system	Production system	Plant biomass Mg for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg Mg/ha ----------------			
Control	None	7.2 b	3.8 c	0.90 a	11.9 c
Conventional	Organic	9.4 ab	18.4 ab	0.74 a	28.6 ab
Conventional	Chemical	12.7 a	23.8 a	0.90 a	37.4 a
Strip-till	Organic	8.2 ab	10.2 bc	0.58 a	19.1 bc
Strip-till	Chemical	10.6 ab	26.1 a	0.81 a	37.5 a
LSD (*P* = 0.05)	4.7	10.1	ns(0.37)	13.8	

[z] Magnesium removed by tomato fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 16. Biomass and fruit sulfur uptake by tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass S for each plant component		
		Stem/leaf	Root	Total plant
		------------ kg S/ha --------------		
Control	None	8.6 c	0.17 b	8.8 b
Conventional	Organic	10.5 ab	0.17 b	10.7 ab
Conventional	Chemical	15.6 a	0.24 ab	15.8 a
Strip-till	Organic	10.4 ab	0.15 b	10.6 ab
Strip-till	Chemical	13.2 ab	0.38 a	13.6 ab
LSD (*P* = 0.05)		5.3	0.16	5.4

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 17. Biomass and fruit sulfur uptake by tomatoes in the various production systems, September 29, 2001.

Tillage system	Production system	Plant biomass S for each plant component: Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg S/ha ----------------			
Control	None	7.4 b	3.8 c	0.25 c	11.5 b
Conventional	Organic	8.8 b	10.1 ab	0.42 ab	19.4 ab
Conventional	Chemical	12.6 a	12.9 a	0.37 abc	25.9 a
Strip-till	Organic	8.2 b	5.8 bc	0.28 bc	14.3 b
Strip-till	Chemical	10.0 ab	12.7 a	0.49 a	23.2 a
LSD (*P* = 0.05)		3.6	5.6	0.15	8.1

[z] Sulfur removed by tomato fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 18. Biomass and fruit carbon/nitrogen ratio for tomatoes in the various production systems, July 26, 2001.

Tillage system	Production system	Plant biomass C/N ratio Stem/leaf	Root
		---- C/N ratio -----	
Control	None	14.5 a	22.7 a
Conventional	Organic	11.5 ab	14.8 b
Conventional	Chemical	8.8 b	16.3 b
Strip-till	Organic	10.2 b	16.8 b
Strip-till	Chemical	8.7 b	14.5 b
LSD (*P* = 0.05)	4.0	2.6	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 19. Biomass and fruit carbon/nitrogen ratio for tomatoes in the various production systems, September 29, 2001.

Tillage	Production	Plant biomass C/N ratio for each plant component		
system	system	Fruit[z]	Stem/leaf	Root
		---------- C/N ratio -----------		
Control	None	9.8 a	30.9 a	24.1 a
Conventional	Organic	11.8 a	14.8 b	13.7 bc
Conventional	Chemical	11.8 a	14.4 b	14.1 bc
Strip-till	Organic	11.2 a	16.4 b	16.0 b
Strip-till	Chemical	11.0 a	12.8 b	13.3 c
LSD (*P* = 0.05)	2.6	3.8	2.3	

[z] Carbon/nitrogen ratio of tomato fruit

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 20. Pepper Plant Biomass at final harvest, September 25, 2001 for the various production systems.

Tillage	Production	Plant biomass for each plant component		
system	system	Stem/leaf	Root	Total plant
		------------ kg/ha ---------------		
Control	None	372 b	91 b	463 b
Conventional	Organic	2260 a	308 a	2568 a
Conventional	Chemical	2638 a	290 a	2928 a
Strip-till	Organic	1961 a	371 a	2333 a
Strip-till	Chemical	2045 a	320 a	2365 a
LSD (*P* = 0.05)	789	100	877	

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 21. Pepper yield in the various production systems, 2001.

Tillage system	Production system	Marketable Yield	Total Yield	Marketable Yield	Total Yield
		------- #/acre------	---- tons/acre -----		
Control	None	19032 c	25786 b	2.6 b	3.3 c
Conventional	Organic	60597 b	64496 a	13.4 a	14.1 ab
Conventional	Chemical	77682 a	79388 a	15.7 a	16.0 a
Strip-till	Organic	67782 ab	70623 a	13.4 a	13.7 ab
Strip-till	Chemical	64518 ab	68233 a	12.6 a	13.0 b
LSD (*P* = 0.05)	15549	16406	2.9	2.9	

Marketable includes Fancy, #1 and #2 peppers. Total includes marketable and culls.

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 22. Biomass and fruit nitrogen uptake by peppers in the various production systems, 2001.

Tillage system	Production system	Plant biomass N for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg N/ha ----------------			
Control	None	15.9 c	7.1 c	1.5 b	24.5 c
Conventional	Organic	80.5 b	67.3 b	7.4 a	155.2 b
Conventional	Chemical	101.8 a	100.8 a	8.5 a	211.2 a
Strip-till	Organic	77.8 b	54.1 b	9.2 a	141.2 b
Strip-till	Chemical	80.0 b	81.9 ab	8.9 a	170.4 ab
LSD (*P* = 0.05)	17.1	30.8	2.5	41.1	

[z] Nitrogen removed by pepper fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 23. Biomass and fruit carbon/nitrogen ratio for pepper in the various production systems, 2001.

Tillage system	Production system	Plant biomass C/N ratio for each plant component		
		Fruit[z]	Stem/leaf	Root
		---------- C/N ratio -----------		
Control	None	19.9 a	23.6 a	24.0 a
Conventional	Organic	17.4 b	14.2 bc	17.4 b
Conventional	Chemical	15.5 b	10.9 bc	14.0 d
Strip-till	Organic	17.5 b	14.9 b	16.7 bc
Strip-till	Chemical	16.0 b	10.0 c	14.6 cd
LSD (*P* = 0.05)	2.2	4.3	2.5	

[z] Carbon/nitrogen ratio of pepper fruit

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 24. Biomass and fruit phosphorus uptake by peppers in the various production systems, 2001.

Tillage system	Production system	Plant biomass P for each plant component: Fruit[z]	Stem/leaf	Root	Total plant
		---------------- kg P/ha ----------------			
Control	None	3.6 c	1.6 b	0.2 c	5.4 c
Conventional	Organic	12.3 b	5.8 a	0.5 b	18.5 b
Conventional	Chemical	16.0 a	7.4 a	0.5 b	23.8 a
Strip-till	Organic	13.5 ab	7.4 a	0.8 a	21.7 ab
Strip-till	Chemical	12.4 b	5.9 a	0.5 b	18.8 b
LSD (*P* = 0.05)	2.6	3.0	0.2	4.3	

[z] Phosphorus removed by pepper fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 25. Biomass and fruit potassium uptake by peppers in the various production systems, 2001.

Tillage system	Production system	Plant biomass K for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg K/ha ----------------			
Control	None	27.2 c	16.8 b	2.2 c	46.2 b
Conventional	Organic	92.8 ab	88.0 a	5.6 b	186.4 a
Conventional	Chemical	108.3 a	90.1 a	5.3 b	203.8 a
Strip-till	Organic	98.0 ab	82.6 a	8.1 a	188.7 a
Strip-till	Chemical	82.3 b	67.8 a	5.9 b	156.1 a
LSD (*P* = 0.05)	19.8	33.3	2.0	48.1	

[z] Potassium removed by pepper fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 26. Biomass and fruit calcium uptake by peppers in the various production systems, 2001.

Tillage system	Production system	Plant biomass Ca for each plant component			
		Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg Ca/ha ----------------			
Control	None	0.8 b	5.9 b	0.9 b	7.6 b
Conventional	Organic	4.2 a	49.9 a	2.4 a	56.6 a
Conventional	Chemical	5.1 a	55.8 a	2.5 a	63.3 a
Strip-till	Organic	4.4 a	38.5 a	3.3 a	46.2 a
Strip-till	Chemical	4.3 a	49.2 a	2.9 a	56.3 a
LSD (*P* = 0.05)	2.7	21.4	1.0	22.4	

[z] Calcium removed by pepper fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 27. Biomass and fruit magnesium uptake by peppers in the various production systems, 2001.

Tillage	Production	Plant biomass Mg for each plant component			
system	system	Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg Mg/ha ----------------			
Control	None	1.6 c	1.9 b	0.6 c	4.1 b
Conventional	Organic	6.1 ab	19.7 a	1.8 abc	27.7 a
Conventional	Chemical	6.8 a	20.8 a	1.6 bc	29.2 a
Strip-till	Organic	6.5 ab	15.4 a	2.9 ab	24.8 a
Strip-till	Chemical	5.5 b	22.2 a	3.4 a	31.1 a
LSD (*P* = 0.05)	1.2	8.9	1.8	10.0	

[z] Magnesium removed by pepper fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 28. Biomass and fruit sulfur uptake by peppers in the various production systems, 2001.

Tillage system	Production system	Plant biomass S for each plant component: Fruit[z]	Stem/leaf	Root	Total plant
		----------------- kg S/ha ----------------			
Control	None	2.0 c	2.3 c	0.3 c	4.6 c
Conventional	Organic	8.6 b	13.7 b	1.0 b	23.3 b
Conventional	Chemical	10.9 a	20.6 a	1.3 ab	32.7 a
Strip-till	Organic	8.7 b	13.1 b	1.5 a	23.3 b
Strip-till	Chemical	8.7 b	16.3 a	1.5 a	26.6 ab
LSD (*P* = 0.05)	1.7	5.7	0.4	6.8	

[z] Sulfur removed by pepper fruit (all grades and all harvests)

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)

Table 29. Weed biomass and nutrient uptake in the various production systems, 2001.

Tillage system	Production system	Weed biomass and nutrient uptake: Biomass[z]	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulfur	C/N Ratio
PEPPER ------------------									
Control	None	3269 a	45.2 a	7.6 a	82.2 a	22.5a	7.8ab	9.8a	32.9a
Conventional	Organic	2355 a	49.5 a	5.9 a	57.6 a	15.4ab	12.0a	9.7a	19.2 b
Conventional	Chemical	0 b	0.0 b	0.0 b	0.0 b	0.0 d	0.0 c	0.0 b	
Strip-till	Organic	2118 a	54.0 a	7.0 a	72.0 a	12.1 bc	12.8a	8.3a	16.6 b
Strip-till	Chemical	405 b	9.7 b	1.1 b	9.6 b	3.9 cd	2.0 bc	1.9 b	17.1 b
LSD (P = 0.05)	1184	28.1	4.5	35.4	10.0	7.0	4.9	6.2	
TOMATO									
Control	None	3052 a	40.5 b	14.5a	77.8a	30.1a	10.6a	9.1a	32.8a
Conventional	Organic	2398 a	52.9 ab	6.8 b	60.0a	17.1a	11.9a	9.0a	18.0 b
Conventional	Chemical	0 b	0.0 b	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	
Strip-till	Organic	2441 a	60.4 a	8.6 b	75.2a	17.4a	13.9a	9.4a	17.3 b
Strip-till	Chemical	329 b	7.5 c	0.8 c	10.5 b	2.4 b	1.4 b	1.1 b	18.4 b
LSD (P = 0.05)	948	17.3	3.3	23.2	13.5	5.7	4.8	7.1	

[z] Biomass removed at final harvest from both the pepper and tomato treatments (September 25, 2001).

Means in the same column followed by the same letter are not statistically different by LSD (P = 0.05)