Soil Amendments in Transition to Organic Vegetable Production With Comparison to Conventional Methods: Yields and Economics

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Abstract. Many producers who have used conventional production methods for vegetables, and who want to convert to organic production, will have to pass through a 3-year transition period before their land can be qualified for organic certification. This transition can produce unique challenges. Use of several amendments has received interest for inclusion in organic production. How these affect vegetable production during the transition period was examined. Land was taken from perennial pasture and converted to production of the vegetables: bell pepper (*Capsicum annuum* L.), cv. Jupiter; processing cucumber (*Cucumis sativus* L.), cv. Earli Pik; and sweet corn (*Zea mays* L.), cv. Incredible (se endosperm genotype) using organic materials and methods with comparison made to production using conventional methods. Conventional and transition to organic portions of the field were separated by 25 m with the buffer zone planted with the same sweet corn cultivar used in the experimental plots and minimally maintained by addition of organic fertilizer. To the organic portion of the field, three levels of humates (0, 112, and 224 kg·ha⁻¹) and three levels of corn gluten meal (0, 448, and 896 kg·ha⁻¹) were applied in nine combinations. Yields for all crops were determined for all years. In the first year, bell pepper yields for plants under conventional production were higher than for the plants in the transition plots. In the remaining 2 years, bell pepper yields were similar under the two production systems. In the first 2 years, cucumber yields for plants under conventional production were higher than for the plants under transition to organic production. In the last year, cucumber yields were similar under the two production systems. In all years, sweet corn yields for plants under conventional production were higher than for plants under transition to organic production. Humates and corn gluten meal did not benefit yields of crops. An economic analysis comparing yields, prices, and costs of production of the crops under conventional and the transition to organic indicated that conventional practices generally provided more net revenue than did transition to organic production. Net revenue for the three species under the transition to organic for the 3 years was \$2749 for three hectares. Net revenue for the three crops under conventional production for 3 years was \$61,821, a difference of \$59,072. Costs, yield, and prices will have to be considered when decisions are made concerning the adoption of organic practices.

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In the United States, there is growing interest in the consumption and production of organically produced food and fiber (Dimitri and Greene, 2002). In the southern plains of the United States, there is also a growing interest in converting land to crops that are not traditional to the region as a result of changes in demographics and economic realities. One such use for portions of the southern plains is vegetable production.

In all types of agriculture, there are products and procedures that can be easily transposed between regions and those that cannot. The traditional use of land for row

crops, or cow-calf operations, may be taken out of those types of production to be used for vegetables. In the latter case, the transition would be from perennial pasture to other types of agriculture. When land was converted from perennial pasture to vegetable production, using conventional methods, it was determined that it would take ≈3 years for bell peppers to produce at levels that would provide an economic return (Russo and Roberts, 1991). In that study, it appeared that soil A-horizon depth, pH, and NPK concentrations interacted to affect yields on soil converted from grass pasture. It is likely that as the conversion takes place, there are changes occurring in the soil structure, chemistry, and biota that could affect production of vegetables. These changes may be mediated by the type of conversion that takes place and by the inputs used.

An underlying philosophy of organic production is to improve the soil condition over the long term (Dabbert and Madden, 1986; Merrill, 1983). The methods used to do this conform to general principles but are also amendable to conditions found at individual locations. A common thread in organic production is the amendment of soil with materials from organic sources. If these are not available on-farm, they must be transported to the site and can be, in part, responsible for additional cost in the production of organic vegetables (Stanhill, 1990). The concept of use of materials from organic sources may be more easily adaptable to a situation in which animals are involved on-site in the recycling of vegetable matter to the soil. Animal manure can be used in the raw form, with restrictions, or as aged compost. The latter has been successfully used for vegetable production (Ozores-Hampton and Peach, 2002).

Most early work on evaluation of alternatives to conventional agriculture has been on crops other than vegetables (Smolik and Dobbs, 1991). Research has begun to report replicated trials on effects of organic concepts, including soil amendments, on protection of crops from disease (Kim et al., 1997; Sumner et al., 2002) and on quality of vegetables (Asami et al., 2003; Woese et al., 1997). Humic substances are a type of organic amendment (Schnitzer and Khan, 1972). These materials, generally found at high levels in soils relatively high in organic matter, can improve plant development (Schnitzer and Poapst, 1967) and have been credited with hormone-like effects (O'Donnell, 1973). Humic substances have been reported to benefit vegetable development (Pertuit et al., 2001; Seyedbagheri et al., 2001). Another material, corn gluten meal (CGM), has properties as a nonspecific herbicide (Bingaman and Christians, 1995; Liu et al., 1994; McDade and Christians, 2000) and contains up to 10% N. There is insufficient information on the appropriate levels of CGM and humates that should be used for organic vegetable production, especially during the transition to organic production.

There are questions about whether organic or conventional is the better production

system. The concept of modern conventional farming can probably be dated to the end of World War II when internal combustion engines and synthetic fertilizers became mainstays of production in the United States. Proponents of organic production argue that conventional agriculture is more detrimental to the environment because it feeds the plant and not the soil and contributes to chemical runoff into water systems (Arden-Clarke and Hodges, 1988). For organic production, the more hands-on approach may add to expense during production and may require a premium market price for produce to make it competitive. Sellen et al. (1995) reported that in Ontario, Canada, in the second and third years of the transition to organic vegetable production, yields and economics of all crops under study were less than for conventionally produced crops.

Regardless of whether production is undertaken with conventional or alternative methods, it is necessary that systems be developed that are applicable to specific regions. Because there is little information on the yields and economics during the transition to organic, this project was undertaken to determine if organic soil amendments affect vegetable yields during the transition to organic production, compare yields with those for conventional production, and compare the economics of the production systems.

Material and Methods

Site description and preliminary activities.

The experiment was conducted on a Bernow fine sandy loam (fine loamy, siliceous, thermic, Glossic Paleudalf) soil at Lane, Okla. Before this study, the land was in perennial, mixed pasture for over 30 years and was occasionally grazed. There had not been any attempt to manage the land on which the experiment was established since 1986. As a result of its history, the land would be eligible for organic certification. However, under other circumstances, pasture is often treated with chemicals that are not suitable for organic production. To better understand the process of transmission from conventionally managed pasture to organic vegetable production, the site was managed as if a transition period was necessary.

In the Fall of 2001, the existing cover was mowed, left for 2 weeks, and then plowed under. The entire field was lightly disked and seeded with wheat (*Triticum vulgare* L.), a common winter cover crop for the region. In late Winter 2002, the wheat was mowed, left for 3 weeks, and the soil disked. Soil samples to determine base rates of available nutrients were taken across the entire field according to the methods of Johnson (1985). The 0.8-ha field was divided into sections for the transition to organic production and for the area to be managed using conventional methods.

The area to be used for the transition to organic was ≈ 0.5 ha and included treatments and guard rows. The remainder of the field contained the area to be treated with conven-

tional management and guard rows and a barrier area between types of management. Raised beds (20-cm-high and 18-cm-wide bed tops), formed from bare soil, were oriented north to south on 0.9-m centers across the entire field. From the west, there were six rows with the western-most two rows seeded to sweet corn before experimental plots were established. The next four rows were not planted with any crops and were disked to maintain them weed-free. The conventionally managed portion of the field was separated from the organic portion of the field by 28 rows running north to south. The middle 16 of the 28 rows were planted with sweet corn. The remaining rows were not planted and kept weed-free by disking. The sweet corn in the barrier area was provided with organic fertilizer. Equipment used in both parts of the field was washed before moving between management types. Crops studied were bell pepper (*Capsicum annuum* L.), cv. Jupiter, processing cucumber (*Cucumis sativus* L.), cv. Earli Pik, and sweet corn (*Zea mays* L.), cv. Incredible (se endosperm genotype).

Yearly activities—transplant production in 2002. Bell pepper was established as transplants produced in Styrofoam trays (Speedling; American Plant Products, Oklahoma City, Okla.) in a greenhouse using conventional or organic potting media and fertilizers. Transplant trays were $88 \times 34.5 \times 65$ cm (L $\times$ W $\times$ D) with 128 truncated pyramidal shaped cells, each of which was $3.5 \times 3.5 \times 60$ cm (L $\times$ W $\times$ D) with volumes of 36 cm^3 . To determine cell volumes, the hole in the bottom of the cell was plugged, the cell was filled with water, the hole was unplugged, the water dispensed in to a graduated cylinder, and the volume measured in milliliters was converted to centimeters squared ($1 \text{ mL} = 1 \text{ cm}^3$).

In early February, trays were filled with Potting Soil (Garden-Ville, San Antonio, Texas) or Reddi-Earth Plug and Seedling Mix (Scotts-Sierra, Marysville, Ohio). The former was used for transplants to be established in the portion of the field in transition to organic and the latter for those established in the portion of the field managed with conventional methods. The potting media were moistened and seed of bell pepper placed in cells. There are no organic equivalent seed for this superior cultivar. It was possible to obtain untreated seed for use in the experiments. The media were kept moist with the use of an overhead irrigation system. At 2 weeks after planting when 90%+ of seedlings emerged, plants were thinned to one per cell; fertilizer applications were begun and continued weekly until seedlings were transplanted to the field. Transplants to be used in the portion of the field in transition to organic were provided with Sea Tea, 2.1–3.3–2.2 NPK, (Garden-Ville) liquid fertilizer applied at $7.5 \text{ mL} \cdot \text{L}^{-1}$, the recommended rate. Those to be used in the portion of the field under conventional cultivation were provided with a solution of a water-soluble synthetic fertilizer (Peters, 20–20–20 NPK;

Spectrum Group, St. Louis, Mo.) at 0.5-fold the recommended rate ($5 \text{ g} \cdot \text{L}^{-1}$) based on experience at Lane (Russo, 2005).

Field preparation—2002 transition to organic production. This portion of the field was divided into nine plots, 3 plots wide $\times$ 3 tiers deep, with rows oriented north to south. Each plot, comprising $\approx 438 \text{ m}^2$, had 27 rows, each of which was 18 m in length, on 0.9-m centers. To the north of each plot was a 2-m wide unplanted area, and to the east of each plot was a 1.8-m-wide unplanted area kept weed-free by disking. Within each plot, combinations of three levels of humates (Humate, 50%+ humic acid; 2.5–0.01–0.1 NPK; Garden-Ville), 0, 112, and $224 \text{ kg} \cdot \text{ha}^{-1}$, and three levels of corn gluten meal (CGM; Twin Oaks Wholesale, Denison, Texas), 0, 448, and $896 \text{ kg} \cdot \text{ha}^{-1}$, were applied to three rows in each of the nine combinations to account for the 27 rows. Each three-row subplot was 50 m^2 . The humate was applied before planting in a 10-cm band to beds and lightly incorporated using a Liliston rolling cultivator (Bush Hog Corp., Selma, Ala.). The description of application of the CGM is presented in chronologic order in a following section.

In organic production, and in the transition to organic production, fertilizer recommendations are expressed differently than under conventional culture (McLaurin and Reeves, 2000). This is because recommendations for some materials like composted manure are provided on an $\text{Mg} \cdot \text{ha}^{-1}$ basis. Also, nutrients in organic fertilizers are released more slowly than nutrients from salts (Taylor and Zenz, 1999). A fertilizer produced from natural materials (Soil Food 7–2–2; Garden-Ville) was lightly incorporated with a disk. Soil Food was applied at levels approximating that applied to the area under conventional culture.

Field preparation—2002 conventional production. This portion of the field was divided into nine plots, 3 plots wide $\times$ 3 tiers deep, with rows oriented north to south. Plots in tiers were arranged so that they began and ended in line with those in the transition to organic portion of the field. Plots consisted of three rows, which were 18 m in length, with a 2-m unplanted area to the north of each plot and a 1.8-m unplanted area to the east of each plot kept weed-free by disking. Plots were $\approx 50 \text{ m}^2$. There were six rows to the east of treatment rows with the two eastern-most planted to sweet corn and the next four left unplanted and kept weed-free by disking. Synthetic fertilizer was applied as recommended under conventional management based on the results of soil analysis. The source of N, P, and K was ammonium nitrate, triple superphosphate, and muriate of potash, respectively. Amounts of nutrients provided brought levels in the soil to $\approx 75\text{N} - 112\text{P} - 290\text{K} \text{ kg} \cdot \text{ha}^{-1}$, which supported all crops used (Motes and Roberts, 1994). To the area to be planted with bell peppers and cucumbers, the herbicide trifluralin (Dow AgroSciences, St. Louis, Mo.) was preplant-incorporated at recommended rates.

The herbicide metolachlor (Ciba, Greensboro, N.C.) was preplant-incorporated to sweet corn at recommended rates.

Planting and crop maintenance activities in 2002. Crops in the conventional and transition to organic plots were assigned to plots in a random manner. The crops were spatially arranged east to west in both portions of the field in the same sequence. Six-week-old bell pepper was transplanted on 25 April 2002 with an in-row spacing of 46 cm. Cucumber and sweet corn seed were sown on 30 April 2002. Because there are no organic equivalent seed for these superior cultivars, conventionally produced untreated seed were used in the experiments. After emergence, cucumbers were thinned to a 46-cm in-row spacing and sweet corn to 23-cm in-row spacing.

CGM acts as a preemergent, nonspecific herbicide (Bingaman and Christians, 1995). Cucumber and sweet corn were allowed to develop root systems before CGM was applied to assigned subplots in a 10-cm band over the tops of plants. After application, overhead irrigation was used to remove the CGM from the plants and to lightly incorporate it into the soil. Before application of CGM, weeds were controlled mechanically with a rolling cultivator (Bush-Hog) or with hoes. Within the experiment, no provision was made for weedy control plots to test the applicability of CGM as an herbicide during the transition to organic production. The usefulness of CGM as an herbicide was indirectly evaluated based on the economics of weed control in the transition to organic compared with conventional production.

Crops in both portions of the field were regularly scouted. There was no need to apply pesticides to control insects or diseases in bell pepper. For cucumber, the most damaging pests, Striped [*Acalymma vittatum* (Fabricius)] or Spotted Cucumber Beetle (*Diabrotica undecimpunctata howardi* Barber) occur on newly emerged plants. About 100 g of the compound Adios (BASF, Research Triangle Park, N.C.), a mixture of Sevin dust and ground buffalo gourd (*Cucurbita foetidissima* H.B.K.) seed, was distributed on yellow plastic plates, a color that serves as an attractant. The plates, located in the mowed grass at least 2 m outside the borders of the field, were secured to the ground with a spike. There was one trap on the north, south, and eastern borders of the portion of the field under conventional management. Although this material contains a synthetic insecticide, its use conforms to United States Department of Agriculture, Agricultural Marketing Service, National Organic Program (NOP)

standards (USDA, AMS, 2004a and additions) and could be used during the transition if used as described. The insecticide *Bacillus thuringiensis* (Bt) was applied to sweet corn in the portion of the field in transition to organic beginning at the emergence of first silk and continuing at 3- to 4-d intervals until silks desiccated. The insecticide Permethrin (Helena Chemical, Collierville, Tenn.) at 140 g-ha⁻¹ was applied to sweet corn in the portion of the field under conventional management once at first emergence of silk and then Bt was applied every 3 to 4 d thereafter until silks desiccated.

Overhead irrigation supplied the equivalent of 5 cm of water per week when there was insufficient precipitation. After the last harvest, plants were mowed. After 3 weeks, the debris was tilled under. The soil was seeded with wheat as a winter cover.

Yield data were obtained from all plants in the middle row of the three row plots. Total and marketable numbers of bell pepper, cucumber fruit, and sweet corn ears (with husks) were determined with marketable quality based on USDA (USDA, AMS, 1989, 1992) or industry standards.

Yearly activities in 2003. The process as described was repeated, except that crops were spatially rotated. Cucumber was planted where bell pepper was previously, sweet corn was planted where cucumber was previously, and bell pepper was planted where sweet corn was previously. This rotation was used in both management systems. A problem arose in the production of bell pepper seedlings for use in the portion of the field in transition to organic production. The same materials used in 2002 were used in 2003, but seedlings never developed sufficient vigor to be transplanted. In 2003, bell pepper was direct seeded into the beds on 21 Apr. Cucumber and sweet corn were planted on 28 Apr.

After the plant residue left after the last harvest had been mowed, 12.4 mg-ha⁻¹ of fully composted manure was applied to the portion of the field in transition to organic production using a manure spreader. The level applied was based on an approximated conversion (McLaurin and Reeves, 2000) to bring nutrient levels in the transition to organic portion of the field to that similar to that applied to the portion of the field under conventional culture. The extractable nutrient concentration of the manure is presented in Table 1. The same types of data were collected.

Yearly activities in 2004. These processes were repeated with the exceptions that no 'Soil Food' fertilizer, or additional manure, was applied; and changes were made in

production of bell pepper transplants destined for the portion of the field in transition to organic production. A different organic potting mix (Sunshine; Sun Gro Horticulture, Bellevue, Wash.) for those seedlings was used, and the amount of 'Sea Tea' was increased to 4× the rate recommended on the label (Russo, 2005). Bell peppers were transplanted on 19 Apr. 2004, and cucumber and sweet corn were direct seeded on 27 Apr. 2004. The same types of data were collected.

Data analysis. The experimental design, for each crop, was a split-plot with three replications. In each tier, there were three plots under transition to organic and three under conventional cultivation. The same crops were present in two of the six plots, in one plot under transition to organic and in one plot in conventional cultivation. During the 3-year rotation, each crop was in each plot in a tier under both management systems. Comparison was made between management types. In this analysis, the average overall treatments in the transition to organic was compared with conventional management. Also, comparison was made between levels of humates and CGM with management type as the main affect and type of amendment the subplot. For the area under conventional production, amendment was designated as none as opposed to the zero levels for humate and CGM for plants under transition to organic. In all analyses, General Linear Models procedures in SAS (SAS Inc., Cary, N.C.) were used. Interactions, if present, were analyzed with least squares means to explain results. If interactions were not significant, means were separated using the Ryan-Einot-Gabriel-Welsch post hoc test.

Economics of the systems were compared. Costs of production were determined by combining actual costs of chemical inputs, labor use, and machinery use on plots. These were converted to 1-ha estimates for normalization and comparison purposes. Chemical costs were calculated by multiplying the actual amount of inputs applied to the crops times the cost of those products during the year of application. The highest rate of humates and CGM were used to obtain the most conservative estimate. Labor was estimated at \$10 per hr. Equipment use was calculated using average custom rates for the specific operation. The time involved in keeping between plot barriers weed-free was not used in the analysis. Prices used for yields were from the Dallas terminal market on the day of harvest (USDA, AMS, 2002–2004). Revenue per hectare minus total cost per hectare produced net revenue per hectare. To obtain total net revenue for all crops, it

Table 1. pH, nutrient content, and some physical characteristics of manure used in the organic portion of the plot on a dry basis².

	C	N	P ₂ O ₅	K	Ca	Cu	Fe	Mg	Mn	Na	S	Zn	Soluble salts	Dry	
														Moisture matter %	EC ^y (μS)
pH (kg-mg ⁻¹)	680.4	52.5	32.1	52.0	114.5	0.1	53.3	19.0	1.3	3.2	13.4	0.4	8.7	6.6	93.4
															2,490

²Analysis performed by the Oklahoma State University Soil, Water & Forage analytical Laboratory, Stillwater, Okla.

^yEC = Electrical conductivity.

was assumed that there were 3 ha, one each for bell pepper, cucumber, and sweet corn, over the 3-year period. Net revenues do not include costs of transportation from the field to the Dallas terminal market and are overestimates of potential net revenue. Any premium available to organic produce was not assigned to yields of crops in the transition to organic because the produce would not be eligible for organic designation.

Organic designation of materials. A process exists for determining if a product conforms to the USDA, AMS, NOP standards. The Organic Materials Review Institute (OMRI), a nonprofit organization, provides testing and lists products that conform to NOP standards. However, if the product does not appear on that list, it only means that it has not been listed by OMRI and may still conform to USDA, AMS, NOP standards. The fertilizer, 'Soil Food 7-2-2', is described by the manufacturer as "natural" and conforms to the definition of organic, and the potting medium 'Potting Soil' conforms to the definition "100% organic" according to NOP. The 'Sunshine' potting medium is listed by OMRI. At the time the project was initiated, use of "compost tea" was generally accepted as being able to be used in an organic program. 'Sea Tea' contains "compost tea" made from plant material. Questions concerning the safety of the use of "compost tea" in production of vegetables have arisen. The concern about "compost tea" is primarily the result of the possible presence of *Escherichia coli* (Migula) Castellani and Chalmers or enterococci bacteria that are human pathogens. It has been determined that "compost tea" can be used in an organic program if certain restrictions are met (USDA, AMS, 2004b). If a product containing "compost tea" has been pretested and meets U.S. Environmental Protection Agency-recommended guidelines (US EPA, 2000) for recreational water quality for fecal contamination for *E. coli* (126 CFU/100 mL) or enterococci (33 CFU/100 mL) or if it has not been pretested for contamination and applied more than 90 days before harvest, it can be used in production of food crops (USDA, AMS, 2004a). Bell pepper fruit from plants fertilized with 'Sea Tea' were harvested no sooner than 64 days after the last treatment in the greenhouse. The manufacturer of 'Sea Tea' indicates that it conforms to the U.S. EPA guidelines (M. Beck, personal communication, 2004), and as a result, it can be used in the unrestricted organic production of transplants for greenhouse culture of bell pepper transplants.

Results

Effect of management system. Analysis indicated that year affected marketable number and yield of all crops, management system affected marketable number and yield of cucumber and sweet corn, and the year $\times$ management system interaction affected marketable number and yield of all crops (Table 2). The interaction was used to explain

Table 2. Analysis of variance table for management system and year effects on number of fruit of bell pepper and cucumber and numbers of ears of sweet corn and marketable yield of all vegetables.

Source	Marketable					
	Bell pepper		Cucumber		Sweet corn	
	Number (ha)	Yield (mg·ha ⁻¹)	Number (ha)	Yield (mg·ha ⁻¹)	Number (ha)	Yield (mg·ha ⁻¹)
Year (Y)	***	**	**	**	**	**
Management system (M) ^y	NS	NS	**	**	**	**
Interaction Y $\times$ M	**	**	**	**	**	**
Interaction Management Year $\times$ system						
2002 Transition to organic	6,325 ^x	0.9	4,527	2.3	6,652	1.9
Conventional	72,322**	12.4**	53,352**	9.6**	14,672**	6.3**
2003 Transition to organic	43,998	7.7	19,940	6.6	7,378	2.1
Conventional	25,342 ^{NS}	5.7 ^{NS}	56,464**	15.6**	26,972**	10.0**
2004 Transition to organic	42,615	9.9	20,583	7.4	17,964	7.0
Conventional	32,159 ^{NS}	6.9 ^{NS}	24,157 ^{NS}	8.4 ^{NS}	11,115**	4.9**

^z NS, ** not significant or significant at $P \leq 0.01$, analysis of variance.

^y For this analysis, the values are averaged across all transition to organic and compared with the conventional management.

^x NS, ** not significant, or significant at $P \leq 0.01$, least squares means analysis. In this analysis values in a year $\times$ management system pair in a column are compared.

the results. In 2002, the conventional system outperformed the transitional system for all crops. In 2003, the conventional system outperformed the transitional system for cucumber and sweet corn, and in 2004, the transitional system performed as well as, or better than, the conventional system for all crops.

Effect of amendment. Analysis indicated that year affected numbers of marketable fruit of bell pepper and cucumber, ears of sweet corn, and yield of all crops; level of humate and CGM affected numbers of marketable fruit of cucumber, ears of sweet corn, and yield of all crops; and, there were no significant interactions (Table 3). In general, the

least numbers of fruit and the lowest yields of bell pepper or cucumber and ears of sweet corn were produced in 2002 than in other years. The exception was for numbers of ears, and yield, of sweet corn produced in 2003 that was similar to that produced in 2002. When conventional production was compared with levels of humates or CGM, it was found that for bell pepper, numbers of fruit produced in the transitional portion of the field, average 30,980 fruit/ha, were not different from numbers of fruit, average 43,274 fruit/ha, produced on the conventional portion of the field; yield for bell pepper was highest for plants under conventional production; and numbers of cucumber fruit and ears of sweet corn and

Table 3. Analysis of variance table for year, and humate, corn gluten meal (with comparison with conventional) effects on number of fruit of bell pepper and cucumber and numbers of ears of sweet corn and marketable yield of all vegetables.

Source	Marketable					
	Bell pepper		Cucumber		Sweet corn	
	Number (ha)	Yield (mg·ha ⁻¹)	Number (ha)	Yield (mg·ha ⁻¹)	Number (ha)	Yield (mg·ha ⁻¹)
Year (Y)	*	**	**	**	**	**
Humate (H)	NS	*	**	**	**	**
Corn gluten meal (C)	NS	*	*	*	*	*
Year						
2002	12,923 b ^z	2.0 c	15,938 b	3.0 b	7,454 b	2.3 b
2003	42,133 a	7.5 b	23,593 a	7.5 a	9,159 b	2.9 b
2004	41,570 a	9.6 a	20,941 a	7.5 a	17,280 a	6.8 a
Humate						
0 kg·ha ⁻¹	28,274 a	6.6 b	15,642 b	4.7 b	10,621 b	3.7 b
112 kg·ha ⁻¹	8,126 a	6.6 b	17,619 b	5.6 b	10,984 b	3.7 b
224 kg·ha ⁻¹	36,539 a	5.3 c	18,443 b	6.0 b	10,391 b	3.7 b
Conventional (none)	43,274 a	8.2 a	44,658 a	11.2 a	17,586 a	7.1 a
Corn gluten meal						
0 kg·ha ⁻¹	29,425 a	7.0 b	18,130 b	5.8 b	9,897 b	3.5 b
448 kg·ha ⁻¹	38,021 a	5.8 c	16,203 b	5.1 b	11,066 b	3.8 b
896 kg·ha ⁻¹	25,490 a	5.8 c	17,372 b	5.4 b	11,033 b	3.8 b
Conventional (none)	43,274 a	8.2 a	44,658 a	11.2 a	17,586 a	7.1 a

^z Values in a column followed by the same letter are nonsignificantly different $P \leq 0.05$, Ryan-Einot-Gabriel-Welsch multiple range test.

^{NS}, *, ** Nonsignificant or significant at $P \leq 0.05$ or $P \leq 0.01$, analysis of variance. None of the possible interactions were significant.

their yields were always highest for plants under conventional production than for any level of humate or CGM.

Economic analysis. Over the 3-year period, when net revenue for all crops were combined, both production systems returned a profit with those from the conventional production system being 22 times greater than for those from the transition to organic production system (Table 4). Only cucumber consistently had a positive net revenue for both production systems, and net revenue for the conventional production system was 2.8 times better than the net revenue for the transition to organic system. The net revenue for bell pepper under transition to organic system was positive in 2 years, for sweet corn never positive, and the sum total for each crop for the 3 years was never positive. The net revenue for bell pepper and sweet corn under conventional production was positive in all years. This was the case although bell pepper under transition to organic had yields as good as those under the conventional system in 2 years, but overall years, bell pepper plants under the transition to organic system had yields that were only two-thirds that of plants under conventional production.

The reasons for the lower net revenue for vegetables under transition production are the result of costs of additional inputs as described in the example budgets (Table 5). The transition to organic production system

included costs of organic fertilizer, humates, and corn gluten meal. In addition, costs of production of transplants using organic methods were 1.4 times that of production using conventional methods. The cost of herbicide used in conventional production was not large and did not offset the cost of corn gluten meal reported to be an organic material used for weed control.

Discussion

The philosophy of organic production states that as changes occur in the soil, long-term benefits will continue to accrue; and plants established in soil cultivated using organic practices and products will not be as susceptible to possible detrimental conditions as plants produced under conventional production. To accomplish this, different inputs can be used.

Humates benefit vegetable production through building of soil, plant development, or by contributing nutrients (Bryan, 1976; O'Donnell, 1973; Pertuit et al., 2001). Humic compounds are reported to provide benefits to vegetables by stimulating root development in bean (*Phaseolus vulgaris* L.) and corn, improving seedling and young tomato (*Lycopersicon esculentum* Mill.) development, and increasing nutrient content of young cucumber (Adani et al., 1998; Bryan, 1976; Lulakis and Petsas, 1995; Rauthan and Schnitzer, 1981; Schnitzer and Poapst, 1967). For potato

(*Solanum tuberosum* L.), yield increases were associated with increased levels of humic substances. However, Kim et al. (1997) found that addition of humates had little effect on *Phytophthora* sp. populations, disease incidence, or severity in bell pepper.

Corn gluten meal, developed for weed control in turfgrass (Bingaman and Christians, 1995), should not be used as a pre-plant, preemergence herbicide in vegetables (McDade and Christians, 2000). In this study, corn gluten meal was applied after bell pepper transplants established new root growth and when seeded crops had established root systems. Efficacy of synthetic materials is, in part, dependent on soil and environmental conditions for the best control of weeds, and this is also the case in organic production.

Benefits to plant development resulting from use of organic amendments are described as improvement to soil over time. Changes in soil are not confined to the period of transition to organic. Russo and Roberts (1991) found that when land is converted to pepper production, from a grass pasture using conventional methods, there appears to be a 3-year period during which yields are not at optimum levels. This was attributed to modifications in the soil that occurred as tillage and other field maintenance activities changed over time.

In this report, overall years, yields for crops under transition to organic were lower when compared with conventional

Table 4. Yields, costs, and net returns for vegetables under transition to organic and conventional production in 3 years.

Yr	Type of production	Number boxes/ha	Price (\$/box) ^a	Total revenue (\$/ha)	Total cost (\$/ha)	Net revenue (\$/ha)	Three-year total net revenue (\$/ha)
<i>Bell pepper</i>							
2002	Transition to organic	86 ^y	15.75	1,354.50	7,877.82	-6,523.32	
	Conventional	1,510	15.75	23,782.50	8,651.18	15,131.32	
2003	Transition to organic	949	11.00	10,439.00	8,426.72	2,012.28	
	Conventional	702	16.25	11,407.50	5,862.60	5,544.90	
2004	Transition to organic	766	11.00	8,426.00	8,422.70	3.30	
	Conventional	492	11.00	5,412.00	5,395.20	16.80	
2002 - 2004	Transition to organic						-4,507.74
	Conventional						20,693.02
<i>Processing cucumber</i>							
2002	Transition to organic	425 ^y	20.00	8,500.00	5,006.81	3,493.19	
	Conventional	600	20.00	12,000.00	4,468.95	7,531.05	
2003	Transition to organic	415	30.00	12,421.86	4,966.56	7,455.30	
	Conventional	971	30.00	28,616.06	5,969.53	22,646.53	
2004	Transition to organic	269	20.00	5,380.00	4,379.48	1,000.52	
	Conventional	306	20.00	6,125.60	3,290.53	2,829.47	
2002 - 2004	Transition to organic						13,589.69
	Conventional						36,891.05
<i>Sweet corn</i>							
2002	Transition to organic	156 ^y	15.25	2,379.00	3,818.18	-1,439.18	
	Conventional	514	15.25	7,838.42	3,670.10	4,168.40	
2003	Transition to organic	173	11.00	1,914.84	3,980.95	-2,066.11	
	Conventional	815	11.00	8,966.10	5,388.95	3,577.15	
2004	Transition to organic	333	9.50	3,163.50	4,351.00	-1,187.50	
	Conventional	385	9.50	3,657.50	3,281.96	375.54	
2002 - 2004	Transition to organic						-4,692.79
	Conventional						8,121.09
<i>All crops for 3 areas of land^b</i>							
2002 - 2004	Transition to organic						2,748.48
	Conventional						61,821.16

^aValues are in US dollars.

^yFor bell pepper, boxes in 2002 for organic fruit were 15.9 kg and otherwise they were 12.7 kg; for cucumber, boxes in 2002 for organic fruit were 8.2 kg and otherwise they were 25 kg; for sweet corn for ears in years, all boxes were 19.1 kg.

^bValues represent the cumulative net revenue for three areas of land because each crop was grown on separate units of land in each of the 3 years.

Table 5. Inputs and costs for vegetables under transition to organic and conventional production, 2003 used as example.

Source	Units	Transition to organic cost per:		Conventional cost per:	
		Unit (\$US)	ha (\$US)	Unit (\$US)	ha (\$US)
<i>Bell pepper</i>					
Revenue	Boxes	11.00	10,439.00	16.25	11,407.50
<i>Transplants</i>					
Production	plants	0.11	2,717.00	0.08	1,976.00
Transplanting activity ^z	1 application	0.08	799.69	0.08	799.69
<i>Field preparation and maintenance</i>					
Soil Preparation	3 applications	10.00	74.13	10.00	74.13
Bed preparation	1 application	10.00	24.71	10.00	24.71
Fertilizer application ^y	1 application	366.94	366.94	108.72	108.72
Corn gluten meal ^y	1 application	0.46	907.34	— ^x	—
Humate ^y	1 application	0.15	152.80	—	—
Herbicide ^w	1 application	—	—	14.05	39.72
Irrigation ^v	8 applications	12.00	237.21	12.00	237.21
Mechanical cultivation	2 applications	10.00	49.42	—	—
Land charge	hectare	247.10	247.10	247.10	247.10
<i>Total cost of production postcrop costs</i>		—	6,754.48	—	4,734.55
Harvesting, grading, and marketing	box	2.00	1,898.00	2.00	1,404.00
<i>Clean up and winter cover</i>					
Mow residue	1 application	5.00	12.35	5.00	12.35
Disk	2 applications	10.00	49.42	10.00	49.42
Plant cover	1 application	17.00	889.55	17.00	889.55
<i>Total postcrop costs</i>		B	951.32	—	951.32
<i>Total costs</i>		—	8,426.72	—	5,862.60
<i>Net revenue</i>		—	2,012.28	—	5,544.90
<i>Processing cucumber</i>					
Revenue	Boxes	30.00	12,421.86	30.00	28,616.06
<i>Field preparation and maintenance</i>					
Soil Preparation	3 applications	10.00	74.13	10.00	74.13
Bed preparation	1 application	10.00	24.71	10.00	24.71
Fertilizer application ^y	1 application	366.94	366.94	108.72	108.72
Cucumber seed	13.6 kg·ha ⁻¹	54.63	134.98	54.63	134.98
Sowing seed	1 application	5.00	12.35	5.00	12.35
Insecticide	0.5 kg·ha ⁻¹	— ^x	—	13.58	13.58
Insecticide	1 application	—	—	10.00	24.71
Insecticide	1 application	—	—	7.26	19.32
Corn gluten meal ^y	1 application	0.46	907.34	—	—
Humate ^y	1 application	0.15	152.80	—	—
Herbicide ^w	1 application	—	—	14.05	39.72
Irrigation ^v	8 applications	12.00	237.21	12.00	237.21
Mechanical cultivation	2 applications	40.00	197.68	40.00	197.68
Land charge	hectare	247.10	247.10	247.10	247.10
<i>Total cost of production</i>		—	2,374.56	—	1,134.21
<i>Postcrop costs</i>					
Harvesting, grading, and marketing	box	4.00	1,660.00	4.00	3,884.00
<i>Clean up and winter cover</i>					
Mow residue	1 application	5.00	12.35	5.00	12.35
Disk	2 applications	10.00	49.42	10.00	49.42
Plant cover	1 application	17.00	889.55	17.00	889.55
<i>Total postcrop costs</i>		—	951.32	—	951.32
<i>Total costs</i>		—	4,966.56	—	5,969.53
<i>Total net revenue</i>		—	7,455.30	—	22,646.53
<i>Sweet corn</i>					
Revenue	Boxes	11.00	1,914.84	11.00	8,966.10
<i>Field preparation and maintenance</i>					
Soil Preparation	3 applications	10.00	74.13	10.00	74.13
Bed preparation	1 application	10.00	24.71	10.00	24.71
Fertilizer application ^y	1 application	366.94	366.94	108.72	108.72
Seed	13.6 kg·ha ⁻¹	17.50	43.24	17.50	43.24
Sowing seed	1 application	5.00	12.35	5.00	12.35
Insecticide	3 applications	10.00	74.13	—	—
Insecticide	475 mL and 68 g·ha ⁻¹	— ^x	—	20.87	62.36
Insecticide	4 applications	—	—	24.53	98.84
Corn gluten meal ^y	1 application	0.46	907.34	—	—
Humate ^y	1 application	0.15	152.80	—	—
Herbicide ^w	1 application	—	—	28.85	71.29
Irrigation ^v	8 applications	12.00	237.21	12.00	237.21
Mechanical cultivation	2 applications	40.00	197.68	40.00	197.68
Land charge	hectare	247.10	247.10	247.10	247.10

(Continued on next page)

Table 5. (Continued) Inputs and costs for vegetables under transition to organic and conventional production, 2003 used as example.

<i>Total cost of production</i>		—	2,337.63	—	1,177.63
Harvesting, grading, and marketing	box	4.00	692.00	4.00	3,260.00
<i>Clean up and winter cover</i>					
Mow residue	1 application	5.00	12.35	5.00	12.35
Disk	2 applications	10.00	49.42	10.00	49.42
Plant cover	1 application	17.00	889.55	17.00	889.55
<i>Total postcrop costs</i>		—	951.32	—	951.32
<i>Total costs</i>		—	3,980.95	—	5,388.95
<i>Net revenue</i>		—	-2,066.11	—	3,577.15

²24,700 plants/ha.³Amounts of organic and conventional fertilizer as described in the text; the highest rates of humate and corn gluten meal were used.⁴—, not appropriate input for management system.⁵Herbicide applied to conventional plots as described in the text.⁶Overhead irrigation with hardset guns.

production. This may be the result of the slower release of nutrients from organic sources in the first year. The humates used in this project provided little in the way of macronutrients. Differences in results in this and other reports may be the result of different locations and crops tested.

For CGM, there did not appear to be a benefit to its use for weed control based on economics. It was observed that weed control using synthetic materials did not provide much benefit over organic methods. For bell pepper, yields were lower when CGM was used than when no CGM was added. For CGM, the yield reduction in bell pepper may be related to metabolites released from CGM that are inhibitory to plants in general and possibly bell pepper development.

Martini et al. (2004) asked whether yield increases occurring under organic production are the result of improving soil quality or additional experience and changes occurring during the process. This project did not provide an answer to that question. A learning curve is the distillation of experience and results that determines future directions of endeavor. However, it was demonstrated that during the conversion from pasture, changes in yield of vegetables occur with the trend being upward when organic materials and principles are used. This is not in agreement with Sellen et al. (1995) and is likely the result of differences in location of the studies, although sweet corn was one of the crops grown in both locations. It remains to be determined if yields continue to increase, or if they remain unchanged, or decrease as production in the future occurs under continuing organic practices. For all vegetables in this report, yields for those on soil undergoing transition were at levels equal to those under conventional cultivation at the end of 3 years and was the result of an increase in yield on land under transition and a reduction, or stabilization, of yield on land under conventional cultivation. Why crops on land under conventional cultivation did not increase is not immediately clear but was not the result of pressure from weeds, pests, or pathogens.

Even if statements of beneficial outcomes based on anecdotal experience, or experimental data, are reported, it does not mean results for one location will be equivalent to those for other locations. This is the case regardless of the produc-

tion system in use. Organic production systems need to be developed for various locations, and it may be that the only conforming activities between regions are the use of organic principles rather than the same organic inputs.

Production costs for vegetables using organic methods are generally considered to be higher than for conventional methods. The analysis by Taylor et al. (2006) appears to reaffirm this. Revenue could be increased for bell pepper if costs of organic production of transplants are reduced and for all crops if a premium is provided to organic products. Even if a premium currently exists, there is no guarantee that it will continue over time if vegetables under organic production acquires a similar acceptance to those from conventional production. In this study, there was a premium provided to organically produced bell peppers at the Dallas Terminal Market in 1 of the 3 years. This may not be the case at other terminal markets where a premium is either more regularly applied or not applied at all.

There are other factors that will cause changes in acceptance and application of organic principles in vegetable production. Chief among these is the increase in cost of petroleum products resulting from worldwide demand. This cost will impact the production, delivery, and application of synthetic materials. It is true that some of these same costs will be applied to organic production, but if the material for use in organic fertilizers and soil amendments does not begin with oil and is locally produced with minimal shipping costs, there may be a closing of the gap between the costs of organic and synthetic inputs.

In the transition to organic production phase, there was no apparent benefit to use of the amendments tested based on yield and economic returns to the producer. However, effects of long-term use of soil amendments are still not well understood and were out of the scope of this project. Under purely economic analysis, it would appear that conventional methods should be chosen for producers of vegetables. However, factors affecting acceptance of use of organic methods can transcend economic justification. For those who chose alternatives to conventional agriculture, it appears that they should be willing to accept initial losses with the hope of im-

provement in return on investment over the long-term.

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