The Connecticut Agricultural Experiment Station, New Haven

Intensive Vegetable Production Using Composted Animal Manures

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SUMMARY

Intensive vegetable production trials were conducted for two years at Windsor (sandy terrace soil) and Mt. Carmel (loamy upland soil) following yearly applications of two organic amendments as the sole source of nutrients: spent mushroom compost and chicken manure compost. Yields of nine crops from these amended plots were compared to yields from control plots fertilized with conventional or organic fertilizers.

Chicken manure compost applied at a rate of 50 T/A (1 inch) provided enough nutrients for all crops, except lettuce, to exceed or equal yields from the inorganic control plots at both sites over the two year period. Eggplant, peppers, and tomatoes responded favorably to the 25 T/A (1/2 inch) rate in both years at both sites. Only peppers responded favorably to spent mushroom compost amended at a rate of 50 T/A. Addition of half the conventional inorganic fertilizer rate (650 lbs/A) of 10-10-10 to the lower (25 T/A) rate of spent mushroom compost improved the nutrient content enough so that spring broccoli and cauliflower, peppers, and spinach had yields greater than or equal to the inorganic controls both years at both sites. This addition of fertilizer to chicken manure compost (25 T/A) raised yields of all crops above the inorganic control.

These experiments suggest that composted animal manures can be used in an intensive cropping system to provide most, if not all, of the fertilizer requirement. The amount of inorganic fertilizer, if any, required to ensure optimum yields was dependent on the nitrogen content of the amendment as well as the nutritional needs of the individual crop.

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To maximize profits and to achieve diversity, most vegetable growers in Connecticut use a multiple cropping system in which as many as three crops are grown in succession on a parcel of land during a single growing season. Proper fertilization of each successive crop is difficult to evaluate without soil tests to determine how much fertilizer remains from the previous crop.

Composted wastes should be ideal for intensive vegetable production because nutrients, particularly nitrogen, are released slowly from these organic amendments. The question arises, however, whether sufficient nutrients are released from a yearly application of compost to support each crop throughout the entire growing season.

Composting animal and plant wastes for use as fertilizer is a well-established procedure in many parts of the world. Most organic materials improve soil structure as well and, in areas where inorganic fertilizers are scarce or too expensive for general use, composts are the only means of maintaining soil fertility. Composting not only provides a product that enriches the soil and improves the structure, it also stabilizes waste materials that otherwise may contribute to pollution of air, soil, and water.

Organic gardening and farming has gained popularity in recent years. Membership in the Natural Organic Farmers Association has increased dramatically and certification of organic farms has begun in many states. Concerns about protection of ground water and the safety of foods are prompting increasing numbers of growers to seek alternative methods for fertilizing their crops. Utilization of composts is a keystone for nutrient management that can reduce the likelihood of pollution of the environment.

Most field studies with vegetables have utilized composted municipal solid waste (MSW). In one study, data collected over a 19-year period show the beneficial effects of MSW compost include sustained higher crop yields of corn, more favorable soil pH, increased organic matter and cation exchange capacity, and enhanced supplies of plant nutrients (Mays and Giordano, 1989). Baumann and Schneider (1980) found yields of a variety of vegetables were generally increased by the addition of MSW compost. Similar results were found by Sarr and Ganry (1985) with tomatoes, Natour (1987) with Swiss chard, and Duch (1979) with onions, beets, and celery. In contrast, Sotomayor (1979) reported that yields of all plant species were greater with inorganic fertilizers than with composts.

Few field experiments have been conducted with the two composts used in this study, spent mushroom compost (SMC) and chicken manure compost (CMC). Even fewer studies have been done on intensive cropping systems with compost serving as the only source of nutrients. Rathier (1982) reported good yields from field crops grown in SMC (10-20 T/A) augmented with a modest amount of 10-10-10 fertilizer. Kaddous and Morgans (1986) reported decreased yields of celery, lettuce, and cauliflower and increased yields of carrots grown in SMC applied at rates up to 36 T/A. Wang et al (1984) grew a variety of common vegetables in the field under four application rates of SMC with mixed results. They attributed the different responses of different vegetables to variability in their tolerance to salinity. Male (1981) reported comparable or higher yields of cabbage, lettuce, and potatoes grown in SMC (5 T/A) compared to those grown in soil amended with chicken manure.

Compost made from chicken manure, sawdust, and sludge from food processing produced yields of spinach, radishes, onions, and potatoes comparable to yields in soils amended with inorganic fertilizer (Kuretani et al, 1981).

In this bulletin I report on experiments in which composted animal manures were the sole source of nutrients in an intensive vegetable production system. Vegetable yields from plots amended with composted animal manures were compared to yields from plots receiving conventional inorganic or organic fertilizers.

METHODS AND MATERIALS

The trials were conducted at the Valley Laboratory, Windsor on Merrimac sandy loam, a sandy terrace soil with somewhat limited moisture holding capacity; and at Lockwood Farm, Mt. Carmel on Cheshire fine sandy loam, a loamy upland soil with a moderate moisture holding capacity. The plots were 20 X 20 ft. surrounded by

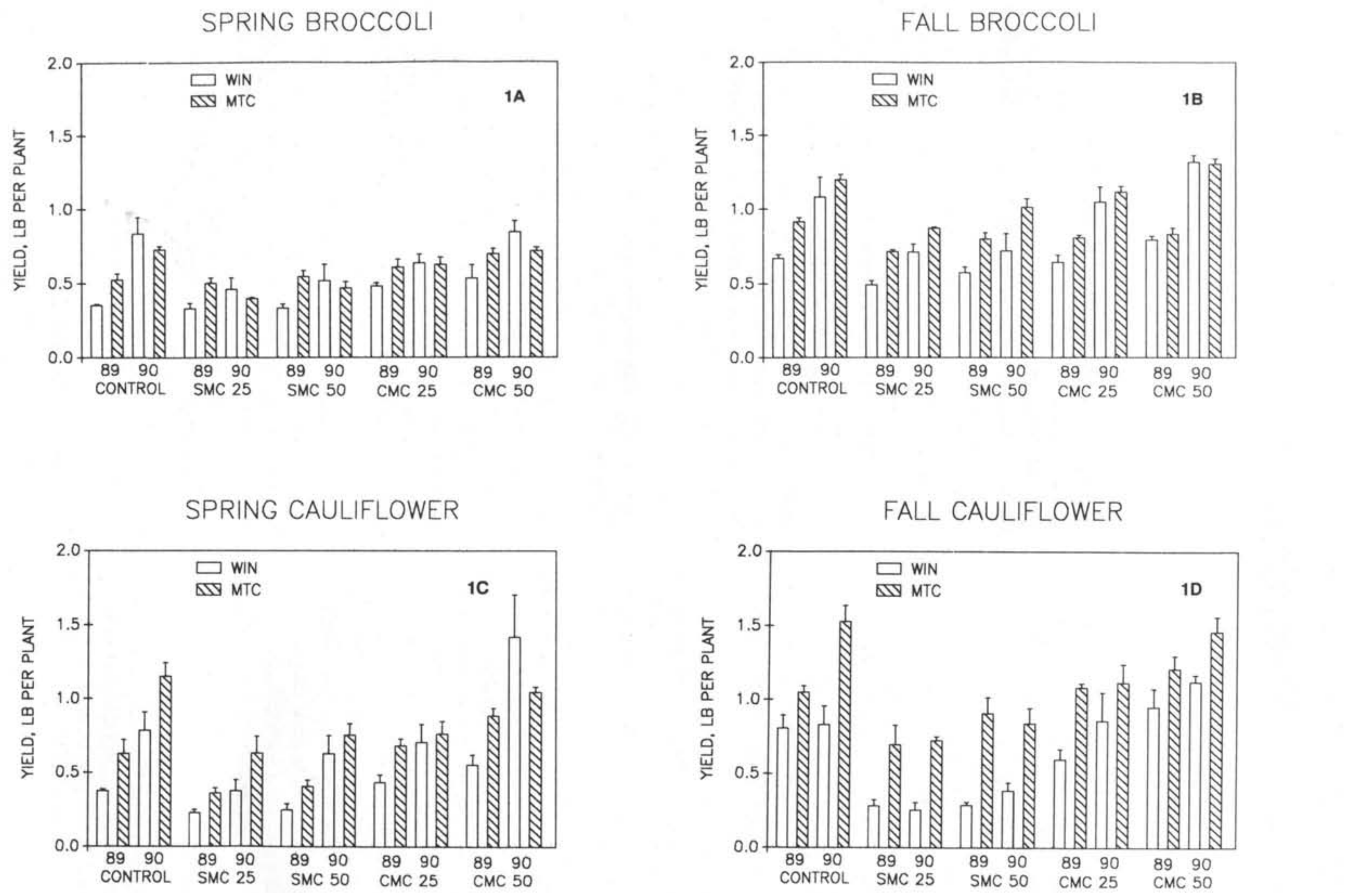

Figure 1. Yields for spring broccoli (A), fall broccoli (B), spring cauliflower (C), and fall cauliflower (D) in plots in 1989 and 1990 at Mt. Carmel (MTC) and Windsor (WIN) amended with spent mushroom compost (SMC) or chicken manure compost (CMC) at 25 or 50 T/A compared to control amended with 1300 lbs 10-10-10/A.

3-foot aisles and replicated four times in a random block design.

The two composts used in the experiments were produced by Earthgro Inc. (Lebanon, CT). Spent mushroom compost (SMC), consisting of horse manure and bedding amended with some chicken manure, gypsum, cottonseed meal, and cocoa bean shells, was composted outdoors for about 6 months in static piles turned monthly. The total nitrogen content was approximately 0.5% (dry weight basis). Chicken manure compost (CMC), consisting of a mixture of chicken manure (43%), horse manure (14%), spent mushroom compost (29%), and sawdust (14%), was composted for about 20 days in an in-vessel system utilizing forced air and an agitated bed. The total nitrogen content was approximately 2% (dry weight basis). Both composts were applied at both sites in the fall of 1988 and 1989 at the rates of 25 or 50 T/A (dry weight basis). These rates were equivalent to a layer of about 1/2 inch and 1 inch of compost. The compost was incorporated into the soil by rototilling in the following spring. In 1989 at Windsor, one-half of the plots were treated in the fall and the other half in the spring of 1990 to evaluate the timing of application. No inorganic fertilizer was added to plots receiving compost. Control plots received a conventional rate of 10-10-10 fertilizer (1300 lbs/A), but no compost. The fertilizer was applied just before planting of each crop.

To ascertain whether low yields of any vegetables were due to nutritive deficiencies or to phytotoxic substances found in some other studies (Wang et al, 1984), I amended additional plots at Mt. Carmel, receiving the low rates of compost (25 T/A), with 10-10-10 fertilizer applied at the full rate (1300 lbs/A) and half rate (650 lbs/A)

Limited trials of an organic fertilizer were also conducted in replicated plots in 1990. The fertilizer, Earth's Best (EB) Natural Vegetable and Flower Fertilizer, (Earthgro, Inc.) is a mixture of feather meal, bone meal, composted animal manure, and Sul Po Mag (sulfate of potash magnesium). Analyses by the Department of Analytical Chemistry showed that it contained 4.5% N, 5.6% P, and 4.5% K. The minimum amount of available nitrogen required for growing most vegetable crops is 130 lbs /A (Lorenz and Maynard, 1980). Since the recommended application rate for vegetables was 580 lbs/A and would only supply 26 lbs N/A, I also applied 10 times the recommended rate (5800 lbs/A containing 260 lbs N/A). Both rates were compared to plots receiving inorganic 10-10-10 fertilizer at the conventional rate of 1300 lbs/A. The EB fertilizer was rototilled into the soil just before spring planting (April 14 at Mt. Carmel and April 18 at Windsor) to evaluate the effect of one application on successive cropping for the entire growing season. The inorganic fertilizer was applied at a rate of 1300 lb/A just before planting of each crop.

Nine different crops of vegetables were grown: three in spring (broccoli, cauliflower, lettuce), three in summer (eggplant, peppers, tomatoes), and three in fall (broccoli, cauliflower, spinach). The cultivars included Cruiser and Premium Crop (broccoli, spring), White Fox and Early Snowball (cauliflower, spring), Ithaca (lettuce) (1990 only), Black Beauty (eggplant), California Wonder (peppers), Celebrity and Nepal (tomatoes), Symphony and Green Valiant (broccoli, fall), Candid Charm and Andes (cauliflower, fall), and Bloomsdale Long Standing (spinach). All crops were grown from transplants except spinach which was direct seeded. The seedlings were grown in Promix BX in standard plastic pots measuring 2-5/8 inches X 2-1/4 inches X 2-5/16 inches and held in packs of 36. Water soluble 20-20-20 fertilizer (1 tbsp/gal) was added to the seedlings 3-4 weeks after germination. Broccoli, cauliflower, and peppers were transplanted in rows 36 inches apart with spacing 18 inches within rows to provide 9680 plants/A. Eggplant and tomatoes were transplanted in rows 36 inches apart with spacing 24 inches within rows to provide 7260 plants/A. Lettuce was transplanted in rows 24 inches apart with spacing 12 inches within rows to provide 21780 plants/A. Recommended cultural practices were followed for each vegetable and each crop was harvested at maturity.

Soil samples, collected from each treatment plot at the beginning and end of the growing season, were analyzed for electrical conductivity (EC), pH, organic matter, as well as the essential soil nutrients.

RESULTS--COMPOSTED ANIMAL MANURES

Yields for the nine crops during the 2-year period at Windsor and Mt. Carmel are presented in Figures 1-3. Each crop will be discussed individually because responses to treatments varied. Statistical analyses of the data was performed utilizing analysis of variance and differences amongst treatments were determined by appropriate F tests. The error bars in Figures 1-3 are the standard error of the mean for each treatment taken individually.

Spring Broccoli (Figure 1A). In 1989, yields of spring broccoli on all compost-amended plots at both sites exceeded or were statistically equal to the fertilized controls. Plots amended with 50 T/A chicken manure compost (CMC) had the highest yields at both sites. The plots receiving 25 T/A CMC or 25 T/A spent mushroom compost (SMC) and amended with half and full rate of 10-10-10 fertilizer had yields 40 to 80% greater respectively than the control (Table 1). The addition of fertilizer at half the rate to compost-amended plots increased yields 34 and 40% CMC and SMC respectively, when compared to unfertilized plots amended with only 25 T/A compost.

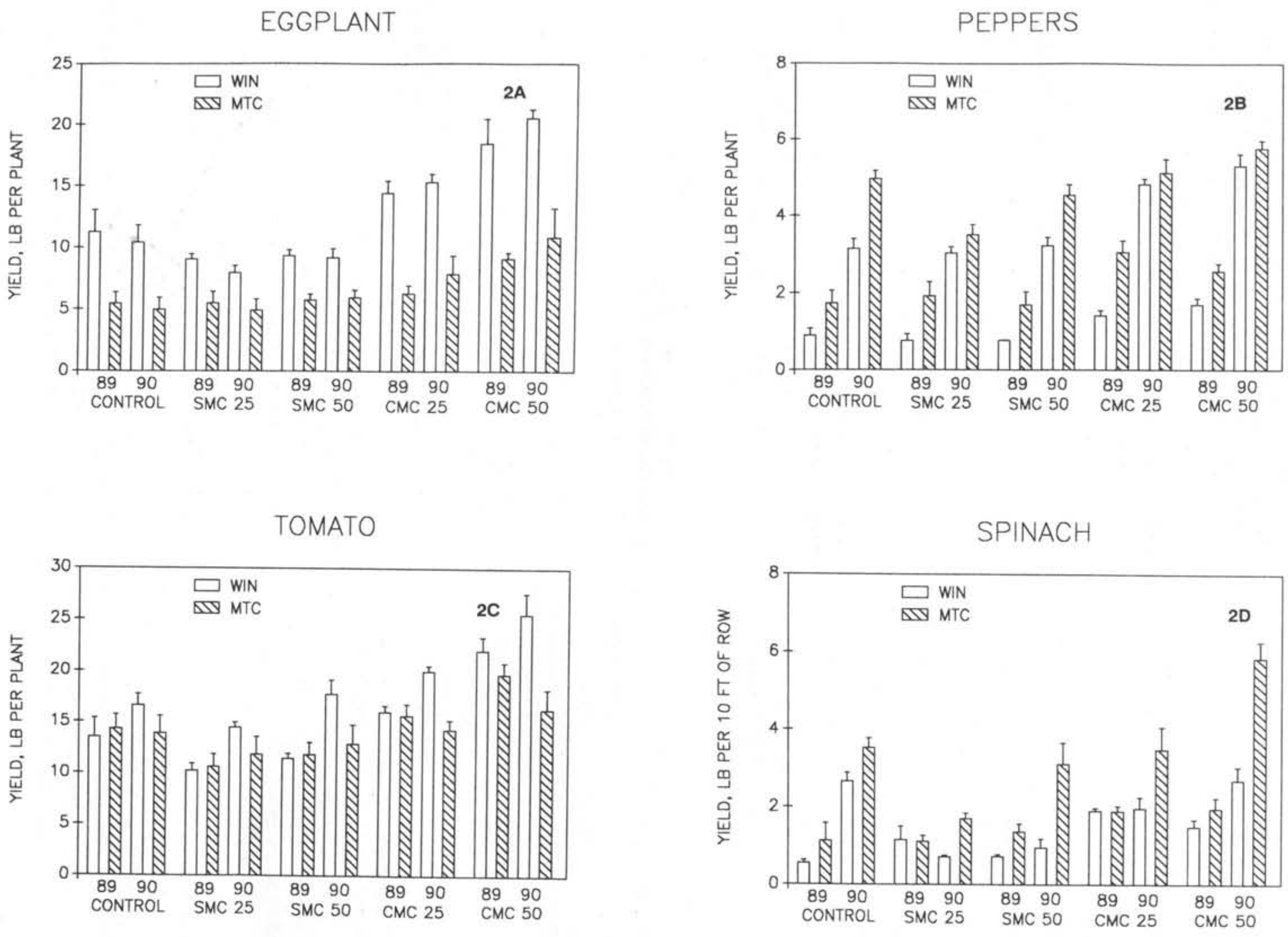

Figure 2. Yields for eggplant (A), peppers (B), tomato (C), and spinach (D) in plots in 1989 and 1990 at Mt. Carmel (MTC) and Windsor (WIN) amended with spent mushroom compost (SMC) or chicken manure compost (CMC) at 25 or 50 T/A compared to control amended with 1300 lbs 10-10-10/A.

In 1990, only the SMC plots amended at a rate of 25 T/A had yields statistically lower than the fertilized control with the other compost-amended plots equalling or exceeding control plot yields. Addition of the full rate of fertilizer to plots amended with 25 T/A CMC or SMC produced yields at Mt. Carmel that were 14% higher than the control (Table 2).

Yields in 1990 from the control plots increased 52% at Mt. Carmel and 152% at Windsor compared to 1989. At the same time, yields in the compost-amended plots at Mt. Carmel remained the same or showed a decrease, while yields from compost-amended plots at Windsor increased 37 to 58%.

Fall Broccoli (Figure 1B). In 1989, only the CMC plots amended at 50 T/A at Windsor had yields higher than the control but all compost-amended plots at both sites were not significantly different from the controls. The addition of fertilizer to SMC-amended soils (25 T/A) improved yields 14% compared to unfertilized SMC plots but all yields were lower than the fertilized controls with no SMC added (Table 1). The CMC-amended plots responded to additional fertilizer. Yields were 12% greater than from plots amended with CMC but no fertilizer. There were no differences, however, compared to fertilized controls with no CMC added.

In 1990, the highest yields of fall broccoli at both sites were harvested from plots amended with 50 T/A CMC. Yields from plots amended with 25 T/A CMC equalled the unamended controls. All SMC plots had yields at least 15% lower than the control. However, the addition of half the recommended rate of fertilizer to plots amended with 25 T/A SMC increased yields 55% over compost alone and 17% greater than the fertilized control (Table 2). Addition of the same rate of fertilizer to CMC-amended plots increased yields 18% over compost alone and 8% greater than the control.

In 1990, yields from the control plots increased 32 and 112% (Mt. Carmel and Windsor) compared to 1989. At Mt. Carmel, average yields of CMC-amended plots increased 50% while the SMC-amended plots increased 23%. In 1990, average yields at Windsor increased 72% and 105% (CMC and SMC, respectively) compared to 1989.

Spring Cauliflower (Figure 1C). In 1989, yields on all CMC-amended plots at both sites increased at least 10% compared to the control. Yields on all SMC-amended plots at both sites while lower were not significantly different from the control. Cauliflower on plots amended with both composts responded well to the addition of fertilizer with even the half rate increasing yields 117% and 300% (CMC and SMC, respectively) compared to plots amended only with compost (Table 1). The yields were 160% and 140% greater than the fertilized control without compost.

In 1990, the 50 T/A CMC-amended plots at Windsor produced yields 75% greater than the control. All other compost-amended plots at both sites were not significantly different when compared to the control. The addition of half the rate of fertilizer to CMC-amended (25 T/A) plots increased yields 38% compared to CMC-amended plots without fertilizer (Table 2). The yields were 5% less than the fertilized control. In SMC-amended plots, the full rate of fertilizer increased yields 8% above the fertilized control plots. Yields on plots amended with the half rate of fertilizer were 17% less than the control.

In 1990, yields from the control plots increased 12% and 123% (Mt. Carmel and Windsor) compared to 1989. At Mt. Carmel, average yields of CMC-amended plots decreased 14% while the SMC-amended plots decreased 10%. In 1990, average yields at Windsor increased 142% and 165% (CMC and SMC, respectively) compared to 1989.

Fall Cauliflower (Figure 1D). In 1989, yields from all compost-amended plots at Mt. Carmel equalled or exceeded the control. At Windsor, only CMC-amended plots had significantly higher or equal yields when compared to the fertilized control. Addition of half the rate of fertilizer to SMC-amended plots increased yields equal to those of the control (Table 1). The addition of the full rate of fertilizer increased yields 27% over the control for both composts.

In 1990, only the 50 T/A CMC-amended plots had yields equal to the control at Mt. Carmel. At the 25 T/A rate, yields were 27% less than the control. At Windsor, all compost-amended plots exceeded or equalled the control except for those amended with 25 T/A SMC. The addition of fertilizer at half the rate to 25 T/A CMC-amended plots increased yields 55% over compost alone and 13% higher than the fertilized control (Table 2). CMC plots amended with the full rate of fertilizer produced the highest yields. The SMC-amended plots required the full rate of fertilizer to attain yields equal to the fertilized control.

In 1990, yields from the control plots increased 49% at Mt. Carmel and remained the same at Windsor compared to 1989. At Mt. Carmel, average yields of CMC-amended plots increased 12% while the SMC-amended plots remained the same. In 1990, average yields at Windsor increased 33 and 9% (CMC and SMC, respectively) compared to 1989.

Eggplant (Figure 2A). In 1989, yields from all CMC-amended plots exceeded the controls at both sites with yields increasing as much as 65% for 50 T/A. Yields from SMC-amended plots were not significantly different from the fertilized controls. Addition of half the rate of fertilizer to CMC-amended plots increased yields 26% over compost alone and 45% greater than the control (Table 1). The full rate of fertilization added to CMC-

Table 1. Yields in 1989 (lbs/plant) in plots at Mt. Carmel amended with 25 T/A chicken manure compost (CMC) or spent mushroom compost plus 1300 lbs 10-10-10/A (F) or 650 lbs 10-10-10/A (1/2).

	CMC			SMC			
	0	1/2	F	0	1/2	F	CON*
SPRING							
Broccoli	0.6	0.8	0.8	0.5	0.7	0.9	0.5
Cauliflower	0.6	1.3	1.2	0.3	1.2	1.4	0.5
SUMMER							
Eggplant	6.3	8.0	8.9	5.5	4.8	7.4	5.5
Peppers	3.1	2.2	2.6	1.9	2.0	2.9	1.7
Tomatoes	15.7	15.9	18.4	10.6	12.7	16.8	14.3
FALL							
Broccoli	0.8	0.9	0.9	0.7	0.8	0.8	0.9
Cauliflower	1.1	1.2	1.4	0.7	1.1	1.4	1.1
Spinach**	1.8	1.2	2.3	1.1	2.1	0.7	1.1

* Fertilization rate of 1300 lbs 10-10-10/A with no compost.
** Yields in pounds for 10 feet of row.

Table 2. Yields in 1990 (lbs/plant) in plots at Mt. Carmel amended with 25 T/A chicken manure compost (CMC) and spent mushroom compost (SMC) plus 1300 lbs 10-10-10/A (F) or 650 lbs 10-10-10/A (1/2).

	CMC			SMC			
	0	1/2	F	0	1/2	F	CON*
SPRING							
Broccoli	0.6	0.7	0.8	0.4	0.8	0.8	0.7
Cauliflower	0.8	1.1	0.8	0.6	1.0	1.3	1.2
Lettuce	0.8	1.3	1.7	1.0	1.4	1.3	1.4
SUMMER							
Eggplant	7.9	9.6	8.9	4.9	6.2	5.1	4.9
Peppers	5.1	5.0	5.3	3.5	5.8	4.8	5.0
Tomatoes	14.3	22.4	20.6	11.9	18.3	19.1	13.9
FALL							
Broccoli	1.1	1.3	1.3	0.9	1.4	1.3	1.2
Cauliflower	1.1	1.7	1.7	0.7	1.1	1.6	1.5
Spinach**	3.5	6.7	7.2	1.7	3.4	4.9	3.5

* Fertilization rate of 1300 lbs 10-10-10/A with no compost.
** Yields in pounds for 10 feet of row.

amended plots increased yields 61% over the control. The SMC-amended plots required the full rate of fertilizer to produce yields 34% greater than the control.

In 1990, yields from all CMC-amended plots exceeded the controls at both sites with yields increasing as much as 117% for 50 T/A. Yields from SMC-amended plots did not differ significantly from the controls. In the fertilizer plus compost plots, the half application rate plots had greater yields than the plots receiving the full rate. For both composts, yields were 25% greater compared to unfertilized compost plots (Table 2). The yields for the half application rate were 93 and 24% higher for CMC and SMC respectively, compared to the fertilized control.

Comparing 1989 yields with 1990 yields, the control and SMC-amended plots decreased or remained constant (less than 10% increase). All CMC-amended plots increased, especially at Mt. Carmel at both rates of application

Peppers (Figure 2B). In 1989, yields of all compost-amended plots at both sites were equal or greater compared to the control. Yields of CMC-amended plots were 54 to 110% greater than the control. In contrast, when fertilizer was added to CMC-amended plots, yields decreased 30 and 17% (1/2 and full rate respectively) (Table 1). The full rate of fertilizer increased yields on SMC-amended plots by 52% compared to the unfertilized compost plot and 71% greater than the control.

In 1990, all compost-amended plots at both sites, except for SMC 25 T/A at Mt. Carmel, had yields equal or greater than the control. The largest increases were found on the CMC plots at Windsor. Yields were not significantly improved when fertilizer was added to CMC-amended plots (Table 2). The addition of half the rate of fertilizer on SMC-amended plots increased the yields 66% compared to unfertilized plots and 17% better than the control.

In 1990, yields from control plots increased 193 and 293% (Mt. Carmel and Windsor) compared to 1989. At Mt. Carmel, average yields of CMC-amended plots increased 94% while the SMC-amended plots increased 76%. In 1990, average yields at Windsor increased 229 and 291% (CMC and SMC, respectively) compared to 1989.

Tomatoes (Figure 2C). In 1989, all CMC-amended plots at both sites increased yields as much as 63% greater than the control. Yields of all SMC-plots at both sites were not significantly different from the control. Addition of the full rate of fertilizer on CMC-amended plots improved yields 18% above unfertilized CMC-amended plots (Table 1). Half the rate of fertilizer did not improve yields compared to unfertilized CMC-amended plots. Yields of the full rate of fertilizer plots were 29% higher than the control. Only the full rate of fertilizer added to SMC-amended plots produced yields 18% greater than the control.

In 1990, all compost-amended plots at both sites had yields statistically equal to or greater than the control with the largest increases occurring at Windsor. The addition of fertilizer to CMC-amended plots at half the rate improved yields 57% over compost alone and 61% over the full fertilized control (Table 2). The half rate added to SMC-amended plots increased yields 55% over compost alone and 32% over the control.

In 1990, all SMC-amended plots showed the largest percent increase in yields at both sites compared to 1989. At Mt. Carmel, the yields of CMC-amended plots were less in 1990 compared to 1989. At Windsor, the yields of the control plots and the CMC-amended plots increased 20-25% in 1990 while yields of the SMC-amended plots averaged a 48% increase.

Spinach (Figure 2D). In 1989, the yields in all compost-amended plots exceeded or equalled the control plots at both sites. Addition of fertilizer to compost-amended plots had mixed results (Table 1). When half the rate of fertilizer was applied to CMC-amended plots, the yields decreased. When applied to SMC-amended plots, the yields increased. In contrast, the yields increased when the full rate of fertilizer was added to CMC-amended plots. When the full rate of fertilizer was added to SMC-amended plots, the yields decreased.

In 1990, yields from most of the CMC-amended plots exceeded or equalled yields compared with the control. Yields from the 25 T/A plot at Windsor were lower but

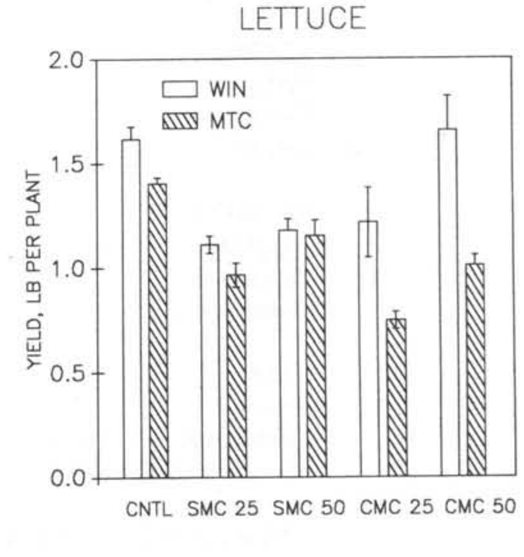

Figure 3. Yields of lettuce in 1990 in plots at Mt. Carmel (MTC) and Windsor (WIN) amended with spent mushroom compost (SMC) or chicken manure compost (CMC) at 25 or 50 T/A compared to control amended with 1300 lbs 10-10-10/A.

Table 3. Yields in 1990 (lbs/plant) from plots amended with 50 T/A chicken manure compost (CMC) or spent mushroom compost (SMC) in fall 1989 or spring 1990.

	CMC		SMC	
	FALL	SPRING	FALL	SPRING
SPRING				
Broccoli	0.8	0.9	0.3	0.7
Cauliflower	1.0	1.8	0.6	0.7
Lettuce	1.4	1.8	1.2	1.2
SUMMER				
Eggplant	19.3	21.7	8.3	10.1
Peppers	4.9	5.7	2.9	3.6
Tomatoes	23.3	27.9	15.4	20.0
FALL				
Broccoli	1.3	1.3	0.7	0.7
Cauliflower	1.2	1.1	0.3	0.5
Spinach*	2.2	3.1	0.6	1.3

* Yields in pounds per 10 feet of row

Table 4. Yields (lbs/plant) from plots amended with Earth's Best (EB) fertilizer at 580 lbs/A (1X) and 5800 lbs/A (10X) compared to control (CON) amended with 1300 lbs 10-10-10/A.

	Mt. Carmel			Windsor		
	1X	10X	CON	1X	10X	CON
SPRING						
Broccoli	0.7	0.7	0.7	0.3	1.1	0.8
Cauliflower	1.0	1.2	1.2	0.4	1.1	0.8
Lettuce	1.3	1.7	1.4	1.0	2.1	1.6
SUMMER						
Eggplant	6.4	9.5	4.9	8.3	16.3	10.4
Peppers	5.3	6.3	5.0	2.2	4.4	3.1
Tomatoes	13.6	15.2	13.9	11.5	21.8	16.6
FALL						
Broccoli	1.1	1.1	1.2	0.5	0.6	1.1
Cauliflower	0.8	1.3	1.5	0.2	0.4	0.8
Spinach*	3.2	3.2	3.5	0.48	0.7	2.7

* Yields in pounds for 10 feet of row

the difference was not significant. Yields from SMC-amended plots were lower than the controls at both sites but only the 25 T/A plot at Mt. Carmel was significantly lower. Addition of half the rate of fertilizer increased yields 92% over the control in CMC-amended plots (Table 2). This fertilization rate increased yields on the SMC-amended plot 100% so that the yields equalled the full fertilizer control. Full fertilizer plus SMC compost increased yields to 40% greater than the control while yields on CMC plus full fertilizer increased 106% compared to the control.

In 1990, yields from the control plots increased 214 and 387% (Mt. Carmel and Windsor) compared to 1989. At Mt. Carmel, average yields of CMC-amended plots increased 148% while SMC-amended plots increased 91%. In 1990, average yields at Windsor increased 42% in CMC-amended plots and remained the same in SMC-amended plots compared to 1989.

Lettuce (1990 only) (Figure 3). Yields from all compost-amended plots were statistically greater than or equal to the controls at both sites except the plots amended with 25 T/A CMC at Mt. Carmel. Addition of fertilizer to CMC-amended soils increased yields 62 and 112% (1/2 and full rate) with the full application rate yielding 21% greater than the control (Table 2). Yields also increased when fertilizer at both rates was added to SMC-amended soils compared with unfertilized compost plots. At 1/2 the rate of fértilizer yields were the same as the control.

Timing of Compost Application. In 1990, an additional experiment was conducted at Windsor to determine whether spring or fall application of compost affected yields. Most crops had 12 to 133% higher yields when the composts were applied in the spring instead of the preceding fall (Table 3). There were a few exceptions. Fall cauliflower amended with 50 T/A CMC in the spring was the only crop to have a 8% decrease in yields compared to fall application. Spring or fall application of compost had no effect on yields of fall broccoli (both composts) and lettuce (SMC).

RESULTS--ORGANIC FERTILIZER PLOTS

Vegetable yields from the different treatments and sites are shown in Table 4. In the sandy soil at Windsor, plots receiving 580 lbs/A of Earth's Best fertilizer (1X EB) had crop yields 20 to 86% lower than control plots receiving the inorganic (10-10-10) fertilizer. As expected, the poorest yields were from fall crops. In the loamy soil at Mt. Carmel, yields from these plots either exceeded the controls (peppers and eggplant) or had a 10% or less decrease when compared to the controls.

The only crop at Mt. Carmel that did not respond to EB fertilizer at the recommended rate was cauliflower whose yields decreased 13% in the spring and 46% in the fall when compared to the control. In the previous experiments utilizing composted manures, the highest yields of cauliflower were obtained with a combination of inorganic fertilizer and compost: compost alone did not supply enough nutrients. It appears that cauliflower has especially high nutrient requirements.

The highest yields in all spring and summer crops at both sites were found in plots receiving EB fertilizer at the higher application rate of 5800 lbs/A. At Windsor, yields increased 29 to 57% when compared to the inorganic fertilizer controls. Yields were 3 to 92% greater at Mt. Carmel. The 92% increase of eggplant at Mt. Carmel was abnormally higher due to the presence of verticillium wilt disease in the inorganic fertilizer controls and not in the organic fertilizer plots. These plots were fallow in 1989 whereas the control plots had grown eggplant, which probably allowed the disease to build. At Windsor, in the absence of the disease, yields of eggplant increased 57% in the 10X EB plots compared to the control.

In the fall crops at both sites, the inorganic fertilizer (10-10-10) control plots had the highest yields. Yields of fall broccoli and spinach grown at both rates of EB fertilizer in Mt. Carmel were only 10% lower than the control. Fall cauliflower yields from the 10X plots decreased 16% compared to the control. Fall cauliflower yields at Windsor were much smaller when compared to the control, showing decreases from 49 to 75% in the high rate plots. Soil tests at the end of the growing season at Windsor showed a depletion of nutrients. Levels of all nutrients remained high at Mt. Carmel at the end of the growing season.

DISCUSSION AND CONCLUSION

One objective of this study was to determine whether composted animal manures could replace highly soluble inorganic fertilizers in intensive cropping systems. The standard to achieve was yields from control plots where optimum nutrients were provided by inorganic fertilizer throughout the growing season.

All crops varied in their response to the different composted animal manures and their rates of application (Table 5). Spring application of compost appears to be preferable to fall application. Chicken manure compost applied at a rate of 50 T/A provided enough nutrients for all crops, except lettuce, to exceed or be within 10% of yields from the control plots at both sites over the two year period. Only eggplant, peppers, and tomatoes responded favorably to the lower 25 T/A rate in both years at both sites. This lower rate with the addition of half the rate of fertilizer raised yields of all crops above the control.

Table 5. Summary of response to year, site and treatment. The means are ranked in order with A = highest yield. The means sharing the same letter were not significantly different. Under site, MC=Mount Carmel and WI=Windsor. NS= no significant difference.

Crop	Best Year	Best Site	CNTL	SMC25	SMC50	CMC25	CMC50
Spring Broccoli	90	NS	A	B	B	A	A
Fall Broccoli	90	MC	AB	C	C	B	A
Spring Cauliflower	90	MC	B	C	BC	B	A
Fall Cauliflower	90	MC	AB	C	C	B	A
Eggplant	NS	WI	C	C	C	B	A
Lettuce	NS	WI	A	BC	BC	C	AB
Peppers	90	MC	B	B	B	A	A
Spinach	90	MC	BC	C	BC	AB	A
Tomato	90	WI	BC	C	C	B	A

Spent mushroom compost, at both rates of application, failed to produce yields of most vegetables comparable to fertilized controls. Only peppers amended at a rate of 50 T/A exceeded the control both years at both sites. No crop responded well both years to the lower 25 T/A rate. The addition of half the rate of fertilizer improved the nutrient content so that spring broccoli and cauliflower, peppers, and spinach had yields greater than or equal to the controls both years at both sites. Measurements of conductivity indicated that salt was not likely a problem in these plots as suggested by others (Wang et al, 1984). Because yields increased when fertilizer was added, lower yields were probably due to nutrient deficiencies.

The high rate of 5800 lbs/A of EB fertilizer produced yields greater than the control at both sites for all spring and summer crops (broccoli, cauliflower, lettuce, eggplant, peppers, and tomatoes). However, this rate, applied in spring only, could not maintain high yields of fall crops especially in the sandy soil at Windsor. Application of this fertilizer at the time of fall planting appears necessary, similar to the common practice with inorganic fertilizers.

As for the individual crops studied, cultural decisions may be based on the availability of compost as well as the need for supplemental inorganic fertilizer. With spring broccoli and cauliflower and fall spinach, excellent yields were obtained with CMC 50 T/A alone or CMC or SMC 25 T/A plus 650 lbs 10-10-10/A. Only the first two options are desirable for fall broccoli and cauliflower. Eggplant and tomatoes responded with high yields to both levels of CMC. Peppers outyielded the control at both levels of CMC, SMC (50 T/A), and 25 T/A SMC plus 650 lbs 10-10-10/A. The fact that peppers were the only crop to respond well to 50 T/A SMC indicates that they require less nutrients than other crops. Too much nitrogen can lead to excessive vegetative growth with a decrease in yields (Lorenz and Maynard, 1980).

Others have found a link between composts and suppression of soilborne plant pathogens (Hoitink and Kuter, 1984). At Mt. Carmel, verticillium wilt disease in eggplant appeared to be suppressed on the CMC-amended plots. In 1990, yields from these plots increased an average of 22% compared to 1989 while the control plots decreased 11% (Figure 2a).

In addition, while the high yields obtained in many of the compost-amended plots are largely attributable to the plant nutrients the composts provide, measurements of soil physical properties indicated that compost also increased waterholding capacity, aggregation, soil structure, aeration, and tilth.

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